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CHEMICAL INDUSTRY IN EARLY WISCONSIN[1]

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The term "chemical industry" can be used in a variety of ways. In its strictest sense it applies only to those industries participating in the production of chemicals, *i.e.*, salts, acids, bases, solvents, and intermediates. Such products rarely reach the hands of ultimate consumers but are purchased by industrial processors who utilize them for their ability to transform raw materials into those products desired by the ultimate consumer. According to this designation, the smelting of lead for use in lead pipe is not a chemical industry but the production of white lead and red lead for the use of the paint industry is one.

Numerous industries not directly involved in the production of chemicals are nevertheless dependent upon chemical changes for their success. This is true of the smelting of metal ores, the fermentation of carbohydrates to alcoholic beverages, the purification of cellulose in the production of pulp and paper, the bleaching of pulp and of textiles, the dyeing of textiles, the tanning of skins, the curing of cheese, and the production of soap. These industries are generally characterized as the "chemical process industries."

A related type of industry is the one which produces no chemicals, depends upon no chemical reactions, but uses chemicals essentially unchanged in the fabrication of consumer products such as paints, matches, and pharmaceuticals. This may well be termed the "chemical consuming industry."

We propose to examine the early development of Wisconsin industry in all of these categories rather than limiting our discussion solely to those industries which are chemical industries only in the strict use of the term. A major reason for using this broad approach lies in the difficulty of separating one activity from another. The paper industry, for example, is quite likely to produce for its own use, such chemicals as chlorine, sodium hydroxide, sulfite, and sulfate. To that extent it is truly a chemical industry. It uses these chemicals in the production of pulp and paper and therefore is a chemical process industry. It uses

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[1] Based upon material presented at the annual meeting of the Wisconsin Academy of Sciences, Arts, and Letters, Madison, Wisconsin, April 24–25, 1953.

such chemicals as alum, clay, rosin, and casein for the sizing of paper so it is also a chemical consuming industry.

GEOGRAPHY

Chemical industry, just as other industry, is influenced in its development by geographic location and the availability of raw materials. The State of Wisconsin fares poorly on both counts. The state's location on the northern edge of central United States gives it an unfavorable position for maximum participation in both national and international chemical commerce. Lake Superior on the north and Lake Michigan on the east form significant water barriers to the movement of people and materials. These water routes would be of greater value if Central Canada were an important user of chemicals or if the St. Lawrence Seaway became a reality. Under the existing circumstances, however, Wisconsin holds no advantage not already possessed in more favorable degree by Michigan, Ohio, and New York.

The prairie states to the west fail to provide either a significant market or an important source of raw materials. To the south there is a market but not one in which Wisconsin has an advantage over other central states. We are forced to conclude that Wisconsin's geographic position is not one naturally to stimulate the growth of a chemical industry.

RESOURCES

Chemical industry depends for its success upon the availability of water, fuel, and suitable raw materials. Wisconsin has water abundantly available in good quality for chemical operations. On the other hand, its availability has made it an obvious route for the disposal of processing wastes with the development of a serious pollution problem.

Fuel resources have not been abundant in the state. Wisconsin lacks coal, petroleum, and natural gas, the more obvious industrial fuels. The one natural fuel source was Wisconsin's extensive stand of timber. This was of greater importance as a source of lumber and pulp, however, and could not serve as an important fuel resource. Proximity to Great Lakes shipping has prevented the lack of natural fuel from being a critical one in the development of industry but this has not completely offset the disadvantage of lack of home fuel resources. The state is also sufficiently rugged that the energy of falling water has been effectively harnessed as a source of power, thus offsetting in part the lack of fuel energy.

Minerals desirable for a flourishing chemical industry are sodium chloride, sulfur, and limestone. Salt serves as a source of alkalies, chlorine, and salt cake, as well as a variety of lesser chemicals derived from sodium or chlorine. Sulfur is essential in the production of sulfuric acid, industry's most important acid. Limestone serves as a source of inexpensive base, as a flux in metal smelting, and in a variety of other chemical processes. Wisconsin has only limestone, which is also abundant in many other states.

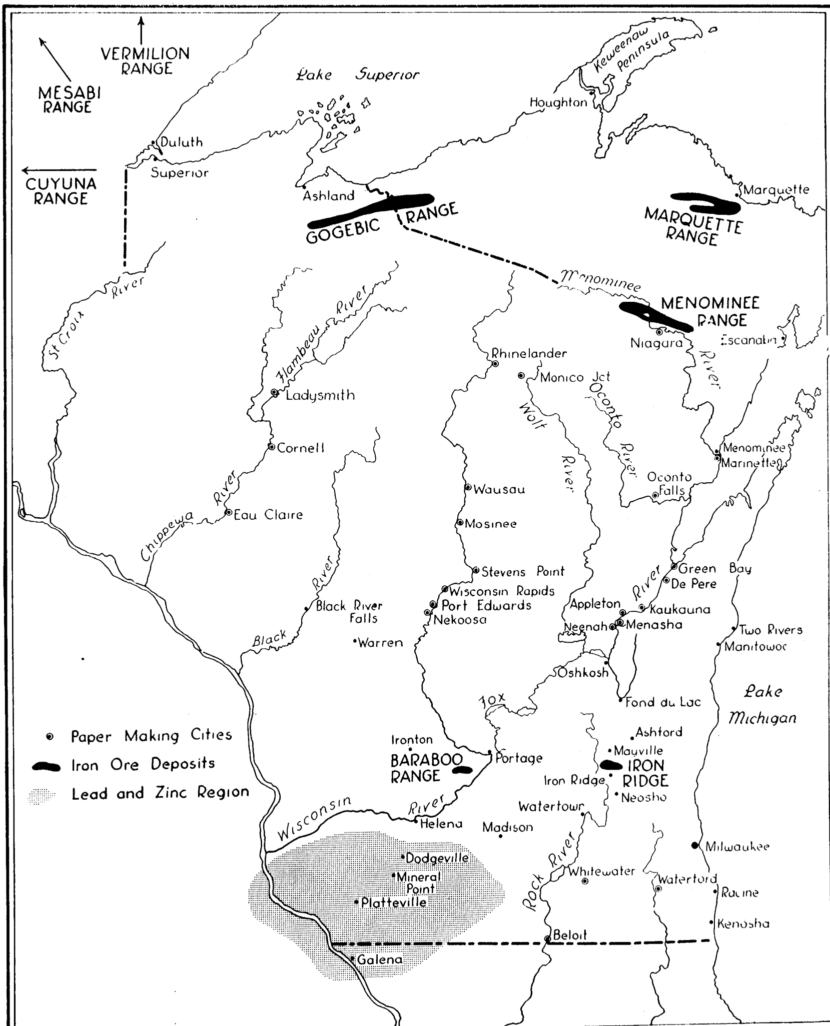
Again we are forced to conclude that Wisconsin is not naturally endowed for a thriving chemical industry. We must then expect that developments would be in such directions as would utilize its more obvious resources, or toward the development of specialty items not greatly dependent on available resources. Our study reveals that both directions were followed. In the early days of Wisconsin's history its chemical industry was based largely upon its most important resource, timber. In time there was a drift toward a chemical industry based on agriculture as the brewing industry developed. Recent times have seen the development of specialty produces such as waxes, flavors, dyes, and pharmaceuticals.

Not only is timber useful for lumber and the various products fabricated therefrom but is also the starting material for the production of such chemicals as charcoal, acetic acid, methyl (wood) alcohol, acetone, and potash. The bark of certain trees, particularly oak and hemlock, is valued as a source of tannins for the conversion of skins into leather. Wood provides the sticks for matches and the cellulose for pulp and paper. Wisconsin's early chemical industry evolved primarily from these products.

Early production of chemicals was small in scale and primitive in technique. Hand labor was aided only by simple and crude machinery. Operators started and terminated operations on short notice as supply and market conditions fluctuated. As a result, records have been hard to trace. It is only possible to indicate the kind of operations and give a few specific examples.

Potash

Crude potassium carbonate produced from the leachings of wood ashes must have been a household product connected with domestic soap-making in early Wisconsin just as it had been in the Eastern States and in Europe. It was natural, in view of the abundance of hardwood in the state, that production for sale should develop early. The operation can be carried out on a small scale with a minimum of equipment. It requires no skilled labor.



LOCATION OF CHEMICAL INDUSTRIES IN WISCONSIN

GEOG DEPT, U of W

Five separate individuals were engaged in commercial potash production by 1857.[2] They were John Mauel, Ashford; Aaron Goodenough, Neosho; F. Y. Mansfield, Oak Creek; Heber Smith, Watertown; and Henry Furguson, Warren. In 1865 factories were established in Milwaukee by W. Ramaker and G. H. Sorens, both immigrants from Holland. A third Dutch immigrant, John B. Hyink, started a Milwaukee factory five years later. All three producers were flourishing in 1881 when Hyink was using 165 barrels of ashes per day, Sorens had 5 men in his employ, and Ramaker produced a ton of potash every week. In addition to local sales the product was marketed in Boston, New York, and Philadelphia.[3] The Eagle Lye Works was founded in Milwaukee in 1874 for the production of alkalies. In 1883, the firm employed 14 workers, in 1909, it employed 40.[4] Census reports for 1860 reveal that potash was being produced by 31 firms located in 12 counties in the southeastern quarter of the state.

In 1880 nine Wisconsin potash companies were producing more than one and one half million poinds valued at $94,424.[5] This amounted to 41% of total U. S. production. The state was the major producer of alkali in the nation. This supremacy did not last long. Decrease in the timber supply was accompanied by competitive developments in the production of caustic. Foreign potash from sugar beet waste and from the newly developed Stassfurt salt deposits was augmented by soda ash produced cheaply by the old LeBlanc and the new Solvay process. Soon thereafter the electrolytic process for the production of caustic soda provided ample supplies of strong alkali. The demand for Wisconsin potash fell to practically nothing by 1890 though a few individuals continued to produce it for local soap factories.

Wisconsin never became an important producer of the sodium alkalies which are produced from rock salt. The supplies of rock salt in the Ohio–New York basin are near Niagara Falls where cheap electric power makes a particularly favorable situation for production of caustic. The Eagle Lye Company continued to do business in Milwaukee but as a distributor rather than as a pri-

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[2] "Wisconsin State Directory of 1857 and 8", Strickland Co., Milwaukee, **1858,** p. 14 and 273.

[3] Flower, Frank A., "History of Milwaukee", Western Historical Co., Chicago, **1881,** p. 1517.

[4] Wisconsin Bur. Labor and Industrial Statistics, *Biennial Rept.*, **1884,** p. 191: **1911,** p. 665.

[5] Rowland, W. L., "Report on the Manufacture of Chemical Products and Salt", p. 20–1. A part of the *Rept. on the Manufactures of the United States at the 10th Census*, **1880,** folio pp. 1010–11. Other important producing states were Michigan, New York, Ohio, Maine, Indiana, and Minnesota.

mary producer. It became a part of the Pennsylvania Salt Manufacturing Company in 1926.[6]

SOAP

A large amount of Wisconsin potash found its way into soap, but since soap manufacture is such a simple chemical operation it is difficult to trace the development with any accuracy. Soap making was a household operation in the nineteenth century Wisconsin, as it continues to be in some rural households in Wisconsin even today.

In the urban centers, commercial soap manufacture achieved some importance. In Milwaukee, for instance, Flower found four flourishing establishments in 1880.[7] The oldest, that of F. Trenkamp, had been established in 1848. Weekly production had risen from 1000 pounds in the first year to 30,000 pounds in 1880. Frederick Wackerow's factory had been established in 1856 by John Langdon. Gross Brothers, established in 1867, was producing 125,000 pounds per week in 1880. This level of production was exceeded by the youngest firm, that of Ricker, McCullough and Dixon, established in 1873, with a production of 173,000 pounds per week. Most of the soap manufacturers were German immigrants who found in Milwaukee a good source of alkali and, as a result of the rapidly developing meat packing industry, a good source of fats.

MATCHES

Milwaukee was the site of the first match factory to be established in the west. Its founder, R. W. Pierce, came from Massachusetts in 1844, bringing the necessary chemical supplies with him. Wood for matchsticks was both abundant and inexpensive in Wisconsin. The first matches were produced in the upper story of a dwelling house. Three employees produced $900 worth of matches during the first year, but Pierce sustained a net loss of $300. Despite the loss, Pierce expanded into a small factory building during the next year. The enterprise grew and "Superior Percussion Matches" found a ready market as far east as Cleveland and as far south as New Orleans. When Pierce sold his interest in 1860, the factory was employing 30 persons. Subsequent owners failed to carry on successful operations and, after changing hands several times, the business was abandoned.[8]

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[6] Haynes, W., Ed., "American Chemical Industry", D. Van Nostrand Co., New York, 1949, vol. 6, p. 332.

[7] Ref. 3, p. 1226.

[8] See ref. 3, page 1509.

The Diamond Match Company began operations in Oshkosh in 1881. Within four years it was employing 175 people. By 1907, 570 employees were listed. Another factory, operated by the Oshkosh Match Company was in operation by 1885.

Working conditions in these early match factories left much to be desired. This was still the day of the white phosphorus match. Match manufacture was dangerous, not only because of the fire hazard, but because of the poisonous effects of the phosphorus fumes which led to necrosis of the jaw. The Commissioner of Labor and Industry was prompted to speak out in 1886:[9]

> I want to say a few words in regard to the conditions of these match factories generally, but more particularily of the dipping rooms. To ameliorate the condition of the people at work in those rooms would be an act of charity. Imagine being in a closed room, the atmosphere of which is constantly contaminated with the fumes of the chemicals used, especially those of phosphorus, which act directly on the bone, and you have the case as I saw it. Found an attempt had been made to purify the air by the aid of suction fans; but the effort seems to be futile, as the rooms were filled with foul odors, the conducting pipes not being large enough, and the fans lacking the requisite power.
>
> I expostulated to some extent with the proprietors and suggested some changes; but as a matter of course they would entail some expense, I left without expecting to see the changes made. But at whatever cost, the working people should be provided with pure air, which the Creator of all things ordained.

In 1891 it was necessary for the commissioner to order the discharge of four girls under fourteen, but health and safety conditions had markedly improved. The task of dipping matches had been taken over by machines, ventilating fans were in operation, and automatic sprinkers had been installed on all floors.[10] It was not until 1913, however, that the white phosphorus match was taxed out of existence in the United States. At that time, the manufacture of this highly poisonous type of match was dropped in favor of the more costly but safer phosphorus sesquisulfide match.

WAX

The processing of wax was initiated in Wisconsin as an outgrowth of the wood industry. The S. C. Johnson Company was

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[9] Flower, Frank A., Bureau of Labor and Industrial Statistics, *Biennial Rept.*, 1885–1886, Madison, **1886**, p. 501–2.

[10] Dobbs, J., *ibid*, **1892**, p. 91 a.

founded in 1886 for the manufacture of parquet flooring. The business took an unexpected turn when builders and home-owners began asking how to keep floors in good condition. Wax was recommended since Samuel Curtis Johnson knew that parquet floors in Europe had stood the wear of centuries with only wax treatment. The company began the sale of floor wax and similar products. By 1898, the dollar sales of wax and allied materials exceeded those of flooring. In 1916, the sale of flooring was discontinued entirely with the company concentrating on wax products and expanding into a world market.[11]

TANNING

It was natural that Wisconsin should develop a strong tanning industry. The hemlock forests provided an abundant source of tanbark. The lesser oak forests provided an additional source of tanning materials. The growing emphasis on livestock as Wisconsin became transformed from a wheat-growing state to one putting emphasis on diversified agriculture, in particular meat production and dairying, brought about a fortunate proximity of hides and tanning materials.

By 1880, Milwaukee had become an important tanning center with at least eight tanneries in operation. Several of these establishments traced their origins back to midcentury. The Wisconsin Leather Company had its origins in an enterprise started in Cazenovia, New York, in 1809. As the New York supply of tanbark became depleted, action was taken to obtain new supplies to the westward. A tannery was opened in Two Rivers, in the heart of the hemlock[12] region of Wisconsin, in 1850. A second tannery was built in the same city in 1861. In 1870, the Milwaukee tannery was opened in order to be near the source of hides from the local meat-packing establishments. In 1880, the company was tanning 175,000 hides, worth about $600,000.

The Pfister and Vogel Leather Company was formed in 1857 through the merger of two small tanneries which had been operating since 1847. In 1880, it was tanning around 100,000 hides. The Kinnickinnic Tannery was established in 1849. The Herman

[11] "This Company of Ours", S. C. Johnson and Co., Racine, **1949**, and personal correspondence.

[12] See R. H. Zinn in J. G. Glover and W. B. C. Cornell, Eds., "The Development of American Industries", revised edn., Prentice–Hall, New York, **1941**, p. 272–3. However, we are unable to confirm the statement of the author that the use of hemlock bark stems from the researches of Humphrey Davy. Neither Davy's research paper on tanning materials, *Phil. Trans. Royal Soc.* (London), **93**, 233–73 (1803), or his general remarks on tanning in his lectures, see the "Collected Works" **3**, 287, 416 (1839), give any indication that he studied hemlock bark.

Zohrlant Leather Company dated from 1857. Trostel and Gallun was started a year later.[13]

Besides these Milwaukee companies, there were tanneries scattered around the state. Manitowoc and Fond du Lac were natural tanning centers due to their proximity to the hemlock forests. The census reports of 1880 indicated 73 producers of tanned leather in the state.[14] All of these establishments were founded mainly because of the availability of tanning materials. By the time the hemlock bark was exhausted they were well established in a center where hides were easily available. Improvements in transportation no longer made proximity to tanbark as crucial as had been the case at midcentury.

Pulp and Paper

The first Wisconsin paper was manufactured in Milwaukee by Ludington and Garand in 1848. Within the next two decades paper was also being produced in Appleton (1853), Waterford (1853), Beloit (1855), Whitewater (1857), and Neenah (1865). These mills were not engaging in chemical operations, however. Their source of cellulose was rags (straw in the first Beloit and Whitewater mills) and the process used was like that used by other American manufacturers. The demand for paper was growing and the supply of rags was short so an active exploration for substitutes was in progress.

Wood was an obvious source of cellulose but practical success in the conversion of wood into paper was not achieved until 1840 when Friedrich Gottlob Keller and Henry Voelter, in Germany, developed a successful woodgrinder. Wood was reduced to a pulp by forcing it against a grindstone cooled with water. The process, successfully operated in Europe from 1854, was introduced into the United States in 1867. In 1872, Colonel Henry A. Frambach introduced it into Wisconsin when he built the Eagle Mill on the Fox River at Kaukauna.[15]

Groundwood pulp did not supplant rag pulp but was added to it as an extender. It did make available a larger paper supply at a time when demands were steadily increasing. The best grades of paper continued to be made of pure rag pulp.

In spite of the popularity of rag paper, the availability of pulpwood in Wisconsin stimulated the growth of the groundwood

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[13] Ref. 3, p. 1438.

[14] "Rept. on the Statistics of Manufactures of the U. S.", **1880**, p. 191.

[15] Brice, C. W. in ref. 10, p. 128. Also see L. H. Weeks, "A History of Paper Manufacturing in the United States, 1690–1916", Lockwood Trade Journal Co., New York, **1916**, p. 234, and Francis F. Bowman, Jr., "Ninety-two Years of Industrial Progress", **1940**, p. 10. This booklet under the cover title of "Paper in Wisconsin", was distributed by the Marathon Paper Mills Co., Menasha, Wisconsin.

process. By 1882, eighteen such mills were in operation on the lower Fox River at Neenah, Menasha, Appleton, and Kaukauna. As the forests of east-central Wisconsin became depleted, the pulp industry began to spread westward into the valleys of the Wisconsin and Chippewa Rivers. Such names as Kimberly, Clark, Gilbert, and Whiting were rising to prominence in the industry. A number of the mills were established on the water-power sites of flour mills which abandoned operations when Wisconsin lost its wheat-growing status to the more westerly prairie states. Concurrent with this, the development of the roller process for flour milling with necessarily high capital investments forced the demise of local stone-operated flour mills such as those which dotted the lower Fox River. Between 1880 and 1925, flour milling slipped from first place as a source of Wisconsin industrial income to twenty-first. During the same period, pulp and paper manufacture rose from eighteenth place to fourth.[16]

During this time, the pulp industry was turning toward chemical operations for the purification of wood fiber. The soda process, which began coming into use in England after mid-century, never figured prominently in the Wisconsin industry. The sulfite process, on the other hand, rose to real importance.

The basis for the sulfite process was laid in Philadelphia by Benjamin C. Tilgham soon after the Civil War. He observed that sulfurous acid dissolved the lignin portion of wood, leaving the cellulose fibers available for pulping. His research was developed into a practical process by Swedish and German investigators and placed in operation in the late seventies.

The process was brought into Wisconsin in 1887 by the Atlas Paper Company at Appleton, and the Appleton Pulp and Paper Company at Monico Junction. The superior quality of sulfite paper over that made from groundwood created a ready market for the product and in turn stimulated the expansion of the process. The paper industry in Wisconsin had become a chemical process industry.

Charcoal and Metal Smelting

The destructive distillation of wood, more commonly called "charcoal burning", was a simple process commonly carried out where hardwood was abundant. Wisconsin's forests contributed to the production of this form of carbon. The charcoal was prepared largely for local use, partly as fuel, partly in connection with the smelting of metallic ores. Production rose and fell with the rise and fall of the state's mining activities.

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[16] Alexander, J. H. H., "A Short Industrial History of Wisconsin", *Wisconsin Blue Book*, Madison, **1929**, p. 34–44.

Lead. The galena deposits in the region where the present boundaries of Wisconsin, Illinois, and Iowa join were exploited for their lead ever since the seventeenth century when the French explorers and traders taught the Indians to smelt the ore.[17] The soft metal with its low melting point quickly assumed importance among the Indians as a source of bullets for the hunting of fur-bearing animals and as an item of trade. Mining operations by white men were carried out only sporadically up

FIGURE 1. Shot Tower Buildings at Helena (facsimile of sketch by John Wilson, made July, 1836).

to the third decade of the nineteenth century at which time a vigorous mining boom occurred. In 1828 production of the metal was 12,000,000 pounds. Troubles with the Indians caused some fluctuation in mining activities but these troubles were ended in 1832 with the termination of the Black Hawk War. Cornish miners began to enter the region in large numbers from 1835.[18]

The metal moved out of the region by water, south on the Wisconsin and Mississippi Rivers to St. Louis, north on the Wiscon-

[17] Kellogg, L. P., "The French Regime in Wisconsin and the Early Northwest", State Hist. Soc., Madison, **1925**, p. 359–63.

[18] Schafer, J., "The Wisconsin Lead Region", State Hist. Soc., Madison **1932**, p. 21 ff. R. G. Thwaites, "Notes on Early Lead Mining in the Fever River Region", *Wis. Hist. Colls.*, **13**, 271–92 (1895). W. F. Raney, "Wisconsin, A Story of Progress", Prentice-Hall, New York, **1940**, p. 89–91.

sin and Fox Rivers to Green Bay from where it was shipped eastward on the Great Lakes. Milwaukee became a similar port for the shipment of lead after suitable roads and railroads had been built. Bullets and shot were the main products made from lead although the manufacture of white lead for paint was started in 1841 at Buffalo, New York.[19]

Shot was even manufactured in Wisconsin following the construction of a shot-tower at Helena.[20] Daniel Whitney, a Green Bay merchant, initiated construction of the tower in 1831 on a cliff overlooking Pipe Creek, a tiny tributary of the Wisconsin River. A vertical shaft was dug through the soft sandstone for a depth of 120 feet and connected to the stream bank by a horizontal tunnel 90 feet long. The molten lead, alloyed with a trace of arsenic, was prepared in a melting house at the top of the cliff and poured through a sieve into a wooden enclosure, or tower, which connected to the top of the vertical hole (Fig. 1). The drops of lead fell a total distance of 180 feet, twirling and solidifying as they fell and finally landing in a pit of water at the bottom of the shaft. Here they were collected, removed, sorted, and prepared for shipment. Shot was produced here until the decline of lead mining in the fifties.

The lead mines drew heavily upon nearby forests for the wood used in smelting the ore. The depletion of the mines after a quarter century coincided with the depletion of local wood resources and the discovery of more important lead ores in states to the westward. The miners turned to full-time farming on the cleared lands or, if mining was permanently ingrained in their system, joined the copper boom in the Lake Superior region or the gold rush to California. Some lead continued to be produced in southwestern Wisconsin but it was marginal production. Operations rose and fell with the price of lead. Wisconsin never again became the leading producer it had been in the forties.

Zinc. Interest in the zinc ores associated with the galena of the region did not develop until 1860. Up until that time, the smithsonite ($ZnCO_3$, called "drybone" by the miners because of its resemblance to partially decayed bones) had been discarded as not worth smelting. In 1860 some 160 tons were successfully smelted. Production of smithsonite and the deeper-lying zinc blende (ZnS, called "blackjack" by the miners) increased rapidly as a zinc boom hit the region. Charcoal did not figure in zinc smelting, however, since coal was shipped in from Illinois or,

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[19] Libby, O. G., "Significance of the Lead and Shot Trade in Early Wisconsin History", *Wis. Hist. Colls.*, **13**, 319 (1895).

[20] Libby, O. G., "Chronicle of the Helena Shot-Tower", *ibid,* p. 335–74. The shaft and tunnel can still be seen in Shot-Tower State Park near Spring Green.

more commonly, the zinc ore was shipped by rail to central Illinois for smelting near the coalfields.[21]

Copper. Wisconsin charcoal never played an important role in the smelting of copper, though there were sporadic efforts at production of the metal. Wisconsin copper discoveries always proved to be a part of the glacial drift brought in from the Lake Superior region so Wisconsin never had a copper boom such as hit the Keweenaw Peninsula of Upper Michigan in the forties. Since the Michigan deposits represented native copper, the smelting problem was never more than one of melting the metal to separate it from contaminating rocks. When charcoal was used, it was obtained from nearby forests and used primarily as a fuel rather than as a reducing agent.[22]

Iron. Charcoal needs at midcentury shifted to the eastern part of the state with the development of iron smelting in the Iron Ridge Region and soon thereafter in Milwaukee County. A charcoal furnace was in operation at Mayville in 1849.[23] The charcoal was produced locally. This furnace, or another at Mayville (built in 1853) was operated by the Northwestern Iron Company, the owners of the Mishawaka furnace in Indiana.[24]

In 1857, two more charcoal furnaces were put into operation. The one near Black River Falls was operated for only a short period by a company of German immigrants. The Ironton furnace was built by Jonas Tower to produce iron for castings. It had a capacity of three tons of iron per day, using ore mined in the nearby Baraboo Range. Another charcoal furnace was built in 1865 at Iron Ridge, near Mayville, by the Wisconsin Iron Company, operating out of Milwaukee.

The next decade saw a vigorous development of iron smelting in Wisconsin. Seven charcoal furnaces were put to blast in the lower Fox River valley during the years 1869–72. These furnaces were located where they could benefit from lake transport of ores from the Marquette Range which was being opened at that time in the Michigan peninsula. Hardwood forests in the counties adjacent to the Fox River provided the charcoal supply.

Milwaukee also began to develop as an iron working center. Two furnaces were put into operation by the Milwaukee Iron Company in 1870 and 1871. Another was built for the Minerva Iron Company in 1873. All three furnaces utilized Lake Superior

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[21] Merk, F., "Economic History of Wisconsin During the Civil War Decade", Wis. Hist. Soc., Madison, **1916**, p. 114–5.

[22] *Ibid,* p. 120–21.

[23] Raney, ref. 18, p. 335.

[24] Swank, J. M., "Statistics of the Iron and Steel Production of the United States", in *Census of Manufactures of the U. S.*, **1880,** p. 109 (folio p. 845).

ores. None of them used charcoal as a fuel but utilized anthracite coal and coke brought in by lake boats.[25]

In 1880 there were 14 furnaces in the state. Eleven of these still utilized charcoal but the three Milwaukee furnaces operated on mineral fuel. From this point, the use of charcoal in iron smelting went into rapid decline. The combination of a rapidly dwindling supply of timber for charcoal and the competition of Lake Superior ores proved deadly for the operators in the central portions of the state. The opening of the Menominee Range in Michigan (and Florence County, Wisconsin) in the early seventies provided a rich ore low in phosphorus against which the low grade central Wisconsin ores could not compete.[26] Although the furnaces in the Iron Ridge region continued in operation for some time, the center of Wisconsin's iron smelting moved to Milwaukee where lake transportation brought in coke from the Indiana–Illinois fields and rich ore from the Menominee Range. Wisconsin continued to figure in ore production with the opening in 1883 of the Gogebic Range on the Wisconsin–Michigan border near Ashland.

The thriving foundry operations in Wisconsin, based at first on flour mill and saw mill machinery, grew with the rapid development of agricultural machinery which was taking place at the time. As the milling of flour gave way to the sawing of lumber, which in turn gave way to agriculture, the need for castings and forgings grew. The rising paper industry also began to absorb products of the iron-working factories and the rapid expansion of the railroads during the period made another large demand. During the decade between 1870 and 1880, Wisconsin rose in iron production from twelfth place among the states to sixth. After this time, the state, while showing continued growth in tonnage of iron produced, lost ground relatively and slipped to eighth position by 1890.[27] By this time, nearly all of the old charcoal furnaces in the state had been abandoned, though a large charcoal furnace, 60 feet high and 12 feet in diameter at the boshes, was placed in operation at Ashland as late as 1888. This furnace, called "Hinkle", had the best production record of any charcoal furnace in the United States.[28] As long as it could draw upon the nearby Gogebic ores and charcoal from nearby forests its operation was a profitable one.

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[25] *Ibid.*

[26] Usher, Ellis B., "Nelson Powell Hulst, the Greatest American Authority on Iron", *Wis. Mag. Hist.*, **1**, 385–405 (1924).

[27] Swank, J. M., *History of the Manufacture of Iron in All Ages.*, American Iron and Steel Association, Philadelphia, 2nd. edn., 1892, p. 331.

[28] *Ibid.*, p. 330.

An indication of the drain on forest resources by charcoal furnaces is given by Billinger.[29] His remarks refer to Pennsylvania furnaces of an earlier day but it is probable that Wisconsin furnaces were at least equivalent in their charcoal demand. One furnace required 800 bushels of charcoal every 24 hours. This could be supplied from 20 cords of wood, the average cut from an acre of woodland.

MAPLE SYRUP AND SUGAR

These saccharine products of maple sap are typically American. The natural abundance of maple trees in Wisconsin resulted in widespread production of both syrup and sugar from the earliest days of the region. Whether or not the Indians were producing maple sugar when the white man came to North America is still a moot question. The best evidence leads to the assumption that the Indians were using maple sap but were taught the art of converting it into sugar by the French. In any case maple sugar became an important item of trade between the French and Indians.

When white settlers populated the region in the nineteenth century, maple syrup and sugar production became a part of their springtime activities in those sections where maple groves flourished. Production was mostly on a small scale by individual families and has largely continued so even to the present day. The operations of boiling, clarification with eggs or lime, and crystallization are little changed from the techniques used by the Indians.[30]

CONCLUSION

As a result of our survey of the early development of chemical industry in Wisconsin we must conclude that the industry was timber-based. The types of products and processes were the result of Wisconsin's primary resource. Had Wisconsin been a prairie state, instead of being heavily forested, its chemical industry could not have shown the development it did. Even the lead and iron industries, which at first glance appear unrelated to wood resources, could not easily have developed commercially in Wisconsin had there been no available charcoal for smelting. By the time that charcoal resources were depleted, the iron-

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[29] *J. Chem. Educ.*, **30**, 359 (1953).

[30] The literature on early maple sugar and syrup production is assembled in "Maple Sugar: A Bibliography of Early Records", Part I., by H. A. Schuette and Sybil C. Schuette in *Trans. Wis. Acad. Sci.*, **29**, 209–236 (1935), Part II by H. A. Schuette and A. J. Ihde in *ibid.*, **38**, 89–184 (1946).

working industry of the state was sufficiently well established to maintain itself on imported ore and coal brought in by lake boats.

It is true that certain industries, such as brickmaking,[31] earthenware, lime, and cement, which formed a part of the chemical industry of early Wisconsin can hardly be associated with timber unless one considers the fuel needs in the preparation of the products. They developed locally due to the presence of such minerals as clay and limestone, as they did in many other states. Hence, they can hardly be considered typical Wisconsin industries as can potash, tanning or pulp and paper.

Depletion of timber resources resulted in considerable shifting of emphasis, primarily toward industries based upon the agricultural pursuits which grew up following the clearing of the land. The rise of the dairy industry from 16th position in 1880 to first position in value of products by 1920 was paralleled by the development of such companies as the Marschall Dairy Laboratory in Madison and Chris Hansen's Laboratory in Milwaukee. These companies supplied testing materials, cheesemaking enzymes, and bacterial cultures to the vigorously growing industry. The fermentation industry too, which grew in importance in Wisconsin following the immigration of German brewers after mid-century, is agriculture based. Timber-based industry, representing the first stage of Wisconsin's chemical industry, was giving way to a new phase at the turn of the century.

ACKNOWLEDGEMENT

We wish to express our appreciation to Professor Arthur H. Robinson and Mr. Randall D. Sale of the University of Wisconsin Geography Department for the preparation of the map of Wisconsin's chemical industry.

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[31] Milwaukee was nicknamed the "cream city" at one time because of the many cream-colored buildings constructed of bricks made of the light-colored clay in the region.

A SHORT WAY AROUND EMERSON'S NATURE

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This paper examines the possible usefulness in interpreting Emerson of approaching his concept of "nature" from a more traditional, particularly neo-classical, point of view rather than from what are generally taken to be the primary romantic significances. Not that nature as sublime landscape, mother earth, and the universe itself is by any means done away with, but an attempt is made to see these ideas as conformable to earlier notions of regularity, law, and reason. Though we cannot claim that considering him momentarily as an adjunct of the eighteenth century and apostle of common sense makes Emerson's work absolutely clear, it does seem to enable us to rationalize some of the contradictions which have bothered critics.

To scholars who have worked on the XVIII–XIX century transition the obligations of this essay, though they can hardly be specified, are obviously manifold. References to Emerson's writings carry the number of the volume in which they appear in *The Complete Works of Ralph Waldo Emerson,* Centenary Edition, 12 vols. (Boston[, 1903–04]).

Distinctions in Emerson are in name only. With everything the same—there being no voids in nature—it is almost impossible for him to be specific, to put a finger on something definite. For what is touched on, because it can't exist in a vacuum, touches something else, fits it, and thus in a way is like it, suggests it, and means it. The suggestions multiply indefinitely, and entities soon lose their identities becoming related parts of one great relation. Talking about one thing is almost immediately by extension, implication, or analogy, commentary on something else: if "it is the fault of our rhetoric that we cannot strongly state once fact without seeming to belie some other" ("History," II, p. 39), it is equally difficult to say one thing without affirming another. For a word which begins by pointing out one—one anything—will not stop vibrating until it implicates others, every last other that bears a resemblance to what was originally intended. One could try to be specific for the sake of an argument, but Emerson abandons the attempt before starting, seeming to feel that he may mean more by being general.

He begins his first important book practically saying it will make little difference if he fails to distinguish between two senses of its one-word title (*Nature,* I, pp. 4–5), and whoever objects at the outset might be asked to explain where "nature" stops and "Nature" begins. Emerson offers two possible meanings, but they are only for beginners, to set them in a context. In effect he is refusing to define his terms, as though he might mean almost anything before he finishes. He is, definitively, impersonal: his more refined nature is the "NOT ME," that is everything except the soul; or, to begin with common usage, it is landscape (approximately) unaffected by man. Shortly, however, he suggests that the "greatest delight" in the ministry of "fields and woods" is produced not by nature, but by man, or by the "harmony of both" (*Nature,* I, pp. 10–1). What Emerson finds significant is that so far as man knows it, nature is inevitably in contact with man. Its own "nature" is its effect on man, or, perhaps, man's effect on it.

Nature is first that "Commodity" of which experience is built, anything that serves purposes, everything that nourishes and knits body and soul together. It is the material out of which are raised "Beauty," "Language," and "Discipline" (*Nature,* chs. ii–v). And, directing experience, it points to something beyond: its "aspect" is "devout"; it "always speaks of Spirit" and "wears" its "colors" (*Nature,* I, pp. 61, 11).

Emerson's subject is not "Nature" as such (whatever that is), but man naturalized, or, at best, nature spiritualized. He tells us not what nature *is,* but what it *means.* And the metaphors it involves him in betray the qualities he finds in it. The assertion elsewhere, "Nature, who made the mason, made the house" ("Nature," III, p. 183), takes in beauty, discipline, and spirit in one mouthful, like Pope's "All Nature is but Art" (*Essay on Man,* i, l. 289). Emerson's nature then not only speaks but is a master-builder. It gives shape, it forms and formulates. It is the model of beauty, the meaning in words, the pattern on which practice is fashioned. It is both the plan and the planning and the substance put into new molds. Nature is what is shaping up or reshaping; it is apparently what enlightens man's experience, the enlightenment itself—intelligence—in any form.

"Idealism" (*Nature,* ch. vi) suggests that in one sense nature is man thinking, the rationality of man—which is appropriate since traditionally reason has been man's own nature. The nature of something is of course the law according to which it operates, the rule which we believe it follows. Thus nature itself may mean law, regularity. Its most basic sense is essence—despite the current tendency to think of it first and foremost as existence. And temporarily Emerson is linked with the eighteenth century rather than struck off from it. Nature is order and "appears to us one with art" ("Art," II, p. 358). The law of nature and natural law are redundancies. If the nature of man is his rationality, then the law of reason is inevitably natural. And the capitalized faculty remains in Emerson's psychology Reason. The reasonable is the natural, the natural is what is expected.

The landscape then, being only one aspect of nature, is perhaps not even that which has lent its name to the whole. What is the whole? It must be whatever is natural—whatever puts man's experience into shape, gives it meaning, explains it, justifies it, and thus makes it what it seems to be—whatever is—life or experience as it *is*. This whole nature must be *the* whole: nature "suggests the absolute" (*Nature,* I, p. 61), and in suggesting it, for Emerson's purposes, becomes it. As Pope had previously suggested, "All are but parts of one stupendous whole,/ Whose body Nature is, and God the soul" (*Essay on Man,* i, ll. 267–8). Nature by starting as the form in which experience or its expression is cast, becomes that experience and/or expression. Emerson tells us in the full circle of his Reasoning what would be, if directly stated, the truism, his life is determined by his life. It (and all other lives, which he knows *through* his own) he calls "nature."

Would one say that whatever is roomy is a "room"? Perhaps not, but one could, though the metaphor becomes involved. The extended meaning of the noun is dependent on the meaning of the adjective, which in turn largely depends on a more specific designation of "room." But Emerson, equally wrapped up in his subject and more concerned with qualities than with things themselves, appears to call whatever is natural "nature."

The meanings reverberate then, grow by bounds, and leap to "whatever is, is" natural, which is according to reason, and thus practically "right." Looked at properly (that is, if you can get yourself to see him in this way) Emerson is a parody of Pope, parody by virtual reduction to absurdity.

What is always seems appropriate and meaningful when juxtaposed to the immediate past. Since it "follows," from what was, it makes sense, functions regularly, proceeds logically and irrevocably, is unified and rational. The natural being the expected, once the present has arrived, no matter what surprises it has caught us in, we soon get used to it, soon find an excuse for it. Emerson might change only one word in Pope's dictum: from whatever "is," to what "happens," is right. For nature, or what is natural, is not standing fast according to laws, it is moving faster, changing shape before our eyes, changed before we are sure what it is all about into history. "What we call nature is a certain self-regulated motion or change" ("The Poet," III, p. 22). Or it is "a mutable cloud . . . always and never the same." It "casts the same thought into troops of forms, as a poet makes twenty fables with one moral" ("History," II, p. 13).

If we search long enough, we find always and everywhere order, logic, reason. Nothing in experience seems extraneous, unlike or unrelated to anything else. "The identity of history is . . . intrinsic, the diversity equally obvious. There is, at the surface, infinite variety of things; at the centre there is simplicity of cause" ("History," II, p. 14). We can rationalize (find reason for) any event, we can inevitably find some other event with which to compare or contrast it. In the lump sum of experience, there is nothing entirely unexpected, nothing we *should not* have expected. "Nature is an endless combination and repetition of a very few laws" ("History," II, p. 15). Even the law of the jungle is natural, and, once recognized, it ceases to be wild. The brutality and fear remain. But that dog eat dog or that through the chain of being species prey upon species is simply part of that "nature of things," accommodation or "abandonment" to which is the obligation of "the intellect" ("The Poet," III, pp. 26–7).

Out of the indicative present—whatever is—we formulate a conditional ought-to-be as a means of abandoning ourselves to what is to come. Looking ahead through continuous change we have no guarantee that our predictions will be satisfied or that our particular scheme of things will be amenable to all possibilities. We simply believe certain laws ought to be obeyed. True, the ambiguity of "ought" suggests further complications in nature; there is more than one tense, or sense, to the expected. A government seems natural when it is well suited to the environment and the temperament of a people, and then the exhortation is for that people to adhere to their given constitution—which seems to mean that they must try to keep on being what they can't help being already. A state of nature may be things as they are or ideal conditions toward which enlightened men strive. But eventually it is possible to identify moral law and physical law—for both are what-we-expect. Thus Emerson as well as the eighteenth century speaks of both as laws of nature.

Is all this tantamount to saying that everything conceivable is natural? Well, Emerson certainly means that all our conceptions are founded in nature, everything conceived, everything formulated, realized, rationalized, all our hopes *and* fears. And beyond that, whether there is a conceivable which is not conceived is perhaps a meaningless question.

"The world exists for the education of each man" ("History," II, p. 8). Read "nature" for "world." Read "history" for "nature." Read "past experience" for "history." Then past experience "exists for the education of each man." Each man's life is based on (his) life, and following Emerson we complete circles of our own.

Emerson's nature is now close to being the world each one of us is forced to live with and believe in, the world of common sense. Earlier it seemed to be the sense that is made out of this world. But this is no contradiction: we merely have two ways of saying the same thing—as he tries to explain in "Idealism" and "Spirit" (*Nature,* chs. vi, vii) : "nature" and our conception of the nature of things are names derived from two different ways of considering what is identical—our experience. Emerson has perhaps made the sense of this world somewhat less common and more individual by granting each person the privilege of interpreting it for himself. But he tolerates such varied attitudes from a realization that "the sailor, the shepherd, the miner, the merchant, in their several resorts, have each an experience precisely parallel, and leading to the same conclusion." The reason why all men, though they spell it out in different gestures, go through the same "experience," is that it is Emerson's nature. Thus, he says, "the likeness in them is more than the difference, and their radical law is one and the same" (*Nature,* I, pp. 42, 44). There remains a "common" sense—a world of it.

Nor from Emerson's point of view can this world be entirely different from the eighteenth century's. Even the Reason of common sense sooner or later contradicts itself, or, too strongly stating one side, seems "to belie some other." Thus common sense always distrusts systems and refuses to believe that well-trained minds discover a brand of reality not encountered (and thus not liable to proof or prosecution) in ordinary living. Common sense accepts a dogma, not as long as it is logical, but as long as it is useful in some fashion.

Emerson too is anti-intellectual, in the sense of being unsystematic, of belittling "foolish consistency," of being eclectic, of refusing to accept one set of ideas to the exclusion of every other, of trying to see around nature from as many points of view as possible. After all, the supposed reaction against eighteenth-century thought occurred partly in such standard neo-classical terms as "law" and "Reason." Emerson's own "Reason" he willingly equates, at least for a useful moment, with one of the faculties of the eighteenth century: "The common sense of Franklin, Dalton, Davy and Black, is the same common sense which made the arrangements which it now discovers" ("Nature," III, pp. 183–4). Common sense is only nature *finding* itself, as, a few lines before, when nature was the mason *and* the house, nature was building itself—*"natura naturans"* ("Nature," III, p. 179). And Emerson even tries to put some life into that "famous aboriginal push" without discarding the mechanistic universe which proper romantics are supposed so to despise. As he says, the push "propagates itself through all the balls of the system, and through every atom of every ball; through all the races of creatures, and through the history and performances of every individual" ("Nature," III, p. 184). Intellectual history is an appreciation of mixed metaphor.

The world of common sense does not make good sense. Since philosophical systems do not explain a universe of infinite sides, shades, and shapes, the wise man passes beyond philosophy to poetry and prophecy, and the common man acts without stopping to think. What confuses us is the paradox that nature is "always and never the same." It is always the same because contained within our one experience: every part of nature is a part of that experience: and all parts of the whole are ultimately related, have something in common, are practically the same. Yet common sense tells us there is a difference. Although we accept what is as inevitable, we expect a change; although we know our present to be determined by its relation to past experience, we believe we can steer our life along a new course. Whether we profit by the lessons of history or fail to do so, our dénouement is equally natural or logical. Or in the last analysis, it is equally unnatural or inexplicable. "We live in a system of approximations. Every end is prospective of some other end, which is also temporary; a round and final success nowhere. . . . Our music, our poetry, our language itself are not satisfactions, but suggestions" ("Nature," III, p. 190).

Our logic then is only an instrument of common sense, useful in describing things from various points of view. The truth itself is always the same. Once we accept "whatever is" as right, or natural, the next epistle must begin as Pope's, "Know then thyself": it is a presumption to scan God: self-reliance is "the proper study of Mankind." And this "Man" of Pope's is no different from Emerson's nature: "The glory, jest, and riddle of the world" (*Essay on Man,* ii, ll. 1, 2, 18). Telling us that our life is what we make of it at the same time that it is being made for us, Emerson says nothing essentially different from the eighteenth century before him, or from pragmatists and existentialists since. His importance is purely in the way he says it. Given a redundant world, we may all begin to sound and go round a little like Gertrude Stein, who in the course of talking about "everything" happens to give the best suggestion of what Emerson means: "Everything is the same except composition and as the composition is different and always going to be different everything is not the same." After all, Pope and Emerson are not alike. As Stein says, "Romanticism is then when everything being alike everything is naturally simply different and romanticism" (*What Are Masterpieces,* Los Angeles, 1940, pp. 34–5). And the triumph of classicism must be the discovery, after the art of making fine distinctions, that everything is confoundedly the same.

NOTES ON WISCONSIN PARASITIC FUNGI. XXI

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The collections on which this series of notes is based were, unless stated otherwise, made during the season of 1954.

PLASMOPARA HALSTEDII (Farl.) Berl. & DeToni, collected at Madison, July 19, 1953 on leaves of *Helianthus strumosus*, is overgrown by a species of *Cladosporium*. The hyphae of the latter appear to penetrate the sporangiophores of the *Plasmopara*, but the relationship is uncertain. The slender ultimate threads of the *Cladosporium* mycelium are subhyaline, and the overgrowth thus has somewhat the aspect of a mucedine.

Undetermined powdery mildews have been collected on the following hosts: *Grindelia squarrosa*, near Forward, Dane Co., August 5; *Aster shortii*, near Monticello, Green Co.; *Capsella bursa-pastoris*, Madison, September 2. Coll. E. A. Stowell.

GLOMERELLA PHOMOIDES Swank is described (Phytopath. 43: 285. 1953) as the perfect stage of *Colletotrichum phomoides* (Sacc.) Chester. *C. phomoides* has been collected in Wisconsin on tomato and pepper.

VENTURIA sp. (immature) on *Gaylussacia baccata* was collected at Hope Lake Bog, Jefferson Co., September 19 by M. S. Bergseng. Immature *Venturias* have been found on a number of Ericaceae in Wisconsin. It is assumed they require overwintering to mature.

PLEUROCERAS POPULI G. E. Thompson is described (Mycologia 46: 655. 1954) as the perfect stage of *Marssonina rhabdospora* (Ell. & Ev.) Magn. which occurs in Wisconsin on *Populus grandidentata* and *P. tremuloides*.

G. W. Fischer's "Manual of the North American Smut Fungi", which recently appeared, introduces a number of name changes affecting smuts which occur on Wisconsin hosts. *Entyloma gauraniticum* Speg. (on *Brauneria pallida*) is a synonym of *E. polysporum* (Pk.) Farl. *Entyloma irregulare* Johans. (on *Poa pratensis*) and *Entyloma crastophilum* Sacc. (on *Agrostis alba, Glyceria pallida, Phleum pratense*) are both considered as synonyms of *Entyloma dactylidis* (Pass.) Cif. *Entyloma saniculae* Peck (on *Sanicula gregaria, S. marilandica*) is a synonym of *Entyloma eryngii* (Cda.) DeBary. *Entyloma gratiolae* (Davis) Cif. is used instead of *E. linariae* var. *gratiolae* for the smut on

Gratiola neglecta, and *Entyloma linariae* Schröt. instead of *E. linariae* var. *veronicae* Wint. for the smut on *Veronica peregrina. Farysia olivacea* (DC.) Syd. replaces *Ustilago olivacea* (DC.) Tul. (on *Carex rostrata*). *Melanopsichium austro-americanum* (Speg.) Beck is said not to occur in North America and the Wisconsin smut (on *Polygonum lapathifolium*) is *Melanopsichium pennsylvanicum* Hirschh. *Sorosporium cenchri* Henn. replaces *S. syntherismae* (Pk.) Farl. for the smut on sand bur and some of the *Panicum capillare* group. *Tilletia caries* (DC.) Tul. replaces *T. tritici* (Bjerk.) Wint. and *T. foetida* (Wallr.) Liro, also on wheat, is used instead of *T. foetens* (B. & C.) Tul. *Urocystis colchici* (Schl.) Rabenh. is employed instead of *U. cepulae* Frost for the smut on cultivated onion. The smut of *Waldsteinia fragarioides* is removed from *Urocystis* to *Ustacystis* Zundel, as *U. waldsteiniae* (Pk.) Zundel. *Ustilago perennans* Rostr. (on *Arrhenatherum elatius*) is regarded as a synonym of *U. avenae* (Pers.) Rostr. For the smut on species of *Glyceria, Ustilago davisii* Liro replaces *U. longissima* var. *macrospora* Davis. *Ustilago maydis* (DC.) Cda. replaces *Ustilago zeae* (Schw.) Ung., and *Ustilago nuda* (Jens.) Rostr. is substituted for *Ustilago tritici* (Pers.) Rostr. *Ustilago syntherismae* (Schw.) Pk. (on *Digitaria sanguinalis*) replaces *U. rabenhorstiana,* regarded as a synonym.

PUCCINIA SIMULANS (Pk.) Barth. II on *Sporobolus cryptandrus* was reported by Davis (Trans. Wis. Acad. Sci. 30: 14. 1937). A collection made near Cambria, Columbia Co., in September 1954 has some teliospores as well, eliminating the possibility of confusion with the closely connected *Uromyces sporoboli* Ell. & Ev.

PHYLLOSTICTAE, undetermined as to species, have been found on various hosts. Descriptive notes on some of these follow: 1) On *Conocephalum conicum.* Sauk Co., Parfrey's Glen, May 19. Micro-conidial. Parasitism is dubious, although the dead portions of the gametophytes on which the fungus occurs are closely connected with fresh, green living portions. 2) On *Scirpus atrovirens.* Dane Co., Madison, August 9. The hyaline, bacilliform conidia are 4–6 x 1.5μ, and are very likely connected with a subsequently produced ascomycetous stage. This organism was discussed at some length in my Notes XVI (Amer. Midl. Nat. 48: 747. 1952), but until the present collection no conidia of any sort had ever been noted by me. 3) On *Phaseolus vulgaris.* Dane Co., Madison, August 1952. In an uncertain relationship on dull brown lesions on leaves which also bear *Cercospora canescens* Ell. & Mart. The pycnidia are pale brown, thin-walled, subglobose, about 160–175μ diam., with conidia hyaline, short-cylindric, 5–7 x 2.5–3μ. 4) On *Ilex verticillata* (cult.). Dane Co., Madison, August 28. The conidia are 5–6 x 2μ, the pycnidia about 125μ diam., of the dimensions of *P. haynaldi* Roum., but the spots are not as well defined as those in European specimens on *Ilex opaca*. 5) On *Amsonia trabernaemontana* (cult.). Dane Co., Madison, July 7. The lesions are tan and elongate, following the leaf midribs. The pycnidia are pale olivaceous by transmitted light, subglobose, about 125μ diam. The conidia are hyaline, with a faint greenish cast, short-cylindric, 4–7 x 3–4μ. 6) On *Solidago flexicaulis (latifolia)*. Lafayette Co., near Fayette, August 25. This fungus is characterized by spores that approach those of a *Septoria*. The large, conspicuous spots are deep brown, faintly zonate, with a yellowish halo surrounding them, orbicular, 1–1.5 cm. diam. The scattered pycnidia are smoky-brown, subglobose, with those measured running from about 165–200μ diam. The conidia are hyaline, rod-shaped, straight or very slightly curved, biguttulate with a tiny shining droplet at each end of the conidium, 7–10 x 1.5μ.

ASTEROMELLA (?) sp. was destructively parasitic on leaves of *Toefieldia glutinosa* at Madison, August 25. The small, non-ostiolate, shining-black, globose fruiting bodies (or sclerotia?) are about 35–55μ diam., clustered, and connected by strands of dark, dendritically arranged mycelium, which permeates the leaf and resulted in total killing back from the tip. Conidia were not produced, so far as observed.

PHOMOPSIS (?) sp. on *Cannabis sativa*. Dane Co., near Mazomanie, August 25, and in Green Co. at Brodhead, September 1. Descriptive notes: Lesions very striking, conspicuous ashen areas on living leaflets, tending to run from margin to midrib, variable in length and width, but in general somewhat rounded or orbicular, with the pycnidia arranged in concentric rings easily visible to the naked eye. Pycnidia black, strongly developed above, less perfectly so in the leaf tissue below, flattened in the lower portion, sometimes confluent, ostiolate, 80–200μ in long diam. Conidiophores very short and inconspicuous, lining the pycnidial cavity. Conidia hyaline, often guttulate, subcylindric to subfusoid, 5–8 x 2.5–3.5μ. Scolecospores not observed.

It is difficult to see how this striking fungus, if it is at all common and widespread, has hitherto escaped mycologists' notice, but I find nothing reported on *Cannabis* which seems even suggestive. *Phyllosticta cannabis* (Kirchn.) Speg., already reported from Wisconsin and in addition represented in our herbarium by an authentic European specimen, is quite different and much less well marked.

I am, and always have been, uncertain as to the exact morphologic limits of *Phomopsis,* and my uncertainty has in no way been allayed by examination of the numerous specimens labeled as being of that genus in our herbarium. I have considered the presence of both alpha- and beta-type spores as being perhaps the most important feature. In addition, those species which occur on living tissue, of which I have listed several, tend to have large black pycnidia on prominent lesions and the alpha spores are subfusoid.

STAGONOSPORA sp. on *Equisetum hyemale,* collected at Madison, August 7, appears strongly parasitic on the upper portions of stems, which are killed back and have become whitened. This is perhaps *Stagonospora equiseti* Fautr. which is inadequately described, except for spore characters which are like those of the specimen in hand. The spores are said to be cylindric or tapered at both ends, hyaline, 3-septate, 20–25 x 4–5μ. No statement is made as to pycnidial characters. In the Wisconsin specimen they are approx. 250–300μ diam., dark brown, subglobose, seriate, sometimes two or three very close together in a row.

STAGONOSPORA BRACHYELYTRI Greene (Trans. Wis. Acad. Sci. 38: 244. 1946) was first collected in midsummer. In 1954 the fungus was found again in the type locality in May, strongly infecting the first leaves of shoots of the host just pushing out of the ground, indicating a possible systematic condition.

STAGONOSPORA sp. on *Abutilon theophrasti* was collected August 17 near Black Earth, Dane Co. I find no report of *Stagonospora* on this host. The lesions are sharply defined, and the fungus appears strongly parasitic, but the specimen is too small for use as a type. The spots are small, rounded, 2–4 mm. diam., with pale brown centers and a darker brown border. Pycnidia are subglobose, about 125μ diam., thin-walled, yellow-brown, with a well-marked ostiole surrounded by a ring of darker cells. The spores are hyaline, cylindric, 18–22 x 3–4μ, and when mature seem to be uniformly 3-septate.

PHAEOSEPTORIA FESTUCAE var. ANDROPOGONIS R. Sprague was described in these notes (Amer. Midl. Nat. 41: 722. 1949) as having pycnospores 60–85μ long, but in a specimen collected near Lodi, Columbia Co., in August, many of the spores are up to 115μ long. In essential morphology, however, they do not differ from those of the type.

GLOEOSPORIUM sp. occurs on leaflets of cultivated rose, collected at Madison, July 1926, by R. Sprague. Descriptive notes are as follows: Spots none; acervuli hypophyllous, subepidermal, scattered or gregarious, brownish, elevated, approx. 100–150μ

diam.; conidia hyaline, ovoid to subfusoid, 7–10 x 2.5–3.5μ. According to Jenkins (Mycologia 23: 223. 1932) *Gloeosporium rosae* Halsted is a nomen nudum.

COLLETOTRICHUM sp. occurs associated with and in questionable relationship to *Septoria saccharina* Ell. & Ev. on leaves of seedlings of *Acer saccharum,* collected near Albany, Green Co., August 25. The *Colletotrichum* is epiphyllous on small, angled, grayish spots which are usually, but not always, adjacent to those bearing the *Septoria,* and it appeared consistently on large numbers of leaves. The small, rounded acervuli have dark brown, straight, evenly tapered setae, 100–175 x 4.5–6μ, 2–4-septate. The conidia range from the typical boat shape to straight-fusoid, and are 17–20 x 3.5–4μ. There seem to be no reports of *Colletotrichum* on *Acer saccharum* and related maples.

OIDIUM PIRINUM Ell. & Ev., the type of which is in the University of Wisconsin Herbarium, was collected at Racine, Wis. in June 1888 by J. J. Davis on a host identified as *Pyrus coronaria.* The host appears instead to be *Crataegus* sp. bearing *Monilia crataegi* Died. (Annal. Mycol. 2: 529. 1904). Diedicke's description and that of Ellis and Everhart (Jour. Mycol. 5: 68. 1889) correspond closely. As is pointed out by Cash in her valuable contribution entitled "A Record of the Fungi Named by J. B. Ellis", Sumstine (Mycologia 5: 58. 1913) transferred, arbitrarily and mechanically it would seem from an examination of his article, *O. pirinum* to *Acrosporium,* as *A. pirinum* (E. & E.) Sumstine.

BOTRYTIS sp. occurred on large lesions, up to 5 cm. diam., on leaflets of *Arisaema atrorubens (triphyllum)* in the New Glarus Woods, Green Co., June 14. This is one of a considerable series of the more succulent woodland plants observed over the years as being attacked by a large, coarse species (or more than one species?) of *Botrytis.* All have appeared as at least possibly parasitic, despite the reputation of *Botrytis* species as saprophytes.

DIDYMARIA PUNCTA J. J. Davis (Trans. Wis. Acad. Sci. 24: 290. 1929) was described as parasitizing *Sisyrhincium campestre* at a station near New Glarus, Green Co., and a second collection has recently been made at Madison. This surely verges on *Cercosporella,* but in several mounts no conidia with more than one septum were seen. The host is tentatively identified as *S. campestre,* but the treatments of the genus *Sisyrhincium* in the standard manuals are inadequate.

PASSALORA FASCICULATA (C. & E.) Earle has been reported from Wisconsin on four species of *Euphorbia—E. corollata, E.*

glyptosperma, E. preslii, E. serpyllifolia—largely on the authority of the late J. J. Davis. Comparison of the Wisconsin material with Fungi Columbiani No. 380 (on *E. preslii*) and No. 3234 (on *E. nutans*) has convinced me that probably only the Fungi Columbiani specimens really represent *P. fasciculata,* and this with wide latitude for spore size variation from the original description. The large (20–30 x 8–10μ), hyaline, uniseptate, subfusoid conidia show but a single spore scar, indicating they are non-catentulate. The conidiophores are pale brown, somewhat flexuous, noticeably and strongly fascicled, the fascicles being evenly distributed over the leaf surface. In all the Wisconsin specimens, on the other hand, the conidiophores, although densely aggregated, are not fascicled and are almost confined to the stems, or in the case of *E. corollata* to the leaf midribs. They are in general darker and are often more strongly angled, but with length variable, the longer tending to be angled. The conidia are those of typical *Cladosporium,* pale olivaceous or olivaceous with two spore scars, indicating catenulation. On *E. corollata* they are mostly uniseptate, with a slight constriction at the septum, subcylindric, 15–20 x 6–7μ. On the other species of Wisconsin *Euphorbia* mentioned the conidia are almost uniformly continuous and limoniform, 10–16 x 4.5–6.5μ. In my Notes VI (Trans. Wis. Acad. Sci. 36: 252. 1944), while still tentatively adhering to the *Passalora* conception, I remarked that the Wisconsin collections would be better assigned to *Cladosporium* spp. Which species is a question. *Cladosporium solutum* Link is reported as occurring on stems of *Euphorbia marginata,* but I have been unable to find a description.

CERCOSPORA sp., occurring in small amount on leaves of *Hypericum ascyron* at Madison, August 28, does not in any particular resemble *C. hyperici* Tehon & Daniels, the only species on *Hypericum* mentioned in Chupp's monograph. The fungus is hypophyllous on small, rounded, reddish spots. The conidiophores in lax fascicles, are 50–200 x 4.5–5.5μ, multiseptate, several times geniculate, clear brown, with paler, abruptly conic tips, while the conidia are from 60–140 x 3–4μ, multiseptate, acicular, hyaline, with truncate base.

ALTERNARIA sp. on *Panicum virgatum,* collected at Sylvania, Racine Co., August 19, 1953, appears parasitic and is on narrowly elongate white lesions with a reddish border. There are many lesions per leaf, causing very noticeable discoloration. Insofar as the spots are concerned, this seems quite similar to *Macrosporium panici* Ell. & Ev., as described, (Erythea 4: 28. 1896), but the fungus itself is a larger, coarser form.

ALTERNARIA sp., seemingly parasitic, occurred on living leaves of *Polanisia graveolens* in Iowa Co., near Arena, August 10. The pale brown spots are faintly zonate, rounded, 1.5–4 mm. diam., sharply defined. The fungus is amphigenous, but mostly epiphyllous. The conidia are pale brownish-gray, rapidly tapering from the base, multiseptate horizontally, with only rarely a vertical septation, 80–165 x 11–14μ. The conidiophores are the same shade as the conidia, relatively short, about 30–40 x 4–5μ, straight, simple, sometimes denticulate, 1–2-septate. There is no indication that this fungus is secondary after another or follows insect attack.

CILICIPODIUM AURIFILUM (Ger.) Sacc. has been collected on *Daedalea unicolor* at Madison, October 1953. The status of this interesting fungus is uncertain, but as the *Daedalea* sporophores do not look particularly fresh, it seems probable that the *Cilicipodium* developed saprophytically. The same remark applies to SEPEDONIUM CHRYSOSPERMUM (Bull.) Fr. on an undetermined polypore, also collected at Madison, July 1953.

FUSARIUM sp. occurs on dark-margined, brownish, subzonate, orbicular spots about .7–1 cm. diam. on living leaves of *Abutilon theophrasti* collected near Black Earth, Dane Co., August 17. If any other agent was responsible for the spotting it is not apparent. "*Fusarium roseum* Lk." has been reported on leaves of *Abutilon.*

Panicum leibergii, collected near Albany, Green Co., on September 1, bears black sclerotia on the green leaves and on mottled areas on languishing and dead basal leaves. On the dead leaves the sclerotia are less perfectly formed, perhaps indicating they did not start growth until after death of the leaf, and that it proved a less favorable substrate than the living leaves. In any event the matter of parasitism seems open to question. This is evidently the same organism found in 1949 on the closely related *Panicum scribnerianum* (Amer. Midl. Nat. 44: 633. 1950). Another specimen was collected on dead leaves of *Stipa spartea* at a station near Avoca, Iowa Co., September 27.

ADDITIONAL HOSTS

The following hosts have not been previously recorded as bearing the fungi mentioned in Wisconsin.

PLASMOPARA GERANII (Peck) Berl. & DeToni on *Geranium sibiricum.* Dane Co., near Dane, August 17.

ELSINOE VENETA (Burkh.) Jenkins on *Rubus strigosus.* Dane Co., Madison, September 5. On leaves and canes, only sparingly on the latter.

ERYSIPHE GALEOPSIDIS DC. on *Heliopsis scabra.* Green Co., near Attica, September 1. The rather extensive remarks in my Notes XI (Amer. Midl. Nat. 41: 717. 1949) concerning the occurrence of *E. galeopsidis* on *Eupatorium rugosum* seem to apply in this case as well, characterized as the specimen is by a profuse development of cottony superficial mycelium, exceptionally large perithecia with golden-yellow contents, and with asci which show no spores, so far as observed.

ERYSIPHE CICHORACEARUM DC. on *Solidago graminifolia.* Dane Co., Madison, September 22, 1953. On *Solidago flexicaulis (latifolia).* Waukesha Co., Nashotah, October 22, 1953.

SPHAERELLA (MYCOSPHAERELLA) SICYICOLA Ell. & Ev. on *Echinocystis lobata.* Dane Co., Madison, August 28. On well-defined spots and appearing parasitic.

VENTURIA SPOROBOLI H. C. Greene on *Sporobolus heterolepis.* Columbia Co., near Swan Lake, Sect. 2, Pacific Twp., September 11, 1953.

CLAVICEPS PURPUREA (Fr.) Tul. Sclerotia on *Calamagrostis inexpansa* var. *brevior* (host det. N. C. Fassett). Noted on two phanerogamic specimens, one collected by J. R. Heddle at Madison, August 1909, the other by J. J. Davis at Fish Creek, Door Co., September 3, 1929.

OPHIODOTHIS HAYDENI (B. & C.) Sacc. on *Aster azureus.* Rock Co., Magnolia Station, July 8, 1953. This uncertain organism, which seems nevertheless to be an entity, is discussed in my Notes IX (Trans. Wis. Acad. Sci. 38: 236. 1946).

PHYLLACHORA GRAMINIS (Pers.) Fckl. on *Calamagrostis neglecta.* Door Co., Fish Creek, September 27, 1919. Coll. J. J. Davis. On a phanerogamic specimen in the University of Wisconsin Herbarium. Davis filed the specimen as doubtful *Calamagrostis hyperborea* and did not report the fungus. Fassett later determined the host in connection with his critical revision of the species of grasses occurring in Wisconsin.

PELLICULARIA FILAMENTOSA (Pat.) Rogers on *Erigeron pulchellus.* Grant Co., Nelson Dewey Memorial Park near Cassville, August 3. Basidia present.

UROCYSTIS ANEMONES (Pers.) Schroet. on *Anemone patens* var. *wolfgangiana.* Columbia Co., Pacific Twp., near Swan Lake, June 9.

ENTYLOMA AUSTRALE Speg. on *Physalis subglabrata.* Dane Co., Primrose, August 16, 1953.

COLEOSPORIUM SOLIDAGINIS (Schw.) Thum. II, III on *Aster ptarmicoides.* Dane Co., Madison, August 26.

PUCCINIA GRAMINIS Pers. II on *Trisetum melicoides*. Milwaukee Co., Cudahy, August 9, 1939. Coll. L. H. Shinners. On a phanerogamic specimen in the University of Wisconsin Herbarium. Not reported on this host in Arthur's Manual. On *Poa pratensis* (Merion bluegrass). Milwaukee Co., Milwaukee, September 9. Comm. E. K. Wade.

PUCCINIA GRAMINIS Pers. II, III on *Hierochloe odorata*. Columbia Co., near Swan Lake, Pacific Twp., July 27. In small pustules near the leaf midrib. The flowering stalks of *Hierochloe* are produced in the early spring and disappear before midsummer. The long, semidecumbent summer leaves spring in tufts from a growing point near the ground and there is no well-defined stem on which characteristic lesions of *P. graminis* might be produced.

PUCCINIA SPOROBOLI Arth. II, III on *Sporobolus asper*. Grant Co., Nelson Dewey Memorial Park, near Cassville, August 14, 1953.

UROMYCES AMPHIDYMUS Syd. II, III on *Glyceria borealis*. Dane Co., Madison, September 6. Occurring in massive profusion on the bottom of a recently dried-up pond where the host formed a covering mat. The only earlier collections were made in the 1890's by J. J. Davis on *Glyceria septentrionalis*, in Racine Co.

PUCCINIA EXTENSICOLA Plowr. I on *Oenothera pilosella* Raf. The host is an escape from cultivation. Dane Co., Madison, June 24. II, III on *Carex sartwellii*. Rock Co., Evansville, October 4, 1953. Coll. R. W. Curtis. On *Carex haydenii*. Dane Co., Madison, August 7.

PUCCINIA SILPHII Schw. on *Silphium integrifolium* X *perfoliatum*. Green Co., Brodhead, July 20.

PHYLLOSTICTA ROSAE Desm. on *Rosa setigera* (cult.). Dane Co., Madison, July 8.

PHYLLOSTICTA CACALIAE H. C. Greene on *Cirsium discolor*. Dane Co., Madison, August 18. On *Cacalia atriplicifolia*. Madison, August 26. This species is analagous to the more aptly named *Ascochyta compositarum* J. J. Davis in that both occur on a wide range of hosts within the Compositae.

ASCOCHYTA COMPOSITARUM J. J. Davis on *Aster umbellatus*. Dane Co., Madison, August 9. On *Prenanthes racemosa*. Madison, September 3.

DARLUCA FILUM (Biv.) Cast. on *Uromyces sporoboli* Ell. & Ev. III on *Sporobolus asper*. Lafayette Co., Ipswich, October 6.

SEPTORIA ANDROPOGONIS f. SPOROBOLICOLA R. Sprague on *Sporobolus asper*. Grant Co., Nelson Dewey Memorial Park near Cassville, August 14, 1953.

SEPTORIA OENOTHERAE West. on *Oenothera parviflora.* Dunn Co., Elk Mound, September 5, 1953. Coll. D. E. Meyer.

SEPTORIA SONCHIFOLIA Cke. on *Sonchus oleraceus.* Columbia Co., near Lodi, August 17.

SEPTORIA HELIANTHI Ell. & Kell. on *Helianthus petiolaris.* Sauk Co., near Lone Rock, August 14, 1953.

SEPTORIA PSILOSTEGA Ell. & Mart. on *Galium trifidum.* Dane Co., Madison, September 4. The differentiation between *Galium tinctorium* and *G. trifidum* in the latest manuals is scarcely satisfactory and the above determination is made because the specimen in question seems to have a predominance of the characteristics ascribed to the latter.

HAINESIA LYTHRI (Desm.) Hoehn. on *Oenothera pilosella* Raf. Dane Co., Madison, June 24. On *Potentilla simplex (canadensis).* Waukesha Co., Nashotah, July 13.

GLOEOSPORIUM BRUNNEO-MACULATUM H. C. Greene on *Trillium recurvatum.* Green Co., Oakly, July 9.

COLLETOTRICHUM GRAMINICOLA (Ces.) Wils. on *Agrostis alba.* Dane Co., Madison, August 19. Sprague in his "Diseases of Cereals and Grasses in North America" indicates Wisconsin as a host locality, but there is no earlier specimen in our herbarium and Davis did not report this fungus on red top.

ELLISIELLA CAUDATA (Pk.) Sacc. on *Sporobolus asper.* Grant Co., Nelson Dewey Memorial Park near Cassville, August 14, 1953.

OVULARIA PUSILLA (Ung.) Sacc. & D. Sacc. (*O. pulchella* (Ces.) Sacc.) on *Hierochloe odorata.* Columbia Co., Pacific Twp. near Swan Lake. July 27. The closely related *Phalaris arundinacea* commonly bears *Ovularia hordei* (Cav.) Sprague, but this specimen does not have the serpentine conidiophores which characterize the latter.

RAMULARIA CANADENSIS Ell. & Ev. on *Carex sartwellii.* Dane Co., Madison, August 1. On *Carex trichocarpa.* Lafayette Co., Yellowstone Lake near Fayette, August 25. On the basis of the material that I have examined, it would seem that this would be better referred to *Didymaria.*

RAMULARIA MINAX J. J. Davis on *Solidago altissima.* Grant Co., Nelson Dewey Memorial Park near Cassville, August 3.

SCOLECOTRICHUM GRAMINIS Fckl. on *Alopecurus pratensis.* Monroe Co., Melvina, June 20, 1940. Coll. L. H. Shinners.

HELMINTHOSPORIUM GIGANTEUM Heald & Wolf on *Phalaris arundinacea,* Iowa Co., 3 miles west of Mazomanie, August 10. On *Leersia oryzoides.* Dane Co., Madison, August 29. In the latter specimen some of the conidia measured as much as 350 x

27μ. Drechsler, in his treatment of graminicolous species of *Helminthosporium* (Jour. Agr. Res. 24: 676. 1923), states "The conidia, which are produced in relatively small numbers, are easily the most massive of any species of *Helminthosporium* hitherto described, and are probably among the very largest produced by any group of fungi. . . . The volume of a spore of such dimensions is several hundred times greater than the volume of spores of molds that are not by any means regarded as minute fungi, while on comparison with some of the smallest types, like species of *Actinomyces,* ratios of approximately 1 to 300,000 may be obtained."

HELMINTHOSPORIUM SATIVUM Pamm., King & Bakke on *Stipa spartea.* Iowa Co., near Avoca, September 27.

CERCOSPORA CARICIS Oud. (*C. caricina* Ell. & Dearn.) on *Carex tenera, C. vulpinoidea.* Dane Co., Madison, July 17. On *Carex pennsylvanica.* Madison, August 24.

CERCOSPORA SILPHII Ell. & Ev. on *Silphium integrifolium.* Green Co., near Monticello, August 5.

ADDITIONAL SPECIES

The fungi mentioned have not been recorded before as occurring in Wisconsin.

MYCOSPHAERELLA SPLENIATA (C. & P.) House on *Quercus bicolor.* Iowa Co., Arena, April 15. On fallen, overwintered leaves, which developed the fully matured stage after five days in a moist chamber at room temperature. There can be little doubt that the microconidial form on *Quercus bicolor* and *Q. macrocarpa* in Wisconsin, which has been listed as *Phyllosticta livida* Ell. & Ev., is but the immature stage of *M. spleniata.* The type of *P. livida,* collected on *Quercus douglasii* in Amador Co., Calif., has been examined and shows close correspondence to Wisconsin specimens.

MELANNOMA POROTHELIA (B. & C.) Sacc. on *Stereum* sp. on *Cornus femina.* Dane Co., Madison, January 8, 1954. Coll. J. R. Jacobson. Perhaps only doubtfully parasitic. The *Stereum* had girdled the host trunks at ground line and, probably due to favorable moisture conditions, had in its older portions developed a much thicker layer of fungus tissue than is usually seen in *Stereum.*

TRANZSCHELIA SUFFUSCA (Holw.) Arth. on *Anemone patens* var. *wolfgangiana.* Columbia Co., Pacific Twp., near Swan Lake, June 9. Many large, old plants showed very heavy infection. An eastward extension of the Manual range.

PUCCINIA GRINDELIAE Peck on *Solidago nemoralis*. Columbia Co., near Lodi, September 24.

UROMYCES SPOROBOLI Ell. & Ev. II, III on *Sporobolus asper*. Lafayette Co., Ipswich, September 10. A decided eastward extension of the previously known range.

EXOBASIDIUM MYCETOPHILUM (Pk.) Burt. on *Collybia dryophila*. Dane Co., Madison, July 13. Coll. J. H. Grosklags. A very curious and interesting form, described and figured in Peck's 28th Report as *Tremella mycetophila*. Burt (Bull. Torr. Bot. Club 28: 285. 1901), from a study of stained sections, assigns the organism to *Exobasi..ium*. The host was growing under planted pines in the University of Wisconsin Arboretum.

PHYLLOSTICTA AMARANTHI Ell. & Kell. on *Amaranthus powellii*. Dane Co.; Madison, August 19.

Camarosporium parasiticum sp. nov.

Maculis orbicularibus, marginibus latis fuscis, centris pallidioribus, 2–5 (plerumque 2–3) mm. diam.; pycnidiis amphigenis, nigris, muris crassis supra, tenuioribus infra, subrostratis, subglobosis, 150–180μ diam. ca.; conidiis fumosis, cylindraceis, subcylindraceis, subglobosis vel ovoideis, levibus, septatis varie, 13–20 x 10–13μ.

Spots orbicular, with relatively wide dark brown border and paler center, 2–5 (mostly 2–3) mm. diam.; pycnidia amphigenous, black, thick-walled above, somewhat thinner below, subrostrate with a short thick black beak, subglobose, approx. 150–185μ diam.; conidia smoky, cylindric, subcylindric, subglobose or ovoid, smooth, variously septate, 13–20 x 10–13μ.

On living leaves of *Grindelia squarrosa*. Sect. 24, Township of Perry near the village of Forward, Dane County, Wisconsin, U. S. A., August 5, 1954.

The pycnidia are usually, but not always, arranged in a ring toward the margin of the spot. There is much diversity in the arrangement of the cross-septa in the conidia, many running at acute angles.

The only other species of *Camarosporium* which seems parasitic on living leaves with which I am familiar is *C. roumeguerei* Sacc. on Chenopodiaceae. Of a considerable number of species described on North American Compositae this is the only one on living tissue that I have noted.

Gloeosporium eragrostidis sp. nov.

Maculis nullis; acervulis carnosis, amphigenis, elongatis, 200–1200μ longis x 90–135μ latis; conidiophoris hyalinis, gracilibus, ampulliformibus, 25–30 x 3μ ca.; conidiis hyalinis, brevo-cylindraceis vel cylindraceis, 5–10 x 3–4μ.

Spots none, acervuli flesh-colored, amphigenous, more or less elongate, 200–1200μ long x 90–135μ wide; conidiophores hyaline, slender-flask-shaped, 25–30 x 3μ approx.; conidia hyaline, short-cylindric or cylindric, 5–10 x 3–4μ.

On living leaves of *Eragrostis spectabilis* (Pursh) Steud. Two miles east of Arena, Iowa County, Wisconsin, U. S. A., August 10, 1954.

E. spectabilis is a xerophyte with very strongly ribbed, inrolling leaves. The acervuli evidently originate in the mesophyll below the stomatal chambers, which are large and deep-set in this host. The acervuli develop within these chambers, filling them, and eventually breaking through to the leaf surface on one or both sides of the leaf. The conidiophores arise from a mass of pseudoparenchymatous tissue, are closely ranked, and appear to be simple and unbranched. The elongate shape of the acervuli is probably due to the xylem ridges of the host which sharply limit lateral development.

Colletotrichum typhae sp. nov.

Maculis flavo- vel rufo-brunneis, elongatis, 1–7 cm. x .25–1 cm. latis; acervulis in cinereis orbicularibus vel subellipticis centris; acervulis gregariis vel confertis, diam. variis, plerumque 100–200μ ca., amphigenis, depressis; conidiophoris hyalinis, confertis, brevibus, 10–15 x 3μ; setis in marginibus, saepe numerosis, muris crassis, laxis, subgeniculatis, fusco-brunneis, apicibus pallidioribus, subobtusis vel acutis, longitudinibus variis, interdum 150 x 4–5.5μ; conidiis hyalinis, granulosis, rectis, subcylindraceis vel subfusoideis, 17–23 x 3–5μ.

Lesions yellow- or reddish-brown, elongate, 1–7 cm. x .25–1 cm. wide, with the acervuli on an orbicular to subelliptic cinereous central portion; acervuli gregarious or crowded, diameter variable, mostly about 100–200μ, amphigenous, sunken; conidiophores hyaline, crowded, short, about 10–15 x 3μ; setae marginal, often numerous, thick-walled, rather lax, subgeniculate, dark brown with paler, subobtuse to pointed tips, length variable, up to 150 x 4–5.5μ; conidia hyaline, granular, straight, subcylindric or subfusoid, 17–23 x 3–5μ.

On living leaves of *Typha latifolia*. University of Wisconsin Arboretum, Madison, Dane County, Wisconsin, U. S. A., September 25, 1953. Additional material was collected at the type station on August 7, 1954.

Colletotrichum arisaematis sp. nov.

Maculis fumosis, diaphanis, marginibus fuscis, angustis, orbicularibus, 4–7 mm. diam.; acervulis gregariis, amphigenis, parvis, rudibus, planis vel elevatis leviter, cellis pallido-brunneis; setis unicis vel in parvis fasciis (5–6), fere rectis vel curvis vel sinuosis nonnihil, claro-brunneis, muris crassis, attentuatis, apicibus acutis pallidioribus, 45–120 (plerumque 60–80 ca.) x 3–4μ, 1–2-septatis, cellis basibus amplioribus nonnihil; conidiophoris hyalinis, tenuibus, brevibus, fere obsoletis; conidiis hyalinis, cylindraceis, granulosis, 15–22 x 3–4.5μ.

Spots smoky, diaphanous, with narrow dark border, orbicular, 4–7 mm. diam.; acervuli gregarious, amphigenous, small, rudimentary, plane or even slightly elevated, the cells pale brown; setae single, or in small tufts of not more than 5 or 6, almost straight, or somewhat curved or sinuous, clear brown, rather thick-walled, attenuate, the acute tips paler, 45–120 (mostly 60–80 ca.) x 3–4μ, 1–2-septate, basal cell moderately enlarged; conidiophores hyaline, slender, short, almost obsolete; conidia hyaline, cylindric, granular, 15–22 x 3–4.5μ.

On living leaves of *Arisaema atrorubens (triphyllum)*. New Glarus Woods Roadside Park, Green County, Wisconsin, U. S. A., June 14, 1954.

Scarcely the usual *Colletotrichum* but, in my judgment, best assigned here. The most striking thing about this species is the large number of individual setae, not in tufts and seemingly not associated with the acervuli. The enlarged basal cell of the seta is usually about twice the diameter of the adjacent portion. Although the acervuli, instead of being concave, the plane or even slightly elevated they can hardly, in my opinion, be regarded as sporodochia.

On the fresh green leaflets the spots are rather dull, but following pressing and drying they become very striking, as the normal host tissue tends to become decolorized. In addition to the actual spots there remains a dull green halo approx. 2 mm. wide around them indicating, it would seem, that the green color has been fixed to the outer limits of fungus infection.

Rather poor material of this species was collected in 1947 (Amer. Midl. Nat. 39: 447. 1948), at which time the fungus was discussed as being possibly close to *Ramularia arisaematis* Ell. & Dearn.

RAMULARIA GRINDELIAE Ell. & Kell. on *Grindelia squarrosa*. Dane Co., near Forward, August 5. A small specimen, but on the living leaves and closely corresponding to the original description.

CERCOSPORA BRACHIATA Ell. & Ev. on *Amaranthus blitoides.* On *Amaranthus albus.* Dane Co., Madison, August 28. Also on *Amaranthus retroflexus.* Madison, September 20.

CERCOSPORA AVICENNAE Chupp on *Abutilon theophrasti.* Dane Co., Black Earth, August 17. Davis collected a specimen on this host in 1935 and assigned it to *C. althaeina* Sacc., but Chupp regards the fungus on *Abutilon* as distinct, and describes it as a new species in his "Monograph of Cercospora", p. 369.

CERCOSPORA HALENIAE Chupp & Bisby on *Halenia deflexa.* According to Chupp, in his "Monograph of Cercospora" p. 238, Wisconsin specimens on *Halenia,* determined by Davis as *C. gentianicola* Ell. & Ev., are separate and distinct.

ALTERNARIA TENUIS Nees on *Vigna sinensis* (cult.). Dane Co., Madison, September 12, 1953. Coll. J. B. Sinclair. This appears strongly parasitic. It is highly probable that *Alternaria atrans* Gibson, described as on cowpea in Arizona, is a synonym of *A. tenuis.*

BRIOSIA AMPELOPHAGA Cav. on leaves of *Vitis riparia (vulpina).* Dane Co., Madison, September 11. Det. by S. J. Hughes of the Canadian Science Service. A most striking and interesting stilbaceous fungus, figured in Flora Ital. Crypt. Pt. 1 (Hyphales): 184. 1910. The original description, prepared from material on *Vitis vinifera,* states that the fungus occurred on the fruit, but Hughes points out that in a recent record from Texas (Index Pl. Dis. in U. S.—Pl. Dis. Surv. 5: 1186. 1953) *Briosia* is mentioned as causing "leaf blotch", a most apt designation for the effect produced on *Vitis riparia.* Unless this is a recent introduction to Wisconsin, it is difficult to understand how it has hitherto escaped detection, what with the large and conspicuous lesions that are produced.

AN INVESTIGATION OF THE CHEMICAL OXYGEN DEMAND DETERMINATION

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The biochemical oxygen demand (B.O.D.) determination for evaluating the strength of domestic and industrial wastes is now used almost universally. Despite its wide acceptance it possesses the great shortcoming that five days are required for reliable data. A test that would give results in a much shorter time would of course be very desirable. Many attempts have been made to select a chemical oxygen demand (C.O.D.) test that would give the same results in a matter of hours or minutes. The difficulties encountered in such tests arise from the fact that chemical oxidation of organic matter follows different paths and stops at different points from those of biochemical oxidation. Thus the values obtained by B.O.D. and C.O.D. determinations may have a high degree of correlation but ordinarily they are not the same.

Moore, Kroner, and Ruchhoft (1) as well as Ingols and Murray (2) have given brief histories of the many attempts made to develop a satisfactory C.O.D. test. The main oxidizing agents that have been used are potassium dichromate, potassium permanganate, ceric sulfate, and iodic acid. Standard Methods for the Examination of Water and Sewage (3) at present describes an oxygen consumed test using potassium permanganate as the oxidizing agent. From recently published results (1) (2) (4) it appears that a dichromate oxidizing solution is the most reliable and is not difficult to use.

Rhame (4) used potassium dichromate as the oxidizing agent in a mixture of equal parts of sulfuric and phosphoric acids. He determined the unused dichromate by means of potassium iodide, starch, and sodium thiosulfate. His method did not consider the loss of volatile materials by evaporation from the open container during boiling, and it did not use a constant mixture that would maintain a constant boiling temperature. These two conditions undoubtedly produced results that were not readily reproducible.

Ingols and Murray (2) employed the same oxidizing agent that Rhame had suggested and similarly determined the amount of unused reagent. They refined Rhame's method by refluxing in an all glass apparatus for a definite period of time; by taking a constant amount of reagent and sample, thus causing a constant boiling temperature; and by correcting for the oxidation of the chloride ion. Their work showed that a refluxing temperature of about 150°C was the most satisfactory. They obtained this temperature by using 25 ml. of acid-oxidation mixture and 10 ml. of sample. Samples of that size, however, often gave very small depletions which were conducive to large errors.

Moore, Kroner, and Ruchhoft (1) omitted the phosphoric acid and used sulfuric acid alone in the oxidation mixture. As a result they were able to obtain a satisfactory refluxing temperature of about 150°C. and still use a large sample of waste. Their method of determining the amount of oxidizing agent remaining unused consisted of a direct titration with standard ferrous ammonium sulfate using orthophenanthroline ferrous complex as the indicator.

Their work consisted mainly of determining the chemical oxygen demand of pure organic compounds. They found that sugars and cellulose were oxidized nearly to completion. Straight chain acids, including acetic acid, and straight chain hydrocarbons were scarcely attacked. Many other types of organic compounds were oxidized to various degrees but in all cases where the breakdown resulted in acetic acid the action stopped there.

Muers (5) in a communication to Ruchhoft (6) made it known that silver sulfate is an efficient catalyst for the oxidation of acetic acid. Investigations using this catalyst were later carried on at Cincinnati under the direction of Ruchhoft. (7)

Discussion of the Present Study

The aims of this investigation were:

1. To study and evaluate silver sulfate as a catalyst for the C.O.D. test.
2. To attempt to find other suitable catalysts.
3. To determine, and attempt to correlate, the C.O.D. and B.O.D. values of pea cannery, corn cannery, paper mill and other wastes.

In the present study it was found that excessive and violent bumping often occurred when sulfuric acid alone was used in the refluxing mixture. The following method was developed which appears to be very satisfactory in that bumping is almost completely eliminated and a moderate size sample is used. Potassium dichromate is dissolved in enough 4:1 mixture of sulfuric and phosphoric acids to make the resulting solution 0.125 normal as to potassium dichromate. Fifty ml. of this reagent are mixed with forty ml. of sample and refluxed for two hours in an all glass apparatus. The temperature maintains itself at about 147–150°C. and little bumping occurs. The unused dichromate is titrated with ferrous ammonium sulfate using orthophenanthroline as the indicator.

Reagents and Procedure

The oxidation mixture is prepared by placing 6.125 g. of potassium dichromate in 200 ml. of 85% phosphoric acid and adding concentrated sulfuric acid to make 1 liter. Considerable heat is evolved and the dichromate dissolves slowly. The 0.25 N ferrous ammonium sulfate is prepared by dissolving 100 g. of $Fe\ SO_4 \cdot (NH_4)_2\ SO_4 \cdot 6H_2O$ in enough 0.5 N sulfuric acid to make 1 liter. This solution is standardized daily with 0.25 N potassium dichromate. The orthophenanthroline indicator is prepared by dissolving 1.5 g. of the reagent in 100 ml. of 0.025 N ferrous sulfate solution made with 0.5 N sulfuric acid.

40 ml. of sample, or a lesser amount diluted to that volume, is placed in a round bottom standard taper joint flask (preferably 500 ml.) containing a number of glass beads. To this is added 50 ml. of the oxidizing solution. The mixture is thoroughly agitated, attached to an all glass water cooled condenser and refluxed for two hours. A distilled water reagent blank is refluxed at the same time. When the mixture is cool the condenser is rinsed with distilled water, the flask is removed and approximately 200 ml. distilled water added. The excess oxidizing agent is determined by titration with the ferrous ammonium sulfate. The endpoint is sharp, changing from green to red.

Calculations

$$\text{C.O.D., p.p.m.} = \frac{(a-b) \times N \times 1000 \times 8}{\text{Volume of sample}}$$

a = ml. of ferrous ammonium sulfate used for blank.

b = ml. of ferrous ammonium sulfate used for sample.

N = normality of ferrous ammonium sulfate.

Correction for chloride oxidation.

Chloride corrected C.O.D. = C.O.D. — (0.23 × p.p.m. chloride).

CATALYSTS IN THE C.O.D. DETERMINATION

Muers (5) found silver, in the form of silver sulfate, to be a good catalyst for this test. He used a concentration of about 0.33% silver sulfate in the refluxing mixture. Determinations made under similar conditions confirmed his findings. Water solutions of acetic acid, lactic acid, pyridine, benzene and alanine were made and the C.O.D. of each determined with and without the silver sulfate present. The oxidation of acetic acid, lactic acid, and alanine in the presence of the catalyst was greatly increased but benzene and pyridine were unaffected, as shown in Table I.

TABLE I

THE CATALYTIC EFFECT OF SILVER SULFATE ON C.O.D.

	Percent of Constituent Oxidized	
	Silver Sulfate Absent	Silver Sulfate Present
Acetic acid	4	98
Lactic acid	47	97
Alanine	36	80
Benzene	10	10
Pyridine	1	1

Sulfates and oxides of mercury, copper, sodium, magnesium, manganese, cerium, lead, aluminum, zinc and tellurium as well as elemental selenium were also used to determine any possible catalytic effect on this reaction. None of these materials appeared to be of appreciable value, as shown in Table II.

In the case of selenium the oxidizing power of the reagent was consumed even in the blank, hence no values were obtained. This result does not agree with that of Ingols and Murray (2) who found selenium to be a good catalyst. With tellurium dioxide there was a considerable depletion in the blank as well as in the sample, hence the values obtained are of doubtful value.

Manganese sulfate reacted to form the purple permanganate with which a sharp endpoint was not readily obtained. The apparent increase in the C.O.D. with this compound may have some significance, but it is believed that it would not be a practical catalyst since a comparatively large amount of it produced only a moderate increase in the oxidation values obtained.

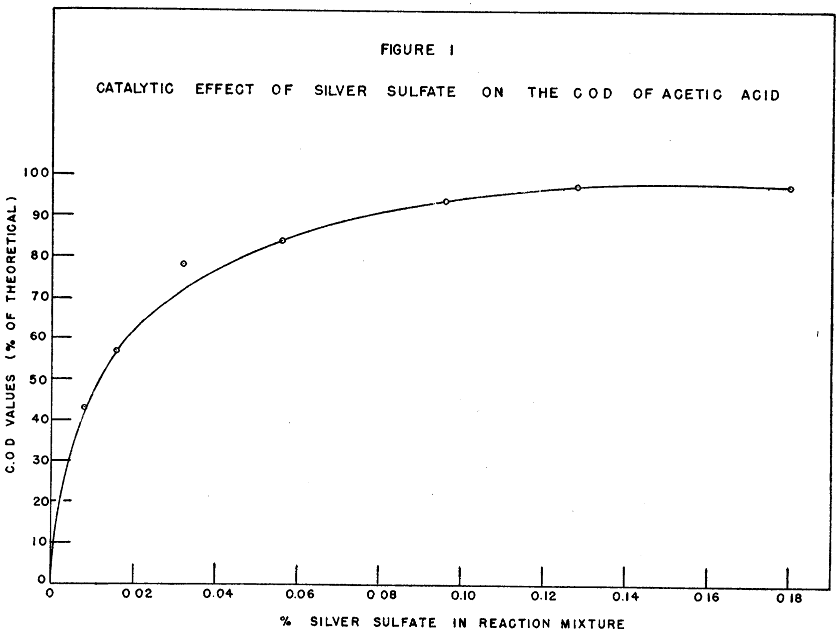
TABLE II

THE CATALYTIC EFFECT OF VARIOUS SUBSTANCES ON C.O.D.

SUBSTANCE ADDED	%	ACETIC ACID	LACTIC ACID	PYRIDINE	BENZENE	ALANINE
None	...	48,000	492,000	24,000	320,000	448,000
Ag_2SO_4	0.15	1,010,000	1,024,000	24,000	320,000	1,000,000
HgO	0.07	64,000	568,000	16,000	...	...
Se	0.75	*	*	*	*	*
$CuSO_4$	0.75	30,000	525,000	20,000	250,000	432,000
N_2aSO_4	0.75	60,000	532,000	16,000	...	...
$MgSO_4$	0.75	40,000	552,000	16,000	...	...
$MnSO_4$	0.75	416,000	790,000	24,000	800,000	...
$Ce(SO_4)_2$	0.75	80,000	504,000	...	190,000	442,000
PbO_2	0.75	000	000	000	000	000
$Al_2(SO_4)_3$	0.75	46,000	510,000	24,000	250,000	416,000
$ZnSO_4$	0.75	38,000	510,000	32,000	260,000	505,000
TeO_2	0.30	224,000	384,000	183,000	350,000	384,000
Theoretical Values	...	1,066,000	1,066,000	2,531,000	3,072,000	1,258,000

*Blanks and samples became green, due to reduction of dichromate by Se itself.

A series of tests were made to determine the amount of silver sulfate necessary for maximum oxidation of acetic acid. The results are shown graphically in Figure 1. The optimum amount of silver sulfate appeared to be about 0.15% by weight. In a similar series of tests with pea cannery waste the optimum amount of this catalyst again appeared to be about 0.15% as shown in Figure 2. Using this value as the standard silver concentration a series of tests were made with acetic acid to determine the



optimum time of refluxing the sample. Figure 3 indicates that in approximately 1.5 hours the oxidation was complete. The two hour reflux period was retained and considered to be entirely satisfactory.

Comparison of C.O.D. and B.O.D. of Various Wastes

The 5 day B.O.D. represents about 68% of the ultimate oxygen demand that is exerted over an extended period of time. It is often assumed that the C.O.D. should correspond to this ultimate B.O.D., but the assumption is true only in those cases where oxidation goes to completion both chemically and biochemically under the conditions of the tests. When that condition prevails the ratio of the C.O.D. to the 5 day B.O.D. should be 1.47:1

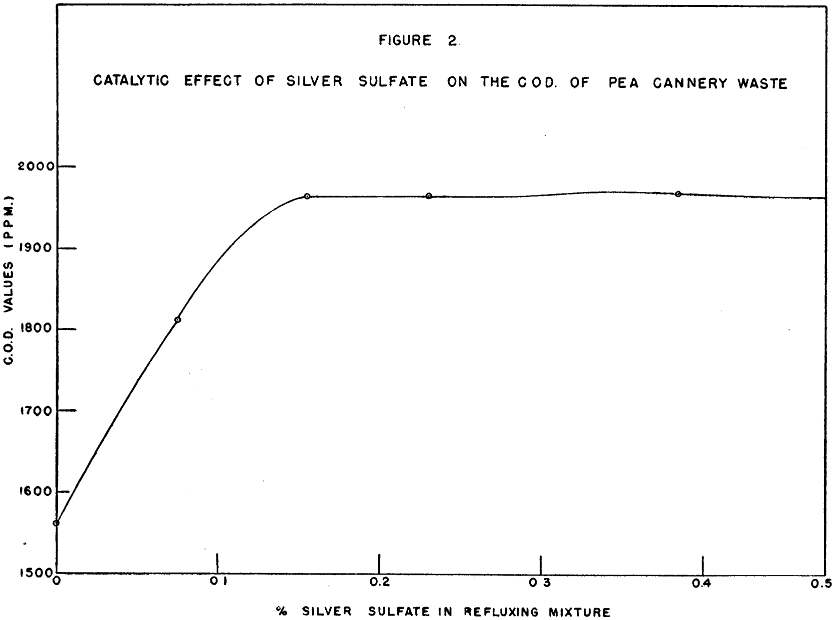


FIGURE 2
CATALYTIC EFFECT OF SILVER SULFATE ON THE C.O.D. OF PEA CANNERY WASTE
C.O.D. VALUES (P.P.M.)
2000
1900
1800
1700
1600
1500
0
0.1
0.2
0.3
0.4
0.5
% SILVER SULFATE IN REFLUXING MIXTURE

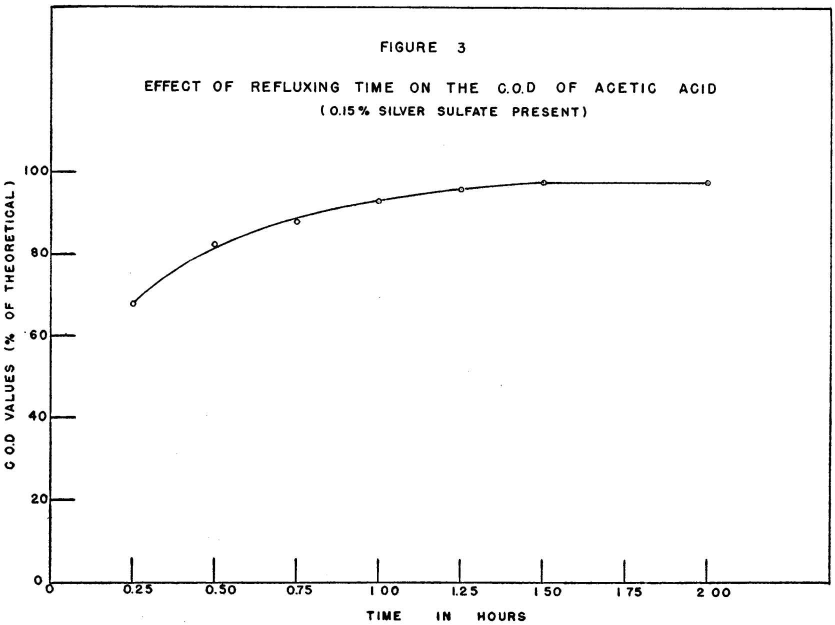


FIGURE 3
EFFECT OF REFLUXING TIME ON THE C.O.D OF ACETIC ACID
(0.15% SILVER SULFATE PRESENT)
C.O.D VALUES (% OF THEORETICAL)
100
80
60
40
20
0
0
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
TIME IN HOURS

(100%:68%). The ratios of the two determinations that are given in this paper in all cases refer to the 5 day B.O.D.

In cooperation with the Wisconsin State Board of Health and the State Laboratory of Hygiene, daily 24 hour composite samples of pea cannery and corn cannery waste were analyzed for their C.O.D. and 5 day B.O.D. The C.O.D. values of the early samples of pea cannery waste were determined without the silver catalyst, but all others were determined both with and without this catalyst. In all cases there was a considerable increase in the C.O.D. values when using the catalyst, the average increase being 18% for the pea cannery waste and 53% for the corn cannery waste.

TABLE III

C.O.D. AND B.O.D. VALUES OF PEA CANNERY WASTE

LAB. NUMBER	5 DAY B.O.D.	C.O.D. NON-CATALYZED	RATIO C.O.D. TO B.O.D.	C.O.D. Ag_2SO_4 CATALYZED	RATIO C.O.D. TO B.O.D.
9073	900	1130	1.25:1	....	....
9074	979	1290	1.32:1	....	....
9076	863	1160	1.34:1	....	....
9077	1445	1590	1.10:1	....	....
9391	84	198	2.36:1	....	....
9392	787	1150	1.41:1	....	....
9393	1380	1655	1.20:1	....	....
9394	83	105	1.26:1	....	....
9566	1180	1460	1.24:1	....	....
9722	1210	1655	1.37:1	....	....
9724	1625	1925	1.19:1	....	....
10115	991	1860	1.87:1	....	....
10116	847	1180	1.39:1	....	....
10281	1580	1880	1.19:1	2070	1.31:1
10282	1530	1650	1.08:1	1885	1.23:1
10819	1507	1720	1.14:1	2030	1.35:1
10820	1610	1940	1.20:1	2150	1.33:1
10821	1850	1970	1.06:1	2200	1.19:1
10822	1125	1550	1.38:1	1940	1.73:1
10977	1470	1560	1.06:1	1940	1.32:1
10978	1585	1560	0.98:1	1900	1.20:1
11254	1180	1470	1.15:1	1860	1.45:1
11255	1455	1700	1.17:1	2130	1.46:1
11380	574	860	1.50:1	1010	1.76:1
11381	1050	1350	1.28:1	1650	1.57:1
11573	1420	2140	1.51:1	2770	1.95:1
11574	1387	1770	1.27:1	1975	1.42:1
11818	1320	1845	1.40:1	2285	1.73:1
11819	1310	1800	1.37:1	2125	1.62:1
12008	1550	2250	1.45:1	2680	1.73:1
Average Ratio			1.31:1		1.49:1

Table III gives the 5 day B.O.D., the C.O.D. with and without catalyst, and the ratios of the C.O.D. to B.O.D. for pea cannery waste. The ratios based on the catalyzed C.O.D. determinations approach the calculated value of 1.47:1, the average being 1.49:1. The deviation from the average ratio is moderate, the maximum deviation for 17 determinations being 31%. For the non-catalyzed determinations the ratios are considerably lower as shown by the average of 1.31:1. From this data it was concluded that the use of silver sulfate in the C.O.D. determinations on cannery waste is practical and desirable.

TABLE IV

C.O.D.:B.O.D. Ratio of Corn Cannery Waste

Lab. Number	Ag_2SO_4 Catalyzed C.O.D.	5 Day B.O.D.	Ratio C.O.D. to B.O.D.
13674	2130	1368	1.55:1
13901	3300	1960	1.68:1
13902	510	298	1.71:1
14117	2720	1660	1.65:1
14118	2400	1750	1.37:1
14219	2800	1665	1.69:1
14220	2720	1455	1.87:1
14595	2230	2085	1.07:1
14596	2010	2040	0.99:1
14941	2480	2530	0.98:1
14942	4320	1960	2.20:1
14943	2280	1730	1.32:1
14944	5060	2330	2.17:1
14945	3040	1975	1.55:1
15428	15900	10000	1.59:1
15429	2920	2670	1.08:1
15700	2260	2400	0.95:1
15701	2440	2125	1.15:1
15702	2540	1270	2.00:1
16126	2210	1365	1.62:1
16127	2810	1270	2.20:1
16988	1920	1475	1.30:1
16989	2300	1280	1.80:1
Average Ratio	....	....	1.54:1

Table IV shows the C.O.D. and B.O.D. values and their ratio for corn cannery waste. As with the pea cannery waste the ratio closely approaches the calculated value, the average being 1.54:1. The maximum deviation from the average ratio is 43%, which is somewhat greater than that for pea cannery waste. A probable explanation for at least a part of this deviation is the fact that the samples did not arrive daily and in many cases were several days old before the determinations could be made.

Table V shows the C.O.D. and B.O.D. values and their ratio for five samples of waste sulfite liquor from various pulp making mills in Wisconsin. It is noted that the ratio deviates widely from the calculated value, indicating that the oxidation proceeds much more nearly to completion chemically than it does biochemically. The maximum deviation from the average is 36% which does not appear unreasonable when considering the fact that the wastes are from various sources and may have contained toxic materials that affected the B.O.D.

TABLE V

C.O.D. AND B.O.D. VALUES OF WASTE SULFITE LIQUOR

LAB. NUMBER	C.O.D. Ag_2SO_4 CATALYZED	5 DAY B.O.D.	RATIO C.O.D. TO B.O.D.
19567	63000	14600	4.3:1
20568	4320	780	5.5:1
20569	600	84	7.1:1
20613	133000	35000	3.8:1
19297	610	120	5.1:1
Average Ratio			5.2:1

Unpublished data obtained by Lea (8), at the Sanitary Engineering Laboratory of the University of Wisconsin, showed that the C.O.D. to B.O.D. ratio for domestic sewage follows a characteristic pattern for any one sewage treatment plant. The ratio is low for raw and settled sewage but increases as the waste is treated, as shown in Table VI. All determinations were made on samples obtained from the Nine Springs Treatment Plant at Madison, Wisconsin.

TABLE VI

C.O.D. TO B.O.D. RATIO OF DOMESTIC SEWAGE

Raw domestic sewage	1.61:1
Primary settled effluent	1.45:1
Filter effluent	4.55:1
Activated slude effluent	3.85:1

In 12 determinations the maximum deviation from the average ratio was 19% for raw sewage, 23% for primary effluent and 27% for activated sludge and trickling filter effluent.

From the data given it is apparent that the C.O.D.:B.O.D. ratio is far from constant when considering various wastes. It does appear, however, that for any specific waste from one source the variation in the ratio is usually moderate.

The bulk of the published data and information relating to the strength of wastes and the effects of wastes on lakes and streams are based on the B.O.D. determination; thus the use of the C.O.D. determination alone results in values that are often inadequate, unless they can be translated into terms of B.O.D. In many cases of routine control or survey work the C.O.D. test will give values that can be satisfactorily translated into terms of B.O.D., providing the ratio between the two has been established for the waste in question. When such use of the C.O.D. test is made the B.O.D. need be determined only occasionally to check the ratio. The main advantage resulting from the use of the C.O.D. determination in place of the B.O.D. is the great reduction in time required to obtain results. The C.O.D. test requires about three hours as compared to 5 days for the B.O.D. The results obtained by the latter are often of historic value only, and in those cases where they indicate that conditions are not satisfactory it is usually far too late to make changes or corrections. With the C.O.D. determination, however, the results are usually known quickly enough that corrective measures can be applied, or changes made to modify the character of the waste. Better control of waste disposal and treatment is thus possible when results are quickly available.

CONCLUSION

1. The phosphoric acid-sulfuric acid oxidizing mixture as previously described is very satisfactory for the C.O.D. determination.

2. Silver sulfate catalyzes the reaction and increases the C.O.D. values of most wastes. The optimum concentration of silver sulfate in the refluxing mixture was found to be 0.15%.

3. The C.O.D. to B.O.D. ratio varies considerably between types of wastes.

4. The C.O.D. to B.O.D. ratio for any specific waste from one source varies only moderately.

5. For routine control and survey work the C.O.D. determination may often replace the B.O.D. determination providing their ratio has been established for the particular waste being determined.

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DYLAN THOMAS: THE ELEMENTAL POET

MARTHA HALLER WILDE*

Dylan Thomas' songs of the fundamental passions of mankind were terminated by the poet's death last year. While the Welsh bard lived critics sometimes felt compelled to warn the reader against obscurity in his poetry. Such evaluations are likely to lead us away from a major feature of the greatness of the poems: their ingredients are actually the staples that have constituted poetry and life for time immemorial. A close reading of Thomas' poetry suggests that beneath the difficult syntax and startling word combinations lies a unity of elemental concepts and language.

A Thomas poem is "elemental" in form and content; in fact, the form is the content, for the order and use of words and verse techniques cannot be divorced from the meaning. The words and images are basic and often traditional, the ideas and themes simple and fundamental. Elemental language is not difficult, academic, or four syllabled; unfamiliar words can usually be traced to a homely Welsh background. Often the language of the Bible can be recognized. The fundamental emotional nature of man is here; the elements are mixed by the associative processes that characterize the mind of natural man who sees himself as an extension of the external world.

The associative method of creation in Thomas does not imply lack of control. Despite strange juxtapositions and syntax, a unity of feeling is created because the combinations are not products of a blind "pin the tail on the donkey" game. Such unity courses through the entire body of Thomas' poetry. As one reads the poems *en masse* they become canons of a special, personal scripture. In his later poetry Thomas himself learned to label the primary material projected in these scriptures:

> Four elements and five
> Senses, and man a spirit in love

There is hardly a poem that does not employ variations upon air, earth, water, and fire—the four elements. To a young poet the water is womb water of fertility; as he matures the water becomes the sea of life familiar to all readers of poetry. And the

* University of Wisconsin. The author is indebted to Professor Haskell Block of the Comparative Literature Department for helpful suggestions and criticisms.

fertility of green earth is inside the young poet, just as the earth's worm of death is in him; the older poet is able to place this greenness and the dangers of rock barrenness in the natural world, still projecting himself so that his later poems have been called Wordsworthian. The youthful wind is his own breath of life and self destruction, whereas the wind becomes a cry of nature in later poems. The fire is the heat of his own veins at first, but it becomes the potential life-giver and life-taker, as well as the means of purification through phoenix-like resurrection and a reminder of hellfire and brimstone religious background.

After the "four elements" come the "five senses" which also suggest development from self-exploration to exploration of God, nature, and other creatures. This progress is not from subjectivity to objectivity, however; the subjective poet's "I" is ever present, even in the latest volume, *In Country Sleep,* but the "I" has become aware of something besides its own body. Early poems employ the correspondence of nature and body with the center of action being the latter; later poems employ the same correspondence but the natural world is the scene. Whereas the world of seasons and elements was first used to elucidate the world of the senses, later the senses elucidate the world of nature. The "Five and Country Senses" work synaesthetically in "lunar silences," "green thumbs," "nostrils that see her breath and burn," "nutmeg, civet, and sea-parsley serve the plagued groom and bride," "moonshine echoing clear," and "the louder the sun blooms." Sight and sound are the favored senses.

The third label that Thomas provides is "Man a spirit in love." "Man be my metaphor" betrays the poet's primary theme. The man is usually himself, a spirit in love with life and out of love with death. In his own words, then, Thomas gives us a key to his imagery and the emotions expressed in his poetry. An investigation of themes as bound up in imagery will suggest the nature of the music of personal passions and problems in the elemental man.

The theme of death pursues Thomas throughout his poetry. "Death's feather" appears to taunt him in at least two of the first *18 Poems* and in two later poems; even as he describes the prenatal development of the foetus in the womb and the birth and development of the child through maturity, we find death waiting to pull "down the shabby curtains of the skin" in "The Process of the Weather of the Heart." A symbol from the external world (weather) is juxtaposed with a symbol of the internal world (the heart); thus mutability is depicted as the forces of nature are applied to the physical changes in the development of the individual. Life is "the Eastern weather" in "Before I Knocked" and the archetypal pattern of spring weather is utilized in "Hold Hard, These Ancient Minutes in the Cuckoo's Month." The poet continues to use this comparison. The "golden weather" of "We Lying By Seasand" can only be disturbed by the "rock arrival" of barrenness and death. "Storm snow, and fountain in the weather of fireworks" tells us something of the violence of the sinner of old time revival religion in "It Is the Sinner's Dust-tongued Bell." The "outside weathers" quarrel with the internal temperament of the animal inside of "How Shall my Animal." Thomas sees "the boys of summer in their ruin," knows "the message of the winter," feels the "October wind" punishing his hair, that "Beginning with doom in the bulk, the spring unravels," that "Here In This Spring" the world wears away, that "love in the frost is pared and wintered by," that there is "dark-skinned summer," "A Winter's Tale," and "Holy Spring." In all of these poems from the earliest to the latest there is the simple correlation of the seasons of the year with the seasons of man's life and the recognition of what Jeremy Taylor designated in his conduct book, *Holy Dying*—mutability of life where seeds of winter are present even in our spring fever.

Like the seventeenth century divines, Hamlet, and non-conformist preachers, Thomas is early preoccupied with cadavers, worms, and the grave. At first the poet is "dumb to tell the lover's tomb/ How at my sheet goes the same crooked worm." He writes, "I sit and watch the worm beneath my nail/ Wearing the quick away" and, Hamlet-like, there's the "rub"; "The shades of girls, all flavoured from their shrouds,/ When sunlight goes are sundered from the worm." In October he is conscious of the "wormy" winter"; in dreaming his "genesis" he knows that limbs "had the measure of the worm"; the "worm in the scalp" haunts "All All and All the Dry Worlds Lever," and finally the "Worms/ Tell, if at all the winter's storms/ Or the funeral of the sun" in "Here in This Spring." After the early poems the worms disappear from the limelight.

But death is ever present. Time and the transciency of things are the poet's foes. "When like a running grave, time tracks you down," as you grow older, you try to catch the physical sensations life has to offer before "time/ on track/ Shapes in a cinder death." "Who kills my history?/ Time kills me." "Time let me play and be"; "Time held me green and dying." Time smirks because the poet knows that birth is only the beginning of dying:

Time is bearing another son.
Kill Time! She turns in her pain!
The oak is felled in the acorn
And the hawk in the egg kills the wren.

There is nothing more basic than the dust unto dust theme. "The corpse's lover," "cadaverous gravels," "Man was Cadaver's masker . . ." "time's maggot," "Death hairy heeled," meat on bones, marrow, and winding sheets become "the atlas-eater with a jaw for news (in fact death is "all metaphors")," "the meat eating sun," and "the last Samson of your Zodiac." The emphasis on the Elizabethan or Gothic physical obsession with death has been exchanged for a less traditional kind of imagery.

Death as a personal experience continues to haunt the poet, but he reaches out also to others. By 1939 Thomas can write "In Memory of Ann Jones," his feelings about the death of another person. "The Tombstone told when she died" finds him again exploring his relationship to an older dead woman. "The Refusal to Mourn" for a child killed in an air raid, "The Conversation of Prayers," "Ceremony After Air Raid," and "Among those Killed was a Man Aged a Hundred" objectify the problem of death, from which the poet even here cannot disassociate himself.

There is a development away from black pessimism as the poet matures. Death is always the destroyer; time is always at his back, but the poet can cry that "Death Shall Have No Dominion" for life itself goes on. Like the birthday poems, "Holy Spring" blesses and clings to life despite death's shadow. Thomas wrote "Unluckily for Death" and finally that bold but controlled defiance

Do not go gentle into that good night,
Old age should burn and rave at close of day,
Rage, rage against the dying of the light.

Like Yeats, he refused to acquiesce, and like a seventeenth century counterpart, he wanted to gather his rosebuds while he might.

The lyric poet whose concern is bluntly sex and death must on the other side of the coin, then, sing love songs. The melancholic is balanced by the sanguine humor. Again the technique of correspondence between microcosm and macrocosm serves him. John Donne's countryside of the female body is approximated by the elements that make the "waters . . . green knots . . . (and) tides" of "Where Once the Waters of your Face." The sexual imagery of "Light Breaks Where No Sun Shines" may be understood by similar elemental correspondence plus a Freudian candle symbol. "I sent my creature scouting on the globe,/ That globe itself of hair and bone" explains the correspondence in "When Once the Twilight Locks No Longer." "Now in the cloud's big breast lie quiet countries/ Delivered seas my love from her proud place" in "I Make This in a Warring Absence" and "Love's countries" of "When All My Five and Country Senses See" suggest correspondence again. In "Ears in the Turrets Hear" Thomas approaches the subject of the isolated individual in the ivory tower of "this island bound/ By a thin sea of flesh/ And a bone coast" by another comparison which forces us to recognize simultaneously the little world of the individual and the big world of nature. The difficult "Unluckily for Death" carries us to a more profane kind of comparison; as in Donne's "Canonization," sensual love is described in terms of holy love. "Marriage of the Virgin" also operates on these two levels.

This use of imagery from Christian belief is basic to the total Thomas scripture, but, unlike the metaphysical poets of the seventeenth century and Gerard Manley Hopkins, the Welsh poet never got far beyond the Jack Donne stage. Thomas' highest exultation is never far beyond the elemental man of flesh and fear.

Even early poetry not directly concerned with man's awareness of God contains many Biblical allusions, terms in which to case less spiritual matter. We are reminded of the Bible and sermonizing of non-conformist Christianity by phrases such as "a little sabbath with the sun," "Before I knocked," "The message of his dying christ," "In the beginning," "my genesis," "this bread I break," "incarnate devil," "manna up through the dew of heaven," "fell from grace," "Vision and Prayer," and "Suffer the heaven's children through my heartbeat."

Biblical characters, especially from the Old Testament, are presented sometimes as straightforward allusion and sometimes with a special verbal twist reminiscent of Hopkins. Henry Treece has collected a list of Biblical references that covers all of the poetry through 1946. Adam, Eve, Eden, and Christ are among the most prevalent words listed. In the middle period of "Altarwise by Owl-Light" Thomas lets fly a volley of Biblical allusions that includes the juxtaposition of Jacob's ladder and Adam's ribs: "Rung bone and blade, the verticals of Adam/ And, manned by midnight, Jacob to the stars." Other startling juxtapositions include "My camel's eye will needle through the shroud," "Two-gunned Gabriel," "Jonah's Moby (with Melville and Jonah appropriately mixed)," "typsy from salvation's bottle," "Adam, time's joker," and "Jack Christ." Even in the early poetry he describes Christ as "Jack of Christ born thorny." "Ceremony After a Fire Raid" and "Vision and Prayer" with its emblematic form might be defended as basically Christian in form and content, but even here I feel that Thomas doesn't transcend a religion of fear.

In the later poetry of *In Country Sleep* the poet clings to life, recollecting mortality rather than immortality. The pastoral nature of this poetry represents a change in scenery but not in theme; internal stresses are now objectified. "Fern Hill" paints a picture of childhood in green and gold and blue which glorify a country scene. "In Country Sleep" utilizes fairy tale and mother goose material to create a rustic scene of elemental innocence—air, water, earth and sun, where still the "Thief" of time stalks. "Over Sir John's Hill" suggests symbols and themes of other modern poets: Hopkins' falcon Christ with "The hawk on fire hangs still," Hart Crane's frisky children so unaware of danger in "Voyage I" with "the shrill child's play," Stephan Spender's "I Hear the Cries of Evening" where gulls, rooks, and the world are singing a kind of swan song too—where both poets hear with consternation the cries before the "lunge of night."

The "Poem on His Birthday" embodies some of the new calm Thomas gained in an elemental world affirmed by God as the poet sails "out to die." "Lament" traces the development of man, the poet who is Thomas' metaphor, through the elemental life of the passions, the life of the medieval humors—the windy boy, green leaved, in the swelter of summer, when the blood creeps cold; but like Yeats the poet wars against the "deadly virtues" that age would impose upon him. In these later poems the nightmarish dream imagery of earlier poetry has developed into wide-eyes childhood dreams. Physiological imagery of parts of the body has been replaced by familiar animal imagery—turtles, fish, dogs, mules, and birds—or by natural objects. "In the White Giant's Thigh" praises the body and physical life in terms of the "conceiving moon," "seed to flow," "green countries," and "breasts full of honey." Ultimately to the elemental man who goes "to the elemental town," death is the greatest fear, love of life the greatest joy.

Thomas doesn't seem to distinguish himself and the world which becomes a projection of the poet's self. Although this poetic anthropomorphism juxtaposes macrocosm and microcosm with startling fluency, the technique itself allies Thomas with poetic tradition rather than with any violent break with it. Only occasionally does topical language suggest the age in which the poetry was written. One finds references to war, flying, moving pictures and modern idiom. Images from tailoring are no newer than the Fateful sisters or Carlysle.

Concern for their art has given bards throughout the ages material to forge into poetry. Thomas, self-conscious, is conscious of his art; the tools of his trade work their way into his imagery. He tells us his subject matter with:

> I would be tickled by the rub that is:
> Man be my metaphor.

He creates a unity of himself, his art, and nature when his "busy heart/ Sheds the syllabic blood and drains her words . . . wordy shapes of women . . . vowelled beeches . . . oaken voices . . . water's speeches . . . spelling in the scurry . . . hears the dark-vowelled birds." Further utilization of the poet's tools is found welded to this explanation of the poetic process:

> And from the first declension of the flesh
> I learnt man's tongue, to twist the shapes of thoughts
> Into the stony idiom of the brain,
> To shade and knit anew the patch of words.
>
> In the beginning was the word, the word
> That from the solid bases of the light
> Abstracted all the letters of the void;
> And from the cloudy bases of the breath
> The word flowed up, translating to the heart
> First characters of birth and death.

And finally the superb explanation of "In My Craft and Sullen Art" exercised

> for the lovers, their arms
> Round the griefs of the ages,
> Who pay no praise or wages
> Nor heed my craft or art.

The very fact that he wrote for the lovers "their arms / Round the griefs of the ages" suggests the elemental nature of this music. Man's life itself and its tragedies are his topic and metaphor: the foetus, the baby, the child, the lover, the adult who fears age and wars against death, who is aware of religion and occasionally attends a revival meeting, the country man who can hear the "pleasure bird whistle" and feels the rush of life in all its elemental beauty, in himself and nature. Thomas was an individual bard who sang traditional songs in startling new keys, who felt synaesthetically and sympathetically and saw the big world of the elements in immediate correspondence with the little world of the single man. He sang in the romantic tradition for every man with a heart ("I have been told to reason by the heart") and auditory apparatus. His images are so bound up with his meaning that a study of them should reveal his fundamental preoccupations, not philosophical or religious or social, but with the core of man—himself. His canons of poetry shout a gradual emergence from the cacoon of self to winged flight in the natural world. Although he did not develop in a literary vacuum, he did not associate himself with any school. His school is the oldest one—that of the singer of "The Elemental Music."

EFFECT OF ERADICANTS ON THE MICROBIOLOGICAL PROPERTIES OF NURSERY SOILS[1]

D. J. PERSIDSKY and S. A. WILDE[2]

Current nursery practice employs a large number of toxic compounds, or eradicants, for the control of destructive insects, parasitic fungi, and noxious weeds. The application of these chemicals is not without adverse influence upon the beneficial soil organisms, state of soil fertility, and the growth of nursery stock. This study aimed to detect the effects of commonly used eradicants upon microbiological characteristics of soils which serve as indicators of unimpaired soil productive capacity.

The trials were conducted in greenhouse cultures with outwash siliceous sand possessing a reaction of about pH 5.0, exchange capacity of 1.9 m.e. per 100 g., and 0.7 per cent of organic matter. The biocides studied included chlordane, benzene hexachloride, calomel, thiosan, aluminum sulfate, formaldehyde, allyl alcohol, and Stoddard solvent. These were applied at the rates slightly exceeding those used in current nursery practice. Such treatments were justified in view of the local concentration of chemicals resulting from their uneven distribution under conditions of actual soil management. The following microbiological characteristics were investigated: the relative density of micropopulation, rate of cellulose and protein decomposition, nitrification capacity, rate of carbon dioxide evolution, growth of excised roots under the influence of volatile substances emitted by the soil, growth responses of *Aspergillus niger*, and the development of mycorrhizal short roots. Monterey pine, *Pinus radiata*, was used as a test plant and a carrier of symbiotic organisms. The extreme poverty of the soil, the use of enclosed containers, and fluctuating content of soil moisture, unavoidable in watering by hand, all undoubtedly contributed to the adverse effects of biocides.

The number of microorganisms present in untreated and biocide-treated soils was determined on the basis of colonies developed on the molecular membrane filters (Clark et al., 1951).

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[2] Research Associate and Professor of Soils, respectively.

The results, presented in Table 1, indicate that all biocides used appreciably decreased the soil micro-population. The most drastic reduction of microorganisms was caused by calomel and benzene hexachloride. The least harmful effect was exerted by chlordane.

The activity of cellulose- and protein-decomposing microorganisms was appraised on the basis of a modified method of Richard (1945). The soils were incubated for two weeks at 24° C in a saturated environment and then transferred into petri dishes together with the standard cellulose and protein cords. Cultures with cellulose cords were incubated for one week; cultures with protein cords were incubated for two weeks. The tensile strength of the cords was recorded by means of a wire tensilometer, and the results were expressed in percent of the tensile strength of sterile cords. The averages of quadruplicate determinations, given in Table 1, indicate that the processes of organic matter decomposition are retarded to a marked degree by application of all eradicants. The reaction of cellulose-decomposers and protein-decomposers suggests that these two groups of microorganisms vary considerably in their tolerance of different chemical compounds.

The rate of nitrification was determined by the standard phenoldisulfonic method using an Evelyn colorimeter. The samples were enriched in ammonium sulfate, applied at the rate equivalent to 400 lbs. per acre, and incubated for 3 weeks at 28° C. The results, reported in Table 1, show a depressing effect of all eradicants on the activity of nitrifying bacteria, especially sharply pronounced in treatments with calomel, Stoddard solvent, and chlordane.

For the determination of the rate of respiration of treated soils, 250 g. of air-dry samples were placed in 500 ml Erlenmeyer flasks, moistened, and incubated for 48 hours at 28° C. Before the analyses, 0.5 g. of dextrose was added to each culture. The determination of carbon dioxide evolution was made by the procedure of Heck (1929), using 48 hour aeration periods. The results, presented in Table 1, provide a clear-cut picture of the adverse influence of the biocides.

The effect of volatile substances, emitted by soils, was studied using Cholodny's biotest (Cholodny, 1951; Persidsky and Wilde, 1954). The results of these trials (Table 1) show that the growth of excised roots of blue lupine is depressed in part by the direct toxicity of applied chemicals, and in part by the reduction of the microbiological activity responsible for the release of growth-promoting volatile substances. As indicated by the average growth and longevity of roots, calomel and formaldehyde exert

TABLE 1

Effect of Eradicants on Microbiological Characteristics of a Coarse Sandy Soil (Average Results)

Eradicant Applied and Rate of Application per Acre	Number of Colonies per Membrane	Loss in Tensile Strength of Cellulose Cords	Loss in Tensile Strength of Protein Cords	Nitrification Capacity NO_3	Evolution CO_2	Behavior of Excised Roots of Blue Lupines	
						Longevity	Growth
		per cent	per cent	p.p.m.	mg/g	days	mm
Untreated soil	518	65.3	72.4	7.0	168.3	5.5	7.5
Chlordane 10 lbs.	334	45.4	42.8	1.1	141.9	4.5	5.1
Allyl alcohol 50 gal.	253	29.3	45.7	3.5	58.3	2.0	3.0
Stoddard oil 100 gal.	221	33.3	38.1	0.8	34.1	3.5	4.2
Thiosan 120 lbs.	138	28.1	42.8	2.9	52.8	3.5	2.0
Aluminum sulfate 500 lbs.	51	46.7	44.7	1.7	23.1	4.0	4.3
Formaldehyde 0.7%, 5,000 gal.	63	22.7	33.3	2.7	37.4	1.0	1.6
Calomel, 40 lbs.	48	37.3	38.1	0.6	72.6	1.0	1.5
Benzene hexachloride, g.i. 1 lb.	38	32.0	47.6	1.3	25.3	4.0	2.6

TABLE 2

GROWTH OF MYCELIA OF *Aspergillus niger* IN SOILS TREATED WITH VARIOUS BIOCIDES. RESULTS ON OVEN-DRY BASIS

ERADICANT APPLIED	RATE OF APPLICATION PER ACRE	AVERAGE WEIGHT OF MYCELIUM grams			
		Culture A	Culture B	Culture C	Ave.
Untreated soil	....	1.273	1.398	1.487	1.386
Chlordane (actual compound)	10 lbs.	1.083	1.137	1.170	1.130
Allyl alcohol	50 gal.	0.563	0.706	0.819	0.696
Stoddard oil solvent	100 gal.	0.752	0.993	1.039	0.928
Thiosan	125 gal.	0.762	0.829	0.896	0.829
Aluminum sulfate	500 lbs.	0.754	0.838	0.901	0.831
Formaldehyde (0.7 per cent solution)	5200 gal.	0.810	0.996	1.019	0.942
Calomel	40 lbs.	0.638	0.718	0.759	0.705
Benzene hexachloride (gamma isomer)	1.0 lb.	0.735	0.813	0.858	0.802

TABLE 3

EFFECT OF ERADICANTS ON THE GROWTH AND MYCOTROPHIC FEATURES OF ONE YEAR OLD SEEDLINGS OF MONTEREY PINE, *Pinus radiata*, RAISED IN SAND CULTURES. OVEN-DRY WEIGHTS OF AVERAGE SEEDLINGS

Eradicant Applied and rate of Application per Acre	Seedling "in toto" g	Top g	Root g	Top—Root Ratio	Type of Mycorrhizal Organs or "Short Roots"
Untreated soil	.177	.143	.034	4.2	Abundant normal bifurcate short roots
Chlordane, 10 lbs.	.172	.132	.040	3.3	Abundant nearly normal bifurcate elongated short roots
Allyl alcohol, 50 gal.	.191	.143	.048	2.9	Fairly abundant simple short roots
Stoddard oil, 100 gal.	.180	.108	.072	1.5	Abundant simple "pseudo-mycorrhizal" short roots
Thiosan, 120 lbs.	.146	.114	.032	3.6	Sparse pedunculate roots of "pseudomycorrhizal" type
Aluminum sulfate, 500 lbs.	.130	.087	.043	2.1	Fairly abundant short roots of a slingshot pattern
Formaldehyde, 0.7% 5,000 gal.	.140	.089	.056	1.5	Fairly abundant simple and bifurcate pedunculate short roots
Calomel, 40 lbs.	.107	.098	.009	10.8	Very sparse depressed sessile lobate short roots
Benzene hexachloride, g.i. 1 lb.	.176	.130	.046	2.8	Sparse depressed sessile clovate short roots

the most unfavorable influence. A strong depressing effect is also caused by thiosan and benzene hexachloride. Chlordane proved to be the least inhibiting; this behaviour may have a bearing upon observations of Voigt (1953) who recorded a high rate of oxygen uptake by root tips in the presence of chlordane suspensions.

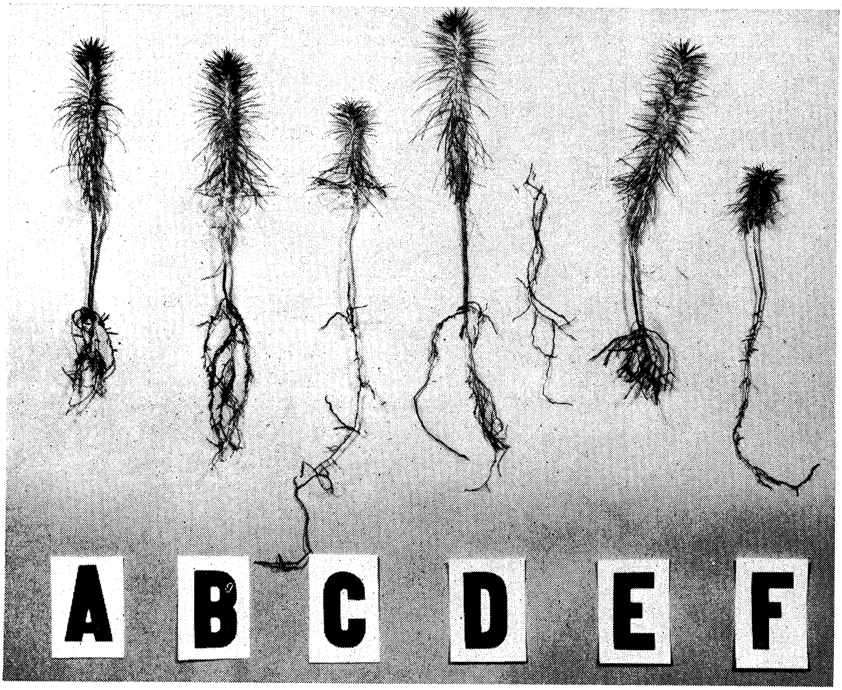

FIGURE 1. Growth of 1–0 *Pinus radiata* seedlings in a coarse sandy soil treated with different biocides at the indicated rate of application: A—Untreated soil; B—Chlordane, 10 lbs/A; C—Thiosan, 125 lbs/A; D—Allyl alcohol, 50 gal/A; E—Benzene hexachloride (gamma isomer), 1.0 lbs/A; F—Calomel, 40 lbs/A.

The direct influence of different biocides on the development of fungi was investigated by observing the growth of *Aspergillus niger* in a suspension prepared from 20 g. of soil and 30 ml of nutrient solution (Mehlich, Truog, and Fred, 1933). Inoculated soils were incubated for 5 days at 35° C. The weights of mycelia, given in Table 2, indicate that the most unfavorable influence, reducing the growth of mycelia about 50 per cent, is exerted by allyl alcohol and calomel. Chlordane proved to be the least toxic. The triplicate results give rather small deviations from the average values and suggest that the direct observations of the behavior of microorganisms may have considerable value in analyses of soils treated with biocides and commercial fertilizers (Wilde and Krumm, 1946).

The effect of eradicants on the growth of nursery stock and the development of symbiotic mycorrhizal fungi was studied in sand cultures, using *Pinus radiata* as the test plant. The results are presented in Figure 1 and Table 3.

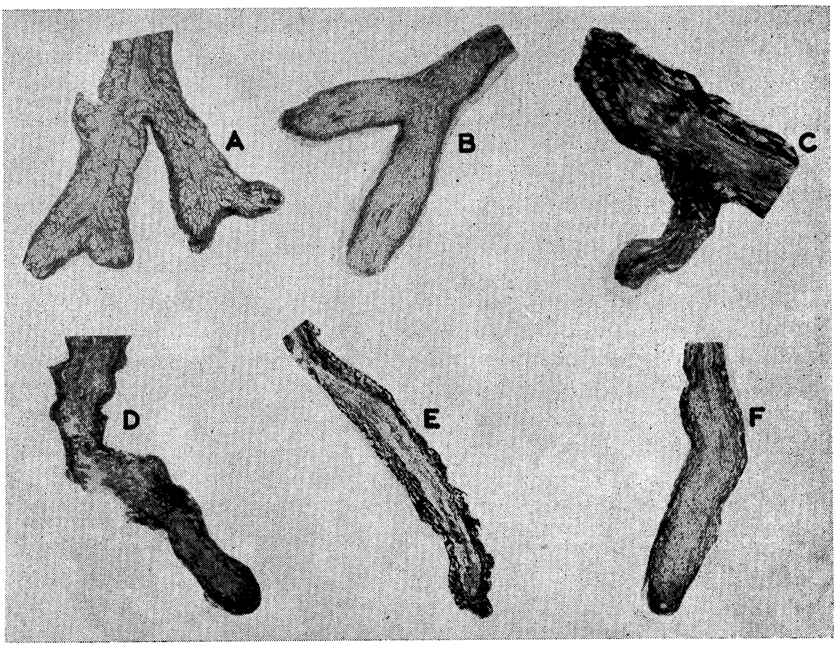

FIGURE 2. Effect of biocides on the development of root tips or "short roots" of *Pinus radiata* seedlings. A and B, normal bifurcate mycorrhizal short roots with a well developed Hartig net, produced in biocide-free soils or in the presence of mildly concentrated less toxic biocides; C to F, simple pedunculate short roots of a "pseudomycorrhizal" type, prevalent in soils or soil regions containing biocides in a high concentration.

Calomel is the only chemical which conspicuously inhibited the development of seedlings and drastically disrupted the normal top-root ratio. Other biocides at this rate of application did not decrease significantly the weights of total seedlings, their tops, or their roots. In some instances, the application of biocides stimulated the production of dry matter. As a rule, the presence of eradicants reduced the quantitative top-root ratios. However, as many previous studies have shown, the appraisal of nursery stock on a weight basis may lead to grossly erroneous conclusions (Wilde and Voigt, 1954). Even a cursory examination of the seedlings' morphology (Figure 1) is sufficient to reveal some of the negative features which the planting material has acquired under the influence of eradicants. This is particularly true of the arrested downward growth of roots (benzene hexachloride), undue elongation of tap roots (allyl alcohol, thiosan), and reduction of laterals (thiosan, calomel).

A more elaborate analysis of the root systems disclosed further detrimental influences—the reduction of mycorrhizal short roots. This reduction was usually accompanied by alterations of the normal bifurcate mycorrhizae into simple pedunculate or clovate short roots of a "pseudomycorrhiza" type (Figure 2). In some cases, especially frequent in the presence of calomel and benzene hexachloride, eradicants caused a complete castration of mycotrophic organs or their deformation into sessile swellings of a lobate pattern (Table 3).

The reason why the unfavorable alterations of the morphology of root systems and mycotrophic organs have not always depressed the growth of seedlings is understood considering the special conditions of greenhouse cultures or nursery beds. The periodic watering of closed containers or treatment of nursery beds with liquid fertilizers supply root systems with nutrients in the form of solution and thus eliminate the need for the solid phase feeding. The intensity of the latter process under natural conditions is directly related to the size of the absorbing surface of roots and the participation of symbiotic fungi.

The study in its entirety suggests that the use of eradicants must be paralleled by a search for ameliorating buffering substances which would reduce the biocide-caused deterioration of plants, beneficial soil organisms, and soil fertility. This task is of a greater importance in the production of forest nursery stock than it is in the production of any other crop. Extermination by drastic means of the undesirable forms of soil life is only a part of nursery management program; another and the essential part of such a program is the production in the same soil of healthy and vigorous planting material destined to form the future forests.

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THE PREHISTORIC ENGINEER-FARMERS OF CHIHUAHUA

ROBERT A. MCCABE[1]

Some time in the Sixteenth Century one of the Spanish explorers traveling through Chihuahua in northern Mexico came upon a series of ruined buildings and terraces of stone. Then as now they stand deserted in the eastern foothills of the Sierra Madre Occidental. It may have been Alvar Nuñez Cabeza de Vaca,[2] or Iberra, who perhaps saw the ruins in the period between 1535 and 1565 and called them *Casas Grandes* or "large houses" and large they were indeed, for one measured 800 by 250 feet[3] and was six stories high. Who performed the feats of primitive construction engineering, and why is not known.

To the gold-seeking Spaniard this desolation at the Casas Grandes was one more bloodless defeat. How much too late were the conquerors and who were the people they had hoped to subjugate?

The evidence, filtered through the minds of many historians and anthropologists, seems to indicate that the builders of the Casas Grandes in Chihuahua were of the same stock that built the Casas Grandes found in the Gila valley in Arizona and at Zuni in New Mexico. The three groups of gigantic adobes are similar in many respects. The one in Chihuahua appears to be the southernmost site for this kind of structure. The "town builders", as Wallace[4] calls them, may have been the "Montezumas" who legends say emigrated southward from the fabled

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[2] Carl O. Sauer states: "There is no evidence that they [Alvar Nuñez Cabeza de Vaca's party] crossed the Sierra Madre of Chihuahua . . . ." p. 16. "The Road to Cibola." Ibero–Americana: 3, Univ. Calif. Press, Berkeley, 1932.

Bandelier's translation, however, has a frontispiece map suggesting that such had happened. The route shown indicates that Cabezà de Vaca's group passed through northern Chihuahua.

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[3] John Russell Bartlett. Personal Narrative of Explorations and Incidents in Texas, New Mexico, California, Sonora and Chihuahua. 1854. Vol. 2, D. Appleton and Co., New York, p. 350.

[4] Susan E. Wallace. *The Land of the Pueblos.* John B. Alden Publisher, New York, 1888, pp. 285.

city of Aztalan to Anhauac in south Mexico. En route they supposedly stopped at three places: Zuni in New Mexico, in the Gila valley in Arizona, and at the Casas Grandes in Chihuahua. The Spanish historian Clavijero is quoted by Cozzens[5] as stating of the Chihuahuan Casas Grandes that they were "similar in every respect to those of New Mexico." There seems to be little doubt that the Casas Grandes in each case were built by people of the same culture.

The builders of the large houses are thought by some to be descendents of the cultured and skillful Toltecs, who were also predecessors of the fierce and war-loving Aztecs. In the end it may have been the Aztec who waged war on the town builder and eventually destroyed him.

One clue as to when the Casas Grandes fell is given by Wallace.[6] In her collection is a water vase from the Chihuahua ruins dated 1864. It has an attached memorandum, part of which reads: "These Casas Grandes (great houses) were reduced to ruin by siege in 1070." This is signed "William Pierson, American Consul 1873." No further enlightenment regarding this date is given us by Susan E. Wallace who owns the vase and who presents the original information in her book *The Land of the Pueblos.*

THE TRINCHERAS

Virtually in the shadow of these house ruins that frustrate the antiquarian are other archeological features to intrigue the powers of deductive reasoning. These are numerous stone dams or walls found in the canyons and on mesas in the surrounding mountains. These dams or *trincheras* rather than the Casas Grandes seem to me to be the more interesting.

In the summer of 1948 I visited northwestern Chihuahua studying game animals and collecting vertebrate specimens for the University of Wisconsin.[7] Other members of the party, Alden H. Miller, A. Starker Leopold, and Ward C. Russell, were also there for the same purpose representing the University of California. Floyd Johnson of Colonia Pacheco, our guide and packer, escorted us to our first camp seven air-line miles southwest of Colonia Pacheco on the Gavilan River.

Even in this remote and rugged mesa country the check dams were present on almost every slope. These *trincheras* are built

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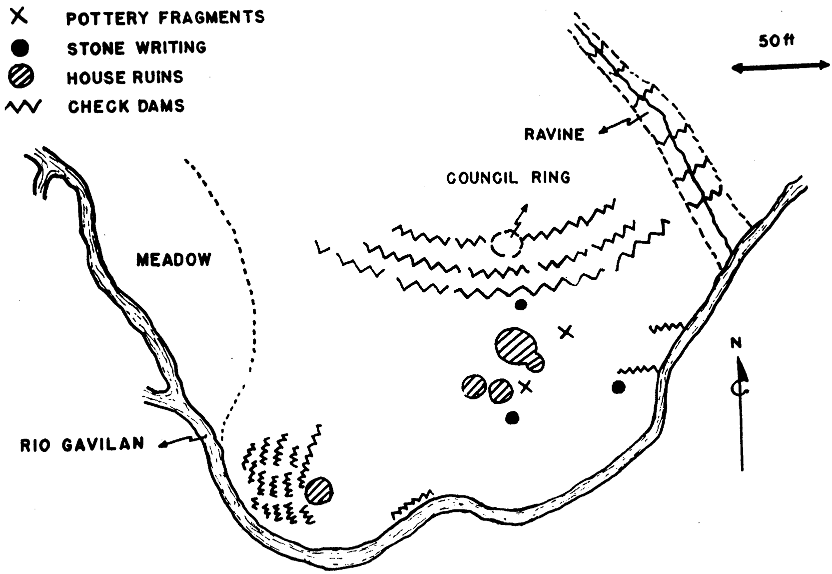
[5] Samuel Woodworth Cozzens. *The Marvellous Country.* Lee and Shepard, Boston, 1876, pp. 547.

[6] *Ibid.,* p. 235.

[7] Supported by the University of Wisconsin College of Agriculture and a grant from the Wisconsin Alumni Research Foundation.

of volcanic stones usually about twice the size of a man's head. The stones are carefully arranged on and against one another so as to hold together without mortar or cementing materials. Principles of engineering were also employed: for example, the greater the height of the dam, the greater the flare at its base. The fact that so many still remain today is *prima facie* evidence that the sites were well chosen, and the construction more than adequate. There are perhaps other aspects of construction proficiency that could be noted by an eye trained in construction engineering.



A diagrammatic view of the ruins area near the Galivan River camp.

We are used to thinking in terms of impounded water whenever dams are discussed. The *trinchera,* however, appears to have been used as a means of slowing run-off during the heavy rains of late summer, not so much a water conservation measure as a means of holding and building *soil* behind the check-dams. No *trinchera* that we saw impounded water.

Aldo Leopold had described these structures to me in great detail and no doubt colored my thinking on their source and function. He visited the Gavilan area on a hunting trip in the winter of 1938. His superb description of the dams and the ecology of this region appear in an essay, "The Song of the

Gavilan".[8] Other writers, Carl Lumholtz,[9] Henry A. Carey[10] and W. J. McGee,[11] have also observed these structures and recorded their presence. Lumholtz, in his two volume work *Unknown Mexico,* gives a rough descriptive outline of where these *trincheras* occur in northwest Mexico. It appears that our Gavilan camp was in the center of the *trinchera* country.

One could not travel long in the Gavilan watershed without encountering these landmarks. They were built on all types of slope. Those in narrow steep-sided ravines were necessarily narrow and taller (3 to 4 feet) than those found in places of low gradient where the dams were often very long but only 1 to 2 feet high. There was a remnant of a dam about a mile down the river from our camp where only the anchor ends of the structure remained. It may well have been part of an impounding wall that cut across the main river channel. It was the only one to suggest that such dams may have been employed to hold water.

Frequently the dams were constructed in a series one behind the other, creating between them a terrace effect reminiscent of the ancient Inca terraces. In one instance on a large mesa above our camp I found a series of four dams protruding above the turf to the height of one stone. Behind these dams was a pear-shaped meadow of about 10–15 acres surrounded by tall yellow pines. Another series on the same mesa in a somewhat narrow draw had spacing between the dams of 8, 16, and 34 feet. This doubling of the spacing was hardly accidental.

In several instances a large heap of stones of the size used in dam building was found at the base of a ravine in the side of a mesa. It is possible, because of the steep slopes, that some time in the past one of the dams washed out. One needs only to be caught in the torrential downpours that drench this country during the rainy season to be convinced that such is likely. Once dislodged the building stones could roll down the ravine like so much talus. I found no such stones that could have been considered natural talus.

This heap of like-sized stones might also be the remains of a *lookout hut* built on the mesa edge and washed into the ravine by the slow erosion of the mesa rim. Several ruins of possible dwellings or shelters were found at vantage points on mesa tops and

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[8] Aldo Leopold. *A Sand County Almanac,* Oxford Univ. Press, New York, 1949, pp. 149–154.

[9] Carl Lumholtz. *Unknown Mexico.* 2 vols. Charles Scribner's Sons, New York, 1902.

[10] Henry A. Carey. "An analysis of northwestern Chihuahua culture", Am. Anthropologist, Vol. 33, 1931.

[11] Lumholtz (*ibid.,* p. 22, vol. 1) states that W. J. McGee saw them on his expedition of 1895. The reference was not explicit and I was unable to locate it for a direct quotation.

in each case had a commanding view of the surrounding country. An excellent picture of such a ruin is presented by Sayles.[12] One ruin in particular overlooked the Gavilan valley. The original building had been built on a small bench just below the rim of the tallest mesa. The stone walls had long since fallen apart but enough remained to show that the single room was about 12 feet by 12 feet. The roof was probably thatched. Ralph L. Beals[13] in his studies on comparative ethnology of northern Mexico indicates that thatched roofs were used by the early inhabitants of this region. It so happens that in the Gavilan area there grows a tall bunch grass of the genus *Muhlenbergia* that appears to be suitable for thatching.

THE "RUINS"

The *trincheras* and the lookout hut were not, however, the only evidences of prehistoric peoples in the Gavilan River area. Floyd Johnson pointed out an area near our camp that he called the

[12] Plate 11, p. 14, E. B. Sayles. "An archeological survey of Chihuahua Mexico", The Medallion, Gila Pueblo–Globe Arizona Private printing, 1936.
[13] p. 138, Ralph L. Beals. "The comparative ethnology of northern Mexico before 1750", Ibero–Americana: 2, Univ. California Press, Berkeley, 1932.

The "council ring" was made of large angular stones that appeared to have been quarried. There was no quarry site found within a mile radius of the ruins area. The stones could have been cut on the spot, but the possibility seems unlikely.

"ruins". Only a discerning eye would have spotted any ruins at this place. I had hunted quail over the site many times without having noticed anything peculiar. Once scrutinized, many man-made features became evident. The site was a flat place or small bench on an escarpment 50 feet above the river. The area encompassed about two acres and was irregular in shape. The sheer walls of the escarpment on the south and southeast quarter dropped directly into the river, which flows around the promon-

One of the stones bearing hieroglyphics found in the ruins along the Gavilan River. This stone measured fifteen by twenty inches.

tory. To the southwest and west the bench fell away more gradually to a flat or meadow along the river's edge. To the north the land rose gently and widened to become part of a mesa slope on which were eleven long dams (each about 150 ft.). On the west the bench was bounded by a narrow deep-cut ravine. In this ravine, which dropped sharply as it neared the river, were six check-dams, but most were in poor condition probably due to the flash floods of many years. During one downpour I saw this ravine spew its brown torrent into the middle of the river when normally the drainage only moistened the stone walls of the cliff.

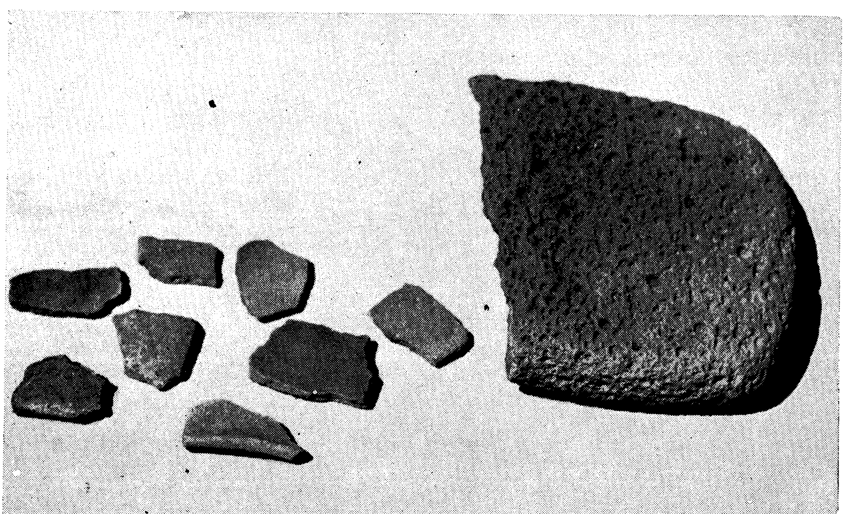
In the center and above the top terrace was a circle about fifteen feet in diameter of large rectangular stones. These were set on end and although irregular in height, they formed what I called a "council ring", *(estufas)* and this it may well have been. The stones appeared to have been quarried, which operation must have involved great difficulties. It would have required the labor of at least five men to move even the smallest for any distance. There was no quarrying site within a radius of at least a mile. The stone ring occupied a commanding position, overlooking the entire bench. The ring today is almost obscured by grass and live oaks. For a culture as primitive as this one appears to have been, and lacking in the use of beasts of burden, this ring of stones is all the more interesting.

Immediately below the bottom terrace and opposite the council ring was a large irregular-shaped boulder 68 inches across the base and 32 inches high, one side of which was covered with hieroglyphics. Viewing this stone for the first time gave me the strange feeling that I was trespassing, even in this wild back country. I dug carefuly at its base to uncover more of the writing, as it was obscured by about six inches of silt. Three other stones were also found bearing inscriptions. These were smaller (about 15 x 20 inches) and appeared to have been part of a wall. In several instances the inscription was incomplete, indicating that the missing part was probably on an adjacent stone. The three stones were scattered and apparently not matched. There was no discernible attempt to portray any figures, animate or inanimate. Some of the inscriptions are similar to those found on *Mesa Verde* in pueblos in Colorado.[14]

Slightly to the west and 50 feet below the terraces out on the bench proper were three mounds. The upper two were groups of stones so arranged that they appeared to be the remains of one large or two small dwellings. They were almost overgrown with

[14] Fig. 3, page 473, J. Walter Fewkes. "A prehistoric Mesa Verde pueblo and its people", Annual Report Smithsonian Institution, Wash., D.C., 1916.

The hieroglyphics found on a large boulder did not appear to contain any figure writing. Only simple designs covered the stone on one face.



The pottery fragments (left) and part of a *mano* found in the ruins on the Gavilan River indicated a maize agriculture had once existed in this area.

grass. The larger building seemed to have had a very small anteroom adjoining. This floor plan was noted on several other occasions along the Gavilan and is shown graphically in Richard J. Hinton's *Hand-book to Arizona.*[15] Fragments of pottery and a broken *mano* were found near these ruins. Lower on the bench near the southwest corner of the area was the third mound with its decadent walls. Here, too, pottery fragments were found. The interesting feature about this latter site was that the side to the west, which slopes rapidly toward the flat meadow adjacent to the river, was supported by a series of short, almost over-lapping stone dams. I failed to record the number of dams involved, but as I now recall, they were so close together as to give the appearance of a cobblestoned hill.

This was a clear-cut example of employing the check-dam technique to protect a slope that would have otherwise eroded. It is inspiring to see the effectiveness of this primitive construction. These little check-dams and terraces have so efficiently held the soil and sod that they can be found only by hunting for them among the yellow gamma grass now covering the slope. These miniature support-dams were also found on the bench in several places along its edge.

The Fort

One morning while collecting birds on one of the larger mesas I chanced upon what was the most imposing of all the ruins encountered in the Gavilan River area. I called it the "fort". It was situated on the corner of a mesa rim where two canyons met at right angles to each other. Both were deep and steep-sided. The larger one, when I saw it in the wet season, had a roaring stream in the bottom. So steep were the sides of this canyon that even a zigzag ascent among the live oaks would have been dangerous. The structure, which was in an excellent state of preservation, was an angular wall shaped like a boomerang. The highest part (7 feet) of this wall was in the center or elbow of the boomerang. I paced the total length and found it to be 280 feet long. There was also an auxilliary wall below the elbow which was five feet tall and about 1520 feet long. It was impossible to photograph this lower wall in perspective because it was down-slope about 35 feet and partly covered with brush. On the flat above the main wall was the stone remnant of what appeared to have been a building. It was not unlike those found in the ruins above our camp.

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15 p. 431, Richard J. Hinton. *The hand-book to Arizona,* San Francisco, Payot, Upham and Co., New York, 1878.

Despite my calling this site a fort, it was probably not used as such. The wall did not stand above the ground level, but appeared as a stone facing for the top edge of a steep-sided mesa. There was no protection from the mesa side, which would have been most vulnerable to attack. These facts preclude any protection from this mortarless masonry. What then was this structure? My guess is that it was built by a family who took pride in their building craft, and who used their skill to protect the mesa rim

The "fort" wall, part of which is shown here, was 280 feet long and seven feet at its greatest height. Note the porous nature of the volcanic rock.

on which the dwelling perched. The building was probably built on this site because it was near several meadows and because of its commanding view. Today water and fuel would be as easy to procure had the dwelling been built a short distance from the canyon rim where no earth-supporting walls would be needed. It may have been otherwise in the days of the builder.

On another occasion, while attempting to photograph some wild flowers near our camp site, I climbed a fallen tree in order to get an overhead view of the blossoms. From a height of about 6 feet I noticed through the reflex lens of my camera that stones near the flowers were arranged in a crude circle about 50 feet in diameter, with other rows of stones radiating from the center to the periphery. These stones were about the size of loaves of bread, partly buried and grown over in places with grass. This wagon wheel design was not easily discernible when walking near it, for I must have passed by or over it 25 times before seeing it in this fresh perspective.

Early Chihuahuan Agriculture

Studying and hunting game animals of this rugged back country left me little time for reflection on the archaic masonry that was seldom out of sight. This much, however, seems obvious: The dams were in some way associated with the pursuit of agriculture. The presence of pottery fragments in the ruins implies that the culture was archeologically recent and probably a corn-bean-squash agriculture.

Were these dams the precursor of modern soil conservation practices and built to check soil erosion? Perhaps, but only as a secondary measure. The real reason, as stated earlier and also as expressed by others, was to catch and hold silt. Most of the country, including fairly level mesa tops, is extremely rocky and unsuited generally even to hand agriculture; the formation of soil from the flaky volcanic rock is reasonably fast and a check-dam along a run-off course would soon collect enough soil to support vegetation. Thus behind each *trinchera* arose a potential field. As the silt accumulated, a new tier of stones could be added to the dam. The water basin, or more properly soil basin, thus formed would mean additional land for the enlarging field.

Seemingly in opposition to this hypothesis is the fact that many of the dams were in places where there was little chance to catch or hold enough soil to make dam-building a worthwhile operation. Likewise there *now* exist slopes that would make very good fields if dammed, located near these almost negligible fields behind well-built dams. Those areas behind dams built on steep slopes and in narrow canyons are subject to periodic washing or side cutting during the rainy season. Thus it seems unlikely these were meant to be fields. It is difficult to guess what other function this type of dam may have served.

If the deductions made thus far are correct, then the preconquest farmer of Chihuahua probably practiced soil conservation *before* he farmed much of his land. This has an ironic twist, since we came from a rich and "enlightened" land to the north where a small group of soil conservationists are trying to help an unwilling country prevent its soil, and indirectly its wealth, from flowing seaward.

Agriculture in many parts of Mexico is still very primitive. Before the advent of the horse, which the Spaniards introduced, we can only surmise that the land was tilled by hand with crude wooden implements. Were the *campesinos* (farmers) many or few in the region of the abundant *trincheras?* The comparatively

The check-dams or *trincheras* found in many places in northern Chihuahua were well built structures. The meadows behind these dams were usually grown to several species of bunch grass. (Photo by Aldo Leopold)

meager evidence of permanent dwellings and the likelihood that the fertility in the thin volcanic soil would be dissipated after a few years of corn and bean agriculture indicate the farmers may have been few in number or partially nomadic in nature.

A simple fallow rotation of many small fields, up and down a watershed could have insured better fertility and account for the tremendous number of check-dams throughout northwestern Chihuahua.

The scarcity of dwellings, however, could mean the farmers spent only the growing season near their fields and returned to a central point after the harvest. This would also explain the ruins of fair-sized villages found in this region which may in some way be associated with the Casas Grandes.

No culture is as difficult to trace or to deal with as that of nomadic or war-scattered peoples. Could our engineer-farmers

Metate and skull of a prehistoric inhabitant of the Casas Grandes region in Northern Chihuahua. (Property of Floyd Johnson of Colonia Pacheco)

have been such a group? If so, it matters little, for whatever their nature, they reveal a history and teach their lessons with piles of little stones on the sides of remote mountains.

DEER AND THE TRINCHERA FARMER

Whether the farmers were few or many, they probably had one problem in common if present and pristine conditions are comparable, namely how were their many small fields protected from the depredations of deer. Today the whitetail deer on the Gavilan can be considered numerous, but were they present in years past or at the time of the *trinchera* builder? The situation during a hunting trip by Aldo Leopold in 1938 was generally the same as we found it in 1948.

Carl Lumholtz[16] who traveled extensively in all parts of Mexico, has this to say of the Gavilan watershed in 1891: "Never have I been at any place where deer were so plentiful." It seems highly unlikely that deer were absent in preconquest times, although *Obregon's History of 16th Century Explorations in Western America*[17] records how the expedition of Francisco de Iberra passed through this region in 1565–66 and almost starved to death, subsisting on bitter acorns, horse flesh and in desperation on shoes, hides and dirty leather straps. However, a noisy, marching army of men untrained in mountain hunting would likely not see a deer where deer might be relatively abundant. In this same narrative of Iberra's suffering, Obregon mentions Indians who live on "all sorts of game and wild reptiles"; deer *per se*, are not mentioned.

Supporting the thesis that deer were present is the account by Cabeza de Vaca,[18] who with several white men and a large group of Indians passed through this same region[19] about 1533. He writes that on one occasion a small group of Indians armed with bows and arrows went into the hills and returned at nightfall with over 20 deer. Another method of taking deer mentioned by Beals[20] was to poison water holes used by deer. Cabeza de Vaca, was an educated white man who traveled and lived like an Indian. His narrative indicates that he was deer conscious principally because of the food value. Frequent mention is made of deer in the late stages of his journey when he crossed Sonora (and Chihuahua?).

A final word on the occurrence of deer in this area during the Sixteenth Century comes from Bandelier's translation of Cabeza de Vaca's narrative:

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[16] *Ibid.*, p. 53.

[17] George Peter Hammond and Agapito Rey (translation). *Obregon's History of 16th Century Explorations in Western America.* Wetzel Publishing Co., Los Angeles, California, 1928.

[18] *Ibid.*, p. 143.

[19] Hubert H. Bancroft's *History of Arizona and New Mexico* (San Francisco, 1889) and Bandelier, 1905, *op. cit.*, indicate that Cabeza de Vaca passed in a westerly direction very close to the Gavilan River. Cleve Hallenbeck's *Alvar Nuñez Cabeza de Vaca: The Journey and Route of the First European to cross the Continent of North America 1534–1536* (The Arthur H. Clark Co., Glendale, Calif., 1940, pp. 326) reviews the various routes that historians say Nuñez was supposed to have taken. I conclude from his route map opposite page 306 that the route proposed by Sauer (*Ibid.*, 1932) and Hallenbeck collectively best fitted the early accounts as presented. This however does not effect the text hypothesis since the route of Sauer and Hallenbeck passes northwest of the hairpin turn in the Bavispe River at a point about 80 air-line miles from the Gavilan watershed. The country topographically, botanically and game wise is generally comparable.

[20] *Ibid.*, p. 103.

"In the village where they had given us the emeralds, they also gave Dorantes [one of the party] over six hundred hearts of deer, opened, of which they kept always a great store for eating. For this reason we gave to their settlement the name of 'village of the hearts'."

Thus in this early period of recorded history it would seem that the native populus kept the deer thinned down to a point where "*trinchera*-fields", if they existed, were not molested. While not wholly comparable, even today where the itinerant lumber camp stays for a short period the deer are extirpated from the surrounding area. This observation I recorded from Floyd Johnson, our guide.

In no case in the several early accounts of this area by Spanish explorers is mention made of the *trinchera* or check-dam.

The evidence, meager as it is, seems to indicate that deer and *trinchera* fields occurred together but that the *campesinos de la trincheras* were not wholly dependent on agriculture. The bow and arrow, spear, or similar weapon may have been used to help provide the bulk of the edible protein and in so doing would have eliminated the problem of deer depredation. If the trees of our forests today were as important to all Americans as the corn behind the *trinchera* was to its planter we would waste no time in dealing with our present overpopulations of deer.

The western slope of the Sierra Madre in northern Mexico still retains much of its wild and primitive appeal for the naturalist. A. S. Leopold records this eloquently in his "Adios Gavilan".[21]

We cannot be complacent and assume that a wilderness will remain forever wild and untouched. Even as this is written, battered lumber trucks rumble over widened donkey trails bringing saws and sawyers to this virgin wilderness.

The proverbial handwriting on the wall came to our camp with the rains. The lumbering operations just beginning in the headwaters of the Gavilan River changed our stream, where rainbow trout could be seen in the bottom of four-foot pools, into an ugly brown torrent that rose three feet in a matter of minutes. Such ushering of soil to the sea is rivaled only by some of the most abused watersheds north of the border.

I cannot here discuss the "merits" of logging this region, but even a layman could see that this very young soil going downstream was the result of the ax and saw. The loss of topsoil is blood letting for this already soil-poor area. The loss of game and the changes in flora and fauna will doubtless follow. The

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[21] Pacific Discovery, Vol. 2, 1949, pp. 4–13.

erosion which now threatens to scar these hills will inevitably wash away the last vestiges of check-dams and stone ruins.

The teeth of the cow are not unlike the teeth of a saw in destroying wilderness. The old dung and a host of weeds near our camp gave mute witness to the fact that the cow and herdsman had at least reconnoitered the Gavilan valley. What will come after lumbering, after grazing to a land that can afford neither?

I am sorry in the knowledge that the tall pines and the mesas must part company and that in turn the hills may wither, the clear streams become dry creek beds, and the *trinchera* stones slide downhill. But I am sorrier still for those who have had no opportunity to see this magnificent wilderness in the period between the Spaniards and the sawyers.

A HARVARD GRADUATE GOES WEST: ROBERT ADAMS COKER AND THE HIGHLAND SCHOOL IN THE 1830's

ROBERT H. IRRMANN
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Robert Adams Coker of West Newbury, Massachusetts, born March 19, 1807, was a member of the Harvard College Class of 1831, one of the lesser lights who flickered briefly and then "went out" to an early grave in March of 1833. The Class of 1831 fostered some of the greatest names in the mid-19th century, among them Thomas Gold Appleton, Francis Gardner Jr., John Hopkins Morison, John Lothrop Motley, and perhaps above all, Wendell Phillips. Robert Coker was not of their calibre; his brief life, post-Harvard, might well be termed the "short and simple annals of the poor in health". Suffering from consumption while in Harvard College, he was dead within little more than eighteen months of his graduation.

A mathematics major in college, Coker did what so many scholars were forced to do to make their way through college: he "kept school" at intervals, in accord with the agreement of the Government of Harvard College. On November 3, 1828, early in his sophomore year, Coker with many others in his class was given leave "to keep school agreeably to the regulations voted October 26th . . ."[1] Upon his graduation, he pursued his profession as a teacher of mathematics, and for a time taught in an academy in Francestown, New Hampshire, in the winter and

[1] *Harvard College: Records of the Immediate Government of Harvard College, Volume X (Septr. 1822)*, (Manuscript records, Harvard College Archives, Cambridge, Massachusetts), October 28, 1828: "Application for leave to keep school to be made on or before Monday, Nov. 3 & notice to this purpose to be given to the several classes tomorrow morning . . .

"It was voted, that the following directions be printed, and a copy put into the hands of each student who has to keep school, viz.

"Students, who are entitled to the privilege by their diligence and good conduct, and whose circumstances are such as to require it, are allowed to keep school for a time not exceeding ten weeks, including the winter vacation.

"Those to whom this privilege is granted, are required to report themselves to the presiding officer on the day of their return to college, with a certificate, stating the time during which they were employed in the School; also to be prepared to pass an examination in all those studies, which their class shall have gone over, which are necessary to their proceeding on with them in their future studies.

"If any student shall exceed the term of ten weeks, he is required to be examined in all the studies of his class during the whole time of his absence, and if he fail to pass a satisfactory examination, his connexion with the college shall cease." Faculty Records, X, pp. 189–190.

Coker was granted leave to teach, November 3, 1828. *Ibid.*, X, 191. He "kept school" at Lexington, Massachusetts.

spring of 1831–1832,[2] but looked meanwhile for greener academic pastures, and greater remuneration. Apparently the chronic discontent of teachers seized upon Coker in his term at Francestown, and he thought for a moment, not of the pleasant pasture of another academy, but of the lure of the green meadows of the great West and its Pacific prospects. His classmate George Coombs was the recipient of one of his plaints, and wrote in reply:

> ". . . I am sorry to find that you are a teacher with the Oregon mania. I trust that you will soon recover from it. It is a vile disaster, and 'many a good tall fellow has laid low'. You really do not seriously think of taking up your connexion with civilized life, and transporting yourself thousands of miles into a waste howling wilderness. What will you do when you get there? What will your literature and your science avail you among the wild beasts, and savages? There are thousands of one half your sense and erudition, and would make as good perhaps better, colonists than yourself. Stay then where your knowledge and understanding may be turned to some profit. If you feel any disposition to roam, come down here to New Bedford . . ."[3]

But the nearer prospect of a "western" academy was already in sight. In early April, 1832, Coker had received a letter from his close friend and classmate, William Austin Jr., then teaching in Brookline,[4] ". . . by which I learn that a gentleman by the name of Watson has written to Mr. Thayer for an instructor in Mathematics; & that Mr. Thayer has written to him in favor of me. Salary $500 & boarded &c."[5] Whatever Coker's other interests might be in this spring of 1832, and he was attracted by several other prospects, by May his future began to be apparent; it was to be cast in the mold of the Highland School,[6] the

[2] Robert Adams Coker to Susan A. Coker, Francestown, N.H., November 3, 1831. Mss. letter in the possession of the author.

[3] George C. Coombs to Robert Adams Coker, New Bedford, Mass., May 6, 1832. Mss. letter in the possession of the author.

[4] William Austin to Robert A. Coker, Boston, Sep. 24th, 1831. Mss. letter in the possession of the author.

[5] *Commentarium Comprehendens Compendia et Notationes, De Personia et Libris de Rebus &c. 16 Kal. Jun. MDCCCXXVI.* (The Diary of Robert Adams Coker), (Two Volumes, Manuscript in the Harvard College Archives), Journal &c., 1832, Volume II, p. 91, entry for the week of April 8, 1832.

[6] "In the evening (Wednesday) I received a letter from my chum (William Austin) by which it appears probable that I shall obtain the place of Instr. in Math. in the Highland School. By this letter, also I learned of my rank at Cambridge in Mathematics. It seems that Mr. Watson, Principal of the Highland School wrote to Benj. Pierce, now Tutor in Math. at Harvard, to enquire my 'collegiate merits'. Pierce referred to the President's papers, & as he told Austin, I had the highest mark in the Mathematical Department. This is higher than I expect, for I was so low in the languages that I thought probable that I was placed as low as the third in Mathematics. I never enquired my rank, & was somewhat surprised at the justice of the Government." *Diary,* II, 96, entry for the week of May 14, 1832.

"western" academy he had learned of through William Austin's letter.

Whatever his several interests might be, Robert Adams Coker's first love was mathematics, if we can accept the confessions of his own pen. "Last week I have read from the beginning of the Application of Algebra to Geometry to nearly the end of the chapter on the Ellipse, except a short chapter on the circle which I read last week. I find it very interesting. I find that I can at present take up Mathematics with relish when no other works charm—even newspapers and novels are dry and incipid (sic) when compared with these."[7] Also, "the past week I have finished reading the Application of Alg. to Geometry. I find in it many beauties which escaped me the first time it was read."[8] Soon that interest and talent, if such it was, was to be put to the service of young scholars in the "west", for Coker left Francestown later in May, and was home in West Newbury about the 18th, and was soon to have confirmation from the Highland School.[9] By June 10th the overtures to the Highland School were concluded: *alea jacta est!* "Monday . . . received a letter from Mr. Watson N.Y. in answer to mine of the 24 ult., in which I accepted his offer."[10] Mr. Watson's letter is extant; it failed to give Robert Coker intimation of the many vexations that were to be his out on the banks of the Hudson across the river from West Point:

> "Dear Sir, in compliance with your request, I acknowledge the receipt of your favour of the 24th inst. . . . (I) presume that you distinctly understand, that besides taking charge of the Mathl. department, we shall expect your assistance in such other modes as we may desire, & as may be in your power; for the business of instruction, important as it is,

[7] Coker's failure to concentrate upon, or find pleasure in, anything but his beloved mathematics might be explained by his concern and fear for his health. He was confiding to his Diary of his possible ill health. "May 13. Monday, raised blood all day—perhaps 4 or 5 spoonfuls in all." "The last part of last week & first part (of this?) I have raised more blood than in the same length of time previously. I cannot think I am in a consumption yet as this is the only simpton (sic), tho' it will probably terminate in one soon unless something can be done." Page 95. *Diary,* II, 93–94, entries for week of May 6, 1832.

[8] *Diary,* II, 94, entry for the week of May 13, 1832.

[9] *Ibid.,* II, 98, entries for the weeks of May 14, 27, 1832. Coker's *Diary* for the week of May 21, 1832, details the steps by which his commitment to John Lee Watson and the Highland School was made: ". . . Tuesday (May 22) rode to Craneneck; & as I returned I called at the Post Office & found that a letter had come for me & been sent to my father's. When I reached home I found a double letter from my chum (William Austin) then on a visit to Groton. The letter from Austin contained one from John Lee Watson, Highland School, Near Cold Spring, Putnam Co., N.Y., offering me $500 per annum and Board, wood, lights, & (sic) if I would take charge of the Mathematical department in the Highland School. Thursday, concluded to accept on Mr. Watson's proposal & wrote him an intimation of my acceptance; . . ." *Diary,* II, 98, West Newbury, entry for the week of May 21, 1832.

[10] *Diary,* II, 99, entry for Monday, June 10, 1832.

forms but a part of our labours; & we wish to secure your aid in the performance of other duties, in which, as a resident of our family, you can participate, with, probably, little inconvenience to yourself, and much advantage to us. . . ."[11]

In the latter part of June, Robert Coker was getting ready to go westward to the Hudson, to take up his duties at the Highland School. In Boston to shop, he bought Grind's Problems and the Economical Atlass. For the journey he also bought a black leather-covered trunk with a "plait (sic) on containing my name &c for $5.50."[12] He was being prepared in another way, should he care to heed the advice, through a letter from his good friend Austin, possibly mirroring advice which Austin found useful in his post that past year in Brookline:

"We were talking about things to be observed on first appearance in N.Y. But we did not conclude upon anything in particular. I found, however, at Brookline the following very serviceable viz. Eyes open, ears open, mouth shut the first two or three weeks and wonder at nothing the first two or three months. This for the meridian of Brookline—may suit other parts of N. England. Don't know about N.Y. And so I am, hoping you success . . ."[13]

The adventure was about to begin! On or about the Fourth of July, Robert Coker took the Haverhill stage and started for Philipstown, New York. Intending originally to go by way of New York, news of the great cholera epidemic there altered his plans, and sent him *via* Albany.[14] It was undoubtedly for the best, for Coker must have lacked the élan that seems to have characterized his classmate Simmons's attitude toward that scourge of New York city, at least as Simmons described his reaction in 1833:

"The Cholera entered New York early in July 1832. For several weeks it probably took off two hundred daily. Every death, that came to my knowledge, was clearly attributable to one or more of three occasions—pre-disposition, from ill health or fright,—intemperate exposure of some kind,—or delay in ye (sic) application of remedies. A hundred thousand people ran away in a weeke (sic); and ye half emptied streets, & shut or silent shops, presented a mere skeleton on ye late flushed & heaving metropolis. Under this reign of terror, I lived quite recklessly 'about town',—, following ye

[11] John Lee Watson to Robert Adams Coker, Highland School, Philipstown (New York), May 30, 1832. Mss. letter in the possession of the author.

[12] *Diary,* II, 101, entry for the week of June 24, 1832.

[13] William Austin Jr. to Robert A. Coker, Brookline, Mass., June 29, 1832. Mss. letter in the possession of the author.

[14] *Diary,* II, 102, entry for the week of July 8, 1832.

devices of my own heart, & resolutely defending, from nervous thrills, melancholic humors, & ye discipline of jejune regimina, my very sane and faithful body."[15]

Fearing, rightly the great epidemic then raging, Coker went overland by stage to Troy, and then by riverboat down the Hudson to West Point. It took three days to cross Massachusetts by stage, and a fourth to go by boat from Troy to the Point. The notation in the *Diary* concludes: "Arrived at West Point 7 P.M. Payed for landing luggage 12½ cts; for carrying to the office 6½ & for carrying from thence to the Hotell 37½ cts. As it was late & I had not found time to shave since I started from Lowell, I determined to put up at the Hotell till Monday. Bill at the Hotell $3.00. Saw the Cadetts parade. They parade and exercise on the Sabbath. There was much company at the point. Accommodations good. Sunday took notes of my journey & Expenses from leaving West Newbury to my arrival at West Point $12.92."[16]

Had Coker gone originally as planned, he would have come up the Hudson from New York city, and seen the river unfold with its sights on either side as anticipated by Vanderwater's *Pocket Manual for Travellers on the Hudson River:* "After proceeding about a mile beyond the (West Point) landing, by taking a retrospect, the traveller has a magnificent view of the *Military Academy,* and all the buildings appertaining thereto. There are nine brick buildings for the officers and professors. The view of the Point from this distance is highly imposing. Mr. Samuel Gouverneur has a beautiful residence opposite West Point. The *Highland School* is located half a mile north. It was commenced in 1830, and is now becoming very popular."[17] On Monday, July 9th, Robert Coker crossed from the Point to the Highland School, where, he recounts, "I arrived about 10 or 11 A.M. Mr. Watson was at the door, & I gave him my letter of introduction, & we walked into the house."[18] Coker was quickly introduced to the "family" of the Highland School, Watsons, and "Mr. Ellis, instructor in drawing & French."

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[15] *Harvard College . . . Records of the Class of 1831* (Mss. Class Book, 1831), Holograph Biography of William Hammatt Simmons, October, 1833, pp. 504–505.

[16] *Diary,* II, 108, entry for the week of July 8, 1832 (detailing the events of the preceding week). Only in rare instances did Coker put personal thoughts or private comments on family or friends upon the pages of his *Diary.* Yet he committed voluminous detail on impersonal matters to the pages of the same volume, and left a very lengthy word-picture of his journey by stage across Western Massachusetts to Troy, and then by the river to Newburgh. *Diary,* II, 103–108.

[17] R. Vanderwater: *The Tourist, or Pocket Manual for Travellers on the Hudson River, The Western Canal and Stage Road to Niagara Falls down Lake Ontario and the St. Lawrence to Montreal and Quebec . . .*, p. 23.

[18] *Diary,* II, 109, entry for the week of July 15, 1832.

For a few days Coker had a chance to shake himself down before the duties of the term began. He described both the site and the school to his family in his first letter home to West Newbury:

"Well, I have found the place, and a fine situation it is. It can be seen to good advantage as you pass on the river. We are 180 feet above the river and scarcely a house in sight except those of West Point, and West Point Foundery, the latter of which is on our side of the river and about a mile from us. Our situation is as retired as any in West Newbury. Our house shows finely as you pass on the river; and also from West Point. It stands on a long narrow plain of perhaps 30 acres, notched into the side of the mountain, as you would call our hills by that name if you had them in Massachusetts. From the edge of this plain the bank descends to the shore of the river so abruptly that the tops of the large trees with which it is covered are scarcely above the level of our feet. From behind the hill rises to a very great height. . . .

"We live among the mountains, & with the exception of the Hudson we see nothing but mountains. They are however perfectly covered with trees which gives them at this season a lovely and beautiful appearance. At this moment (a real N.E. storm) the tops of the mountains are far above the clouds. Indeed the clouds are seen almost every day rolling about the tops & sides of the hills. A few rods from the house is a brook which runs down the side of the mountain called Indian Brook, where there is a beautiful cascade, the water falling about 20 feet. As you stand at the foot of it the trees are so thick that you cannot see 10 rods in any direction except directly upward; & indeed the tops of the trees meet so nearly that the sun can scarcely visit the place at all. . . .

"As the scholars have not returned I cannot say anything of the school. Last term they had 24 scholars & may have 30 this perhaps. The school began with one scholar. They do not want more than 25. Five or six of the scholars were from Massachusetts last term. . . . Mr. W's (Watson) family appear to be a good one & we have plenty of *toasted bread.* The post office is a mile & a half off; but we have a mail from the school to the office every day, so it is the same as if the Post Office were kept in the House. We have 4 instructors to take care of the 25 or 30 boys."[19]

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[19] Robert Adams Coker to John Coker, Highland School, July 11–16, 1832. Mss. letter in the possession of the author. Paragraphing mine. The letter was mailed on the 16th; witness the *Diary*, II, 109, entry for the week of July 22, 1832: "Monday 16 our school began. . . . Walked to Cold Spring . . . Put a letter in the Office for home. . . ."

The new mathematics instructor had a week of leisure to become acquainted with the school, with the Watsons, and with the surrounding countryside.[20] His brief summary in the *Diary* reads thus: ". . . the . . . week has been spent in reading Mathematics, viewing the scenery, looking over Newspapers, reviews, etc."[21] The natural scene fascinated Coker; man's urbanization, in this instance, repelled him. "This week I have examined a waterfall in our vicinity where the water falls, I should think, 20 feet. The banks on either side are very high and steep, being covered with tall trees which completely excluded the sun even at noonday. It is the most wild and beautiful spot I ever saw. Visited Cold Spring in company with Mr. Watson. It is a filthy and forbidding place."[22] Then the informality of the period of familiarization was over, and the routine commenced. "Monday 16 our school began. Only 12 or 14 scholars were returned. I have four classes in Mathematics and one in reading each day, one hour each and one in geography twice-a-week." But the routine did not cut off all leisure time; Coker still found occasions for his walks and his explorations, and gained welcome relief from the classroom when he "discovered a small place of cleared land a ¼ of a mile from our house where blackberries are most abundant & I have paid a semi-diurnal visit almost every day this last week. It is entirely surrounded with woods & free from any interruption from wingless birds. I have spent a very pleasant week."[23]

In his *Diary,* Coker makes but infrequent references to his work and to his students; in those letters of his that survive, there are fewer still. His curiosity was for the countryside, and in his *Diary* and occasionally in his letters he reveals the region around West Point and Cold Spring as he saw it more than 120 years ago:

> "Saturday (July 28th) went to Fort Putnam with Mr. Ellis. It is about 20 minutes walk from the Hotell at the Point. The Fort is in a very dilapidated condition; but it must have been impregnable when well manned. . . . The view from the fort is extensive and beautiful. As you look towards the east you see the Hudson before you covered with vessels and boats, which opening a way thro' the mountains affords a prospect to the north bounded only by the horizon, while at your feet and between you and the river lies the Plain of West Point. . . . Direct your eye to the opposite banks you

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[20] *Ibid.*

[21] *Diary,* II, 109, entry for the week of July 15, 1832, referring, of course, as was Coker's custom, to the events of the preceding week.

[22] *Ibid.*

[23] *Diary,* II, 109–110, entry for the week of July 22, 1832.

may see Cold Spring at the water's edge, and higher up the hills you have a fine prospect of the Highland School, which with one other seat of a gentleman, is the only house of any significance in sight on the hills . . ."[24]

Robert Adams Coker was a sick and a lonely man in this sojourn out on the Hudson; already dying of tuberculosis, he suspected it, but knew it not for certain. In August of 1832 he began to cough blood once again, and at that point in his *Diary,* brought his medical history up to date in great detail, as if the mere expression of it could allay some of the fear involved. Anyone reading this account a century and a quarter later still experiences a catch in the throat for this sickening young man. "Saturday morning, when I first waked up & went to move in the bed I had a slight tendency to cough, which brought up a mouthful of blood. It came up extremely easy as it always has . . . I am not aware that I have raised any since I arrived here till Saturday, i.e. yesterday. I now think these three extraordinary raisings have been caused by overexertion in talking & reading aloud, & I must be more careful for the future & hope, Dei Gratia, I shall recover. Oh! Domine, adjura mihi. I have already refrained very much from long talking or earnest; but I now find that any great exercion (sic) in talking is sure to be followed by bleeding. . . ."[25]

Against this background of personal illness, Coker "kept school". His entry for the week of August 12th, recording the events of the week preceding, runs as follows: "Monday morning, felt sick, eyesight grew dim, something passed my bowels and felt better. Took but a slight breakfast. . . . Saturday walked to Cold Spring, where I took tea and came home in a boat. This week I have slept in the Attic. A wretched way of sleeping—for we are obliged to go to bed at 9."[26]

The following week Coker was again saddled with supervising the "evening school from 7½ to 8½". Sleeping in the Attic, of course, was doing proctor's duty on the "scholars"; so too was keeping the evening school. Coker was thus learning in detail the assumption that John Lee Watson had made in vague terms in his hiring letter; as Mr. Watson had pointed out, ". . . the business of instruction, important as it is, forms but a part of our labours; & we wish to secure your aid in the performance of

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[24] *Ibid.,* II, 110–111, entry for the week of July 29, 1832.

[25] *Diary,* II, 111–116, entry for the week of August 5, 1832. This detailed account carries Coker's "medical" history from *ca.* 1827 down to early August of 1832.

[26] *Ibid.,* II, 116, entry for the week of August 12, 1832.

other duties, in which, as a resident of our family, you can participate."[27]

As the month of August drew toward its close, the generally pleasant life of the Highland School went forward. Coker went out riding on occasion with Mr. Watson;[28] he still was not yet aware of the implications each time such an invitation was extended. The shattering of the illusion was soon to follow. Obviously the mathematics teacher was feeling better, physically and mentally, for he was finding pleasure and an awakened moral indignation in reading other than mathematical tracts and texts. "Finished the Memoirs of Josephine. She was a deceitful miscreant & so ambitious in pleasing everyone that she would attempt it without the least regard to principle. By her own account she married Buonaparte without liking him, yet when she found herself cast off she found it necessary to go through the usual ceremony of fainting, etc. But fortunately Buonaparte was not to be moved by any of her wiles. He knew her too well."[29]

In this fall of 1832, Coker recorded an almost frenetic preoccupation with the longing and search for fresh fruit. Almost every weekly entry in the *Diary* records his looking for, or purchase of, some form of fruit. In mid-August he notes that he "found a great plenty of blackberries this week, & a few whortleberries."[30] September's first entry records the finding of a "fine plate of mush melon in my room. Oh! delicious repast. It is the first fruit I have tasted this season except berries which I picked myself."[31] The following week offered another surprise: "Tuesday I found on my table, when I returned to my room after dinner, two peaches, &c. These being the first cultivated fruit that I have seen I literally leaped for joy after recovering from the anti-motive effects of surprise. They were sent by Mrs. E. Watson."[32] The following week Robert Coker took a Saturday walk down to Cold Spring, "where I found some very ordinary sweet apples, these being the only fruit of any kind in the place I bought a couple & they tasted really good for want of something better."[33] Within two weeks the craving was again so pressing that Coker went back to Cold Spring: "Tuesday walked to

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[27] See footnote #11, Watson to Coker, page 4.

[28] *Diary,* II, 117, entry for the week of August 26, 1832.

[29] *Ibid.* That this was probably the "golden era" of Coker's well being is attested by his somewhat non-professional reading in this period. In addition to Josephine, he was enjoying Washington Irving's *The Companion of Columbus, Anastasius,* Turner's *Sacred History of the World, The Vicar of Wakefield,* and a volume on *Animal Physiology. Diary,* II, 116, 117–118, 119, 122.

[30] *Diary,* II, 116, entry for the week of August 19, 1832.

[31] *Ibid.,* II, 118, entry for the week of September 2, 1832.

[32] *Diary,* II, 118, entry for the week of September 9, 1832.

[33] *Ibid.,* II, 119, entry for the week of September 16, 1832.

Cold Spring after school, on purpose to get some fruit. Found nothing but apples, of which I bought 14, which was as many as I could conveniently carry. Saturday walked to Cold Spring for fruit but could find none worth bringing home."[34] Week after week the pattern was repeated.[35]

On one occasion this search for fruit produced an experience that Coker recorded with wit and the vividness of an etcher's delineation:

"Monday (October 14) walked to Cold Spring for fruit, but found none. Tuesday walked to a farm house 1 mile or so distant to get fruit. Saw a waggon (sic) at the door which indicated company within; however knocked at the door, and was answered by a "come in". Opened the door and found a room full of women and one man with a startling pair of green spectacles and quite ministerial in appearance. Enquired for pears or apples, and succeeded in getting a dozen very good apples. While the woman was gathering the apples, the green eyed knight began, sans ceremony, 'I observe you wear glasses, is it on account of inflammation in the eyes'? This was a real poser, but being in a good humor at the prospect of some fruit, I civilly told the man that such was not the cause of my donning specs. He, however, was not quite satisfied with this, but proceeded say (sic) that it was the cause of his wearing them; he did not know but it might be the reason why I wore them; & then made some remarks upon sight, which induced me to enter upon an optical lecture on the causes, phenomena and remedies of defective vision, which very much surprised but did not silence the knight. Soon the apples came and pay being refused I gave an urchin some money and moved, leaving them in a sad quandry, as to who 'that are' man was, whence he came, whither bound, and what he could want of so many apples."[36]

The thrill of getting the feel of a new position, of learning the foibles and the ways of a new family, of meeting the young scholars as they drifted back to the Highland School were by mid-October giving way to a general discontent and irritation. The veneer of the school had rubbed off, and the reality of the daily routine was stultifying, even to one of so pedantic and pedestrian a nature as Robert Adams Coker. The Tolliver-like qualities of

[34] *Ibid.*, II, 119, entry for the week of September 30, 1832.

[35] *Diary*, II, 119, entry for the week of October 7th: ". . . walked to Cold Spring twice in quest of fruit but could find none worth bringing home." *Ibid.*, II, 120, entry for the week of October 14th: "Saturday walked to Cold Spring for fruit, but found none."

[36] *Diary*, II, 120–121, entry for the week of October 21, 1832.

Mr. Watson were all too soon apparent, and Coker soon eschewed the dubious delights of going upon invited rides with Master Watson. The curious questings to the Point, and to Fort Putnam, the eager walks to Cold Spring, even the quick withdrawals to the hidden glade were all but discontinued by mid-October. The rude awakening had come!

"Yesterday Mr. E. Watson invited me to ride, but I declined, because I find that an invitation to ride the precursor of a request to sleep in the Attic. I am willing to oblige anyone, but am not to be *fished* into the performance of drudyery (sic) by any one."[37] It was not alone the fact that "a policeman's lot is not a happy one", even in the Attic; the daily life in the Highland School had become one of stress and strain for the mathematics instructor. He was now one of the family, with all of the attendant inconveniences thereunto attached. As October drew toward an end, colder weather threatened, and Coker wanted the comfort of a stove. "Tuesday my stove was put up. I was obliged to make two applications before I got it. It is a little sheet iron concern such as is seen in shoemakers' shops & its longest diameter is 16½ inches. The wood is green & it is decidedly the worst that I have ever had any thing to do with."[38] Discontent with the stove was not a frequent reaction these late October days, for Coker was seldom enough in his room to feel the need of the stove, or even to have time enough to light it. "This week sleept (sic) in the Attic—wish it to the deuce every time I sleep there."[39] Early November proved to be no better than late October; "the past (week) I have slept in the Attic on account of Mr. W's absence. Went to bed of course about 20 minutes past 8."[40]

Coker's discontent was at this point not all externally induced. He was wearied of the Watsons, of the school, of the fare, and of the general situation. Little, it seems, could please him. He was sick, literally, unto death, but knew it not. His family had concern for him that fall, and sought from him comments on his health.[41] They were probably more conscious of his danger than

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[37] *Diary,* II, 121, entry for the week of October 21, 1832.

[38] *Ibid.,* entry for the week of October 28, 1832. Tuesday would have been October 22.

[39] *Diary,* II, 122, entry for the week of November 4, 1832.

[40] *Diary,* II, 122, entry for the week of November 11, 1832. The Messrs. Watson were undoubtedly absent to attend the burial of Mrs. E. Watson, recently deceased. It was she who had kindly given Coker the peaches.

[41] When Coker first went to teach in the academy in Francestown, he wrote reassuringly to his sister Susan and the whole family: "You need not fear that I shall study too much here, for there not books (sic) nearer than Boston except two or three that I bought for studying my profession. My profession, you know, the

was Coker himself. As winter approached, he went to Cold Spring to procure a short coat, and notes that he "bought materials for a spencer."[42] In less than three weeks he was back in town to get it, but with no joy in the acquisition. "One day this week I walked to Cold Spring & got a spencer which was made for me there. It is altogether different from what I designed & will be of little use. I set out to get a cheap garment; but I find cheap things always dearest in the end."[43] Even within himself was this season to prove for Coker the winter of his discontents: "Begant (sic) to write an Arithmetic. . . . This week I have made but little progress with my arithmetic. It is a great bore to write. Doubt whether I finish it without an amanuensis."[44]

The combination of ill-health and irritation finally provoked Coker to make an issue of what he considered abuse of his position and disposition. The diet at the table at the Highland School was less than appealing, and Coker's frequent consumption of fresh fruit appears to have produced the inevitable result:

> "This week (November 18th week) much trouble with the Dysentery. Obliged to be up once or twice for three nights. Slept in the Attic the first three nights of this week, for Mr. E. W. I have been called upon for several nights extra every week that I have slept there except the first. Wednesday finding that I was not relieved of the Attic as I was told I should be, I wrote a note to the Messrs. Watsons (sic), stating how much more I had slept there than of right belonged to me & *requesting* to be excused for the rest of the term. This note produced *immediate* relief, & in the evening I received a note of Mr. J. L. Watson, from which I extract the following: 'It gives me pleasure to take this opportunity to express our entire satisfaction with the performance of all the duties we have assigned you.' However they did not excuse me for the whole term; but as only one week of Attic sleeping, or rather waking would fall to me during the term I tho't best to say no more till the vacation when I shall make a more definite agreement if I conclude to stay."[45]

Doctor says will be just the thing for me." Robert Adams Coker to Susan A. Coker, Francestown, November 3, 1831. Mss. letter in the possession of the author.

The family was anxious about Coker's health when he went to New York state, and in their first letter to him after his reaching the Highland School, they inquired particularly: "Mother wants you to send in particular about your health wether (sic) the climate agrees with you better or not as well or wether (sic) there is no difference." Catherine G. Coker to Robert A. Coker, West Newbury, July 31, 1832. Mss. Letter in the possession of the author.

[42] *Diary*, II, 121, entry for the week of October 28, 1832.

[43] *Ibid.*, 122, entry for the week of November 18, 1832.

[44] *Ibid.*, 122, 123, entries for the weeks of November 11, 18, 1832.

[45] *Diary*, II, 123, entry for the week of Novemver 25, 1832. Undoubtedly part of Coker's discontent was fostered by the worsening relations between his scholars and himself. He must have been a humorless pedant, a perfect butt for exhuberant young fiends to torment. As he noted in his *Diary*, "this week all the boys with

Coker's general health improved but little by the end of November, if we can credit the *Diary*. The dysentery still bothered him, and he felt "like a stewed goose for want of proper exercise and food."[46] He was also homesick for family and for Massachusetts. Unusual for him, in the same week Coker wrote both to his family and to his dearest friend William Austin, remembering on the Thursday on which he wrote to the latter that it was then Thanksgiving Day in Massachusetts, "as I remembered when I sat down to our meagre dinner, of which I could scarcely eat 3 mouths full."[47] So angered and hungered was Coker that on the following Saturday he attempted to remedy both the want of exercise and want of food. In so doing, he left a most interesting picture in recounting his excursion to the old foundery:

> ". . . walked to Cold Spring, eat (sic) a pie, & bought a few apples as hard as brick-bats. As I returned, called at the foundery where I saw them cast a shaft &c. &c. The iron was constantly stired (sic) in order to feed it, & from time to time liquid iron was brought from the furnace in ladles & poured in to feed the shaft. Without *feeding* the workman said the casting would be good for nothing. (I.E. not solid). I also saw a cylender (sic) for the Erie being bored. Cylenders (sic) are not cast solid like cannon; hollow and then are bored smooth. The workman said, it took about 12 days to bore such an one as the Erie's, as they went over them twice. The Cylender (sic) is not moved during the operation, the cutter advancing, by means of a screw, as fast as is necessary."[48]

Food and foundery drew Coker again the following week. ". . . walked to the Foundery & stayed a few minutes. Bought some citron, which is the first I ever tasted. Was very sick of my bargain. It is not fit for civilized beings to eat. . . . Yesterday walked to Cold Spring in the rain mainly to get something to eat besides bread."[49]

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the exception of 8 or 10 have been racking their ingenuity to show their spite against me. I have been really amused at their resentment; but have in no instance varied my conduct in the least except to draw tighter the reins. The cause is, I make them learn by *study*, whereas they wish & have been accustomed to learn Arithmetic only by being *shown*. I am also much more strict than their old Math. Instr." *Ibid.*, II, 124. Coker smugly thought he knew where the blame lay, but would have been surprised had Robert Burns' measure been used upon him. Half a century later the Rev. Dr. Morison was to apply a critical rule of evaluation to this dusty scholar, and possibly prove the boys correct in their heckling resentment of poor Coker.

[46] *Diary*, II, 124, entry for the week of December 2, 1832.

[47] *Ibid.*

[48] *Diary*, II, 124–125, entry for the week of December 2, 1832.

[49] *Ibid.*, II, 125, entry for the week of December 9, 1832.

The Highland School, like citron, came for Coker to be "... not fit for civilized beings ...". As discontents mounted, fuel was added to the pyre by a difference of opinion between Coker and the Watsons as to his term of service to the school. John Lee Watson consider Coker as obligated to serve six months, whereas Coker's understanding had been only five months. A battle of letters and conferences followed, and the Watsons' obstinacy convinced Coker that departure alone was possible. In anger at Coker's attitude, John Watson had finally told the mathematics instructor that he, Watson, could make Coker work all night instead of going to bed.[50] Here was the watershed in emotions and relations as concerned Robert Adams Coker and the Highland School. In spirit he was, in mid-December, through with the Watsons and their school; within three weeks he was in fact and in deed to be done with them. Nothing now could please him; all was dust in his mouth. It was more than psychosomatic, for Coker was dying, though none knew it yet. The severing of good relations between Coker and the Watsons was actually for the Watsons' good; had Coker been persuaded to stay on at the Highland School, they might well have had a corpse rather than a mathematics tutor on their hands before the renewed contract had expired. Yet it is impossible to read the year's end entries in the *Diary* without a feeling of intense pity for this lonely man of twenty-five, rebelling against his lot in life without knowing the true cause:

> "This week have been very unwell. One or two mornings when first I got up it hurt me to breath very much, giving a violent pain in my breast, left sholder (sic) and about the left kidney, where, as near as I can judge, is the seat of the disorder. Left coffee and meat and potatos, mostly; and I think, Dei gratia, the difficulty had not increased, but perhaps rather diminished. Felt like a *stewed goose* most of the time. . . . Oh! Deus me sustine, te precor. Saturday walked to Cold Spring, and stayed all night at Longfield's. For 2 meals, lodging, &c. payed 62½ cents. I gave Mr. L 40 cts. to bring me home."[51]

Not even the keeping of Christmas could give Robert Coker a spark of affection for the school. On Christmas Day, "... Messrs. W gave the boys a *Dinner*. It consisted of 1st. Roast Turkey; 2nd a small piece of mince pie, miserable enough, tho' very rich, yet spoiled in cooking; 3rd a desert (sic) of almonds, figs and very good raisins.—Drink, water."[52] But the Watsons' board

[50] *Ibid.*, II, 126–128, entry for the week of December 16, 1832.
[51] *Diary*, II, 128–129, entry for the week of December 23, 1832.
[52] *Diary*, II, 129, entry for the week of December 30, 1832.

stayed heavy in Robert's stomach, and the day after the feast he went off to Cold Spring once more.

> ". . . stayed the night at Mr. Longfield's merely to get a change of diet for a day or two. Thursday it snowed and was wet, got Longfield to bring me home. . . . This week I have felt like a *stewed goose* of the *second degree.* I am now thoroughly disgusted with the place & if ever I get away ye will never catch me here again in this sink of filth and misery. The manner of life is enough to kill a horse either by confinement or wretched food. Today I sent for 25 cents worth of crackers and fish to help me drag along."[53]

Reprieve was soon in sight; the new year came! Two one-sentence entries in Coker's *Diary* record the passage of the old and the entry of the new: "Dec. 31. The recess closed and I taught my classes." "January 1. The Kalends was observed, tho' not as it should be."[54] Nothing was, or could be, right at this house high above the Hudson. By January 5th the moment for departure had come. Reports and recommendations had been turned in to the Messrs. Watson, and the scholars all "classed"; Robert Adams Coker was ready to shake the dust of the Highland School from his heels that Saturday afternoon in January, 1833. "At four I was ready and having bequeathed my relicts to Mr. Ellis, and taken leave of him and Messrs. Watson I stepped into the waggon (sic) and rode off without the least regret at anything except leaving a bottle of fine spring water which the servant had brought me in the forenoon."[55] By wagon to Cold Spring, by river boat to New York, and then a brief visit: "I did not move about the City much. From the appearance of things it seems that one might get anything he wanted. I got oysters there for 8 cents apiece, and large doughnuts, of which 1 is nearly enough for my breakfast, for a cent apiece. The City Hall was the only building to which I payed attention. It is a very pretty building, situated on a plane (sic) in an elevated part of the city. Tamany (sic) Hall close by is a house, on the European plan, where you can get just what you want without being bored with what is not wanted."[56] On Tuesday Robert Coker left New York by boat for New London, from there by stage to Norwich, where he "took a glass of hot water & some crackers and figs." From Norwich the journey went by coach to Boston, stopping at Brookline for supper. "I eat nothing but toast. After changing

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[53] *Ibid.*

[54] *Diary,* II, 129, 132.

[55] *Diary,* II, 133, entry for the week of New Year's Eve and the New Year, 1832–1833. These last several pages are not numbered in the original.

[56] *Ibid.,* II, 134.

our carriage & horses we proceeded to Thompson, where I took a cracker & a glass of wine. . . . We went thro' Mendon & reached Milford about 7, where we took breakfast. I eat little but toast."[57] At West Newbury the journey came to an end.

And so the story has been told. The brilliant mathematician of the Harvard Class of 1831 had gone but a little way West, in pursuit of his "profession". It had proved to be less the glorious realization than he had once imagined. By early January he was home again in West Newbury, home once more with his Mother, who had been so disturbed that there had been no Church near the Highland School, and who had seen the hand of God directing Robert's journey westward across Massachusetts when he went out eagerly toward Philipstown and Cold Spring:

> "I think we ought to consider it as a providential thing that you did not send your trunk by water for of course you would went (sic) into the city and might have been exposed to sickness and danger in the Steam Boat, but God directed you another way. I hope you will ever remember to seek first the Kingdom of heaven and the rightousness (sic) thereof and God will ever direct you in all your lawful undertakings. for the Scriptures teach us that it is of him and through him and to him and from him are all things. I am sorry you have no good meeting on the Sab. But I hope you will remember the commandment to keep it holy and not suffer yourself in any thing unnecessary."[58]

He was home again with the sisters and brothers who had waited impatiently for his letters, and who had laboriously written letters to him, detailing the events of their everyday lives in West Newbury, telling him of the fields and the orchards, the progress of the black colt, and of the visits to aunts and uncles.[59] Now this was all at an end. Robert Adams Coker had come home. He had written his first report from the Highland School six months before, and had noted that "Mr. W's family appears to be a good one and we have plenty of *toasted bread.*" Now the sixmonth was gone, and so was Coker's health. How pitiful it is to read that final sentence in the *Diary* that he had methodically kept since his academy days at Exeter, beginning in 1827: "I eat little but toast." By March, 1833, Robert Adams Coker was dead. One

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[57] *Ibid.*, II, 135–136.

[58] Susanna Coker to Robert Adams Coker, July 31, 1832, West Newbury, Mass. Mss. letter in the possession of the author.

[59] Susanna Coker to Robert Adams Coker, West Newbury, July 27, 1832; Catherine G. Coker to Robert Adams Coker, July 31, 1832, West Newbury; same to same, West Newbury, September 5, 1832; Susan Coker to Robert Adams Coker, West Newbury, November 8, 1832; Catherine Coker to Robert Adams Coker, November 14–15, 1832. Mss. letters in the possession of the author.

of his family added the final entry in the *Diary,* not a holograph entry, but the pasted obituary from a local newspaper.[60]

Forty-eight years later, on the occasion of the 50th anniversary of his Harvard Class, Coker's name was called forth from the shadows of the past, and his personality conjured up for those remaining classmates celebrating in 1881. Ten members of the class were present at this anniversary, and the Rev. John Hopkins Morison read a series of very interesting sketches of deceased members of the class, with estimates of their characters and achievements. In essence the commentator captured well the teacher of the Highland School who did one job, and then went home to die:

> "Robert A. Coker. Single-hearted, honest, a little affected in his profession of exclusive devotedness to mathematics,—hearty in his greetings—it was always a pleasure to meet him, and perhaps it was also a pleasure to leave him—there was so little variety in his conversation. His life was a monotone not devoid of humor, but all slightly in the minor key."[61]

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[60] *Diary,* II, 137. Page not numbered in the original. For an identical copy, see *Harvard Class Book, 1831,* newspaper clipping, no date, no place, p. 271.

[61] *Harvard Class Book, 1831.* Account of the 50th anniversary meeting of the class, Tuesday, June 28, 1881. pp. 45–46; comment on Robert Adams Coker, in Morison's hand (pasted in the Class Book), p. 270.

THE INFLUENCE OF SCIENCE ON AMERICAN LITERARY CRITICISM, 1860–1910, INCLUDING THE VOGUE OF TAINE*

Harry Hayden Clark

I

If American critical thought from 1860–1910 represents, broadly speaking, a revolt against the artificial and "feudalistic" romance of Scott and his followers as well as a revolt against the kind of semi-Coleridgean idealism associated with Emerson and Poe and their major contemporaries, the new trend toward what is roughly called realism (what is habitual and average in human conduct) and naturalism (stressing man's kinship with nature and animals) is complex and is to be explained only by the interplay of many diverse influences. Among these are the growing demand for greater democracy, especially in economic opportunity; the growing need for adjustment to the physical environment of America; the attempts of an expanding journalism to meet the demands of an ever growing public, including immigrants, increasingly alive to the actual realities of their work-a-day world; and the vogue and influence of European thinkers. More important than generally realized, however, in helping us to understand the new trend and the ways in which the influences just mentioned were rationalized, is science. For scientific inventions and industrialism, applied to exploiting frontier resources, brought to a focus many of the problems of our professed ideal of democratic equality and the welfare of all; scientific advances in printing and in transportation implemented an expanding journalism which increasingly reached the masses; and the European thinkers themselves (such as Zola) were mostly greatly influenced by science. But at least equally important were the philosophical and sociological implications of evolution, which gradually led people to see the ideas with which literature was concerned in a new frame of reference and to try to explain literary art and creativeness in terms of the physiological-psychological study of the individual considered as determined by both heredity and environment, by time, place, and race. At the risk of over-simplifying a complex pattern of thought, we

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might bear in mind David Bowers' suggestive thesis that after the *Origin of Species* the bases of American philosophical ideas turned from dualism to monism; from the idea of fixity of species (uniformitarianism, as Lovejoy would say) to the flux and relativity; from individualistic atomism to a sense of society as an organism, growing and changing and interdependent, in which the individual is subordinated to the species and to the functioning of the social order as a whole. And students of this criticism would also find illumination in Richard Hofstadter's *Social Darwinism* (to 1915) and in John Dewey's work, especially his essay of 1910 on the "Influence of Darwin". We must of course remember that (as Osborn has shown) some of the general ideas of evolution go back to the ancient Greeks; that Lamarck, Lyell, Comte and Buckle paved the way for Darwin's literary influence; and we must bear in mind not only the influence of Spencer and Huxley in America but also our own popularizers of Darwinism such as Fiske, Youmans, Le Conte, Draper, Shaler, Asa Gray (not to mention the intermediate and partly hostile Agassiz and J. D. Dana), as well as the American vogue of Herder, Goethe, Hegel, Taine, Bruntiere, Sainte-Beuve, Zola, J. A. Symonds, Dowden, Kidd, Drummond, Leslie Stephen, Haeckel, etc. For example, Dowden's popular essay on "The Scientific Movement and Literature" attributed to science increased interest among literary men in "the relative as opposed to the absolute"; in the idea of heredity; and in the idea of human progress. American reviews and comments on the work of all these men furnished an interesting chapter in comparative literature. In the following paper I shall try to summarize the way scientific ideas entered into the thought not only of the three major critics of the period but of some thirty critics of intermediate stature who reflect the time-spirit and the way ideas associated with science operated on the popular level.

Whitman wrote Dowden he was glad to "entirely accept" his Taine-like interpretation of his literary functions; Whitman would "typify" a representative American "formed & shaped in consonance with modern science, with American [frontier] Democracy." He accepted the facts of science and of Darwinism "from A to izzard," but "furthermore," he said in his essay on the subject, he hoped these could be "blended" with a belief in man's divinity, for he was in part a mystic in debt to the transcendental Emerson. Science gave him authority for his frankness about sex as well as his faith in "vital laws" and in the pantheistic divinity of all things, high and low, before which "the whole theory of the supernatural, and all that was twined with it or educed out of it, departs as a in a dream." Partly because evolution convinced him of progress, his criticism disparaged Scott, Carlyle, and even Tennyson as "feudalistic". And the "law of eternal kosmical action, evolution," inspired his view that individuality (states' rights) will "surely destroy itself" unless subordinated to the Union; he said the Civil War was the "axel" on which all his poems turned. According to C. M. Gayley and F. N. Scott, "Taine's method of criticism is flatly and frankly scientific." And Whitman exults because "Taine . . . has brought to the fore the first, last, and all-illuminating point, with respect to any grand production of literature, that the only way to finally understand it is to minutely study the personality of the one who shaped it—his origin, times, surroundings, and his actual fortunes, life, and ways." (Quoted by R. M. Bucke, *Whitman,* 1883, p. 12)

One of the chief defenders of Whitman, John Burrough's book on him (1896) includes a chapter on "His Relations to Science" which regards "Leaves of Grass" as "the outgrowth of science" especially in its monism, the conviction of "the identity of soul and body, matter and spirit," and its turn from "notions of the absolute, the fixed, the arbitrary, . . . of the dualism of the world." Burroughs' two appealing volumes of critical essays, *Indoor Studies* (1889) and *Literary Values* (1902), center on the relation of "Science and Literature," an essay which concludes that while the interests of the two are "widely different, yet in no true sense are they hostile or mutually destructive." Indeed Burroughs did pioneer work in studying the indebtedness to science of Emerson and Tennyson; and his view that while Carlyle verbally attacked Darwinism his ideas strikingly parallel Darwin's has been supported by the investigations of modern scholars such as Clifford Harrold. Burroughs thought science was especially helpful in turning critics from the arbitrary rules of "the old traditions":

> "This suspicion of nature was the keynote of the old theology. which found its authority in a miraculous revelation, and it is the keynote of the old Aristotelian criticism, which found its authority in a body of rules deduced from the masters. The new theology looks for a scientific basis for its morals, or seeks for the sanction of nature herself; and democratic criticism aims to stand upon the same basis, and cleaves to principles and not standards, not by yielding to the caprices of uninformed taste, but by seeking the law and test of every work within itself." (*Literary Values,* in *Writings,* Riverby Ed., XII, 125)

In *Birds and Poets* (III, 173) he remarks that "After the critic has enumerated all the stock qualities of the poet, as taste, fancy, melody, it remains to be said that unless there is something in him that is *living identity,* something analagous to the growing, pushing, reproducing forces of nature, all the rest in the end pass for little." "It is ever present to the true artist, in his attempt to report nature, that every object as it stands in the circuit of cause and effect has a history which involves its surroundings, and that the depth of the interest which it awakens in us is in proportion as its integrity in this respect is preserved" (III, 171). Following and interpreting Emerson and Whitman, then, Burroughs as a literary critic was an important influence in urging in lucid and appealing essays that literature and science should provide mutual reinforcement in standing for monism, anti-traditionalism, stress on organic and positive natural forces, orientation in terms of "surroundings," a concern for "the true, the vital, the characteristic," and for a rationalism respectful of the unknowable and of personalized poetic emotion.

Another critic of Whitman, E. C. Stedman, while essentially an idealist, called himself an eclectic and prided himself on having written in *Victorian Poets* (1875, pp. 7–21) "almost the first extended consideration" of the impact on poetry of science, which he thought of "an importance equal to that of all other forces combined." In part the effect of science has been iconoclastic: it has helped poets "to cast off a weight of precedent and phenomenal [mythological] imagery," has found "the vulnerable point of an inherited faith" and made his "own time [1875] a turbulent, unrestful interval of transition." Even "our schoolgirls and spinsters wander down the lanes with Darwin, Huxley, and Spencer under their arms." But Stedman (*Life and Letters,* II, 388) is a "soft" or optimistic evolutionist, assured that "Nature is singing the wondrous story of her progress through Evolution, from star-dust up to sentient Man." In this transitional period Stedman, who edited Poe and disliked the heresy of the didactic, thought "the very tendency of modern poetry to wreck its thoughts upon expression, of which Huxley so complains, naturally follows the iconoclastic overthrow of its cherished ideals, confining it to skilful utilization of the laws of form and melody," as Lanier was to illustrate later. And the "disenchanting" effect of science on those accustomed to "empty magician's food" had partly inspired "new phases of psychical poetry, which formerly repelled the healthy minded by its morbid cast," in opposition to the view that art is "mere pastime and amusement." "Poetry will not be able to fully avail herself of the aid of Science, until her votaries shall cease to be dazed by the possession of a new sense. Our horizon is now so extended that a thousand novel and sublime objects confuse us." However, he is convinced that this daze and confusion is merely temporary, and he sees an "approaching harmony of Poetry and Science," her "ally"; with science "at last a clearer vision and a riper faith will come to us, and with them a fresh inspiration, expressing itself in new symbols, new imagery, and beauty, suggested by the fuller truth." This prophecy is partly fulfilled in the vitality and inclusiveness of Whitman, on whom Stedman published an important judicial essay in 1880, included in his *Poets of America* in 1885, which contains many comments on the influence of science. In accord with Greenough and Emerson he accepted something of functionalism, agreeing that ideal beauty "lies in adaptation of the spirit to the circumstances," although these need not be the merely "apparent material exigencies." As we shall see later, he also took a balanced view of Taine (*Victorian Poets,* p. 1), promising to show through this book in the case of the minor poets the "moulding of an author's life, genius, and manner of expression, by the conditions of race, circumstance, and period," while as an idealist he has in the case of the great poets an "equal certainty that great poets overcome all restrictions, create their own styles, and even may determine the lyrical character of a period . . ." Stedman exerted great influence; the public demand for *Victorian Poets* even by 1887 had called forth thirteen editions, and Johns Hopkins University called him to deliver his lectures on *The Nature and Elements of Poetry* (1892). His *Genius and Other Essays* (1911) included "What is Criticism" first printed in 1887. Stedman's discussion of the disadvantages and advantages of science as it affected poetry is an excellent mirror of his period of transition in American criticism.

Howells said the true realist (seeking "fidelity to experience and probability of motive") "cannot declare this thing or that thing unworthy of notice, any more than the scientist can . . ." Because Victorian evolution convinced him that "the beast-man will be . . . subdued," he revolted against "the paralysis of tradition" (disparaging Scott as "mediaeval" and seeing three-fifths of the "clasics" as dead). "Truth . . . is the highest beauty." Therefore he scorned idealization of the Platonic type as like representing a paste-board grass-hopper when a "real grass-hopper" was available for representation. Although at first he disparaged plot and sought "the desultory, unfinished, imperfect," since life "confesses itself without a plan," evolutionary ruthless competition as practised in our capitalistic society led him to favor novels of propaganda devoted to a mild socialism in which the fruits of industrial science and natural resources were subject to government control as a means of making "the race kinder and better." He commends Thornstein Veblen's "methods and habits of scientific inquiry," and feels that "to translate these into dramatic terms would form the unparalleled triumph of the novelist" with a "thinking mind." Following Taine, Howells came to think that literature "is a plant which springs from the nature of a people," and hence the critic should not judge it, any more than a botanist should trample on a flower, but should "place a book in such a light that the reader shall know its class, its function, and character." Howells expressed admiration for the critical theories of H. M. Posnett and his friends H. H. Boyesen and T. S. Perry, critical pioneers reflecting evolutionary trends and he wrote mostly with deep respect of his neighbor John Fiske's views of science and religion. Howells quoted J. A. Symonds' views of evolutionary criticism as the spring-board for his own *Criticism and Fiction,* 1891. Howells' complex critical debt to science will be found more fully studied in my article, "The Role of Science in the Thought of W. D. Howells," *Transactions of the Wisconsin Academy,* Vol. XLII (1953), pp. 263–303.

It will be remembered that Howells wrote a critical introduction to *Main Travelled Roads* (1891) by Hamlin Garland, whose aims and critical theories were even more influenced by science as represented by his essays in *Crumbling Idols* (1894). "I am a disciple of Mr. Spencer," Garland announces, and hence "life is a continual process of change" and there should be "progression, and endless but definite succession in art and literature as in geologic change." "Men did not think . . . until the law of progress was enunciated." "The power of tradition grew less binding, until there came upon the world the splendid light of the development theory, uttered by Spencer and Darwin." (p. 42) Then with the decline of "the statical idea of life and literature, the power of tradition grows fainter year by year." Garland ends these essays on an eloquent note illustrating how evolutionism inspired anti-traditionalism: "Turn your back on the past, not in scorn, but in justice to the future . . . It [the past] is a highway of dust, and Homer, Aeschylus, Sophocles, Dante, and Shakespeare are milestones . . . Idols crumble and fall," but nature calls for "rebellious art." (p. 190) In *A Son of the Middle Border* he reminiscences about how as a youth he studied Taine's critical theories involving determinism; and shortly after Garland as the spokesman of middle-western regionalism and agrarian reform formulated his "great principle" underlying "a really vital and original literature"; "in order to be great [it] must be national, and in order to be national, must deal with conditions peculiar to our own land and climate" in accord with Taine's theory. "Thus Joel Chandler Harris, George W. Cable, Joseph Kirkland, Sarah Orne Jewett, and Mary Wilkins, like Bret Harte, are but varying phases of the same movement, a movement which is to give us at last a really vital and original literature." Technology, however, had enabled the few to amass wealth via industrialism at the expense of the many, especially the western farmers. Hence scientific considerations led Garland to develop his "two great literary concepts—that truth was a higher quality than beauty, and that to spread the reign of justice should everywhere be the design and intent of the artist . . ." (pp. 307, 387, 374).

H. H. Boyesen cites Spencer's definition of evolution and concludes that "if the novel is to keep pace with life, it must in its highest form convey an impression of the whole complex machinery of the modern state and society, and by implication, at least, make clear the influences and surroundings which fashioned the hero's character and thus determined his career." (*Essays on German Literature,* 1892, pp. 232–33. This ran to a fourth edition by 1898). He attacks the use of the "marvelous," and seeks "what is the normal and logical consequence of a line of conduct." Boyesen's book above was popular enough to run to four editions by 1898, and he also wrote *Goethe and Schiller* (1879), *A Commentary on . . . Ibsen* (1893), and *Essays on Scandinavian Literature* (1895). Howells acknowledged his great influence, as did hundreds of his students at Columbia University.

C. C. Everett added the prestige of his deanship of the Harvard Divinity School (1878–1900) to his sponsoring Spencer and the use of scientific ethics in literature. He sees Hegel and Spencer as boring from different sides into the same mountain of truth. Everett's article on "Spencer's Reconciliation of Science and Religion" sees his work as making proper allowances for the "mystery" of "true religion" and making "an immense step toward the perfection of the science of psychology" (*Christian Examiner,* LXXII, 337–52, May, 1862; See also his "Spencer's 'Data of Ethics.' " *Unitarian Review,* XIII, 43ff.) Having "spent a number of terms at the Bowdoin Medical College," Everett said that "if I honor anything in the present age, it is the spirit of scientific investigation. I accept with delight its revelation," so long as it does not deny the soul. In *Poetry, Comedy, and Duty* (1888) the essay "The New Ethics" favors the relative over the absolute, weighs both judiciously and concludes (p. 291) that there is "no need for fear lest the new science shall undermine virtue," for religion and science "while theoretically at variance, are practically working together toward the same end" (p. 292). He liked the scientific ethics for their taking into account historical relations, heredity, and the promise of the amelioration of social evils through environmental changes to implement Christian charity. In his excellent essay on George Eliot he finds that the scientific Comte's "humanitarianism inspired George Eliot's heart," and that she presents tragedy movingly as the result of a "collision between the results of heredity on the one side and of the environment on the other," with stress on heredity (*The Andover Review*, III, 519–39, June, 1885). The judicious C. M. Gayley and F. N. Scott (*Methods and Materials of Literary Criticism*, 1899, p. 97) conclude, "perhaps no writer in America has with equal charm set forth the philosophic connection between Ethics and Art, Art and Imagination, Imagination and the Actual, the Comic and the Tragic, the Beautiful and the Right."

G. W. Cooke's *George Eliot* (1883, the same year as Lanier's *English Novel* which centers on her in somewhat the same vein) is interesting for its bifurcated view of science. Cooke, a disciple in *Poets and Problems*, 1886, of Ruskin whom he credits with being the "opponent of science" (p. 216), and the author of several volumes of criticism, claims that if the Transcendentalists went to extremes on inwardness, George Eliot went to an opposite extreme on evolution. He thinks at times that evolution limited her work and encouraged despondency, yet in inspiring her stress on heredity and environment "the method of science she applied to literature" has "justified itself, and opened up new and valuable results giving the world an enriched conception of the life of man. The speculative mind has been stimulated to fresh activity, and new philosophies of vast and imposing proportions have been the result. The studies of Charles Darwin, and the elaboration of the theory of evolution, have given a marvelous incentive to the new method, resulting in a wide-spread application to all the questions of nature and life" (p. 395). Evolution, he says, has failed to settle the great problems, has added little that is new, yet it "has developed a new literary school" (p. 415); and he praised George Eliot's psychological analysis of character, and finds her superior to Dickens and Thackeray. Cooke's alternate praise and blame of science illustrates the way a critic with a transcendental heritage (see his *Emerson*, 1881) was torn between the two schools of thought in the eighteen eighties. Later he became much more sympathetic toward science.

Both Holmes and Lanier violently attacked Zola's perverse use of science in literature, but they both advocated scientific interpretation of poetic techniques—see Holmes's "Physiology of Versification and the Harmonies of Organic and Animal Life" and Lanier's "Science of English Verse" (1880) dealing with technicalities such as the duration, intensity, pitch, and tone-color of sounds. Holmes as a physician saw "nine-tenths" of human behavior determined by forces beyond our control; hence many criminals in fiction are not responsible for their deeds and are entitled to sympathetic medical treatment, as he suggested in "Crime and Automatism," and "Mechanism and Morals"; and he wrote "medicated novels" such as *Elsie Venner* (1861) to provide a sort of scientific "test of the doctrine of original sin and human responsibility" in the case of one who had inherited evil tendencies. His *The Guradian Angel* (1868) dealt with the successive emergence of three ancestral influences upon the life of his heroine. Holmes' relativistic doctrines involving humanitarianism were of course brought to practical application in the constitutional interpretations of his son, the great Justice, a "block off the old chip." For Dr. Holmes held that "Darwinianism" bridged the chasm between Nature and Grace, "restored 'Nature' to its place as a true divine manifestation," and he decided that "if we have grown by natural evolution out of the caveman . . . we have everything to hope from the future," since "sin, like diseases, is a vital process" and "must be studied as a section of anthropology."

On the other hand, Lanier wrote *The English Novel* (1883) to show parallels in literary and in scientific development: "just as science has pruned our faith (to make it more faithful) so it has pruned our poetic form and technic." *Music and Poetry* tries to show how Darwin, poetry, and landscape-painting are all inspired by "direct sympathy with physical nature." Since "Mr. Spencer has formulated the proposition that where opposition forces act, rhythm appears," Lanier, like Fiske, tries to rationalize evil by arguing that "the awful struggle for existence . . . may also result in rhythm" and social harmony. In Lanier's abortive but highly suggestive *Shakespeare and his Forerunners* (1902) he tries to prove that the dramatist's "advance in art [from end-stopped lines to the later flexibility] and morals is one and the same growth," and he tries to relate his "management of oppositions of the esthetic demands of the ear," to the "management of those moral oppositions which make up life." He illustrates Shakespeare's ethical "opposition of character to character, figure against figure, event against event," culminating in the serene harmonies of *The Tempest*. However, if Lanier thought "evolution . . . a noble and beautiful and true theory," he made "a passionate reaffirmation of the artist's autonomy"—See his prose note on the poem "Individuality" dealing with evolution. He believed that "sensuous things, constantly etherealizing, constantly acquire the dignity of spiritual things." Doubtless his own gallant fight against ill health reinforced his conviction that the human spirit has resources which transcend physical explanation. His criticism is slight in elaboration, but interesting in its *combination* of poetic intuition and scientific analogies.

His contemporary Henry James also combined a rich ethical idealism and respect for the implications and method of science. He had been exposed to ideas associated with science through his brother William (an M.D. and assistant of Agassiz before he turned to psychology), through meeting Herbert Spencer at George Eliot's weekly teas, through his close knowledge from reading for reviews of Quatrefages, Renan, Gobineau, Sainte-Beuve, Zola, and Taine. He repeatedly praised science, hoped Oxford would prove a pathfinder in an education based on the "union of science and sense," on "the happy reconciliation between research and acceptance," and in his essay on Epictetus he thought the moderns superior to the ancients because we are happy possessors of the key to advancement by means of science. He presented a long series of physicians (such as Sir Luke Strett in *The Wings of the Dove*) sketched with deep sympathy, and in "Lady Barberina" he says the physician's "repression of pain, the mitigation of misery, constitute surely the noblest profession in the world." (The physician-hero is in this story a symbol of the dedication to social service which in James' eyes distinguished the American upper classes from a parasitic European aristocracy.)

James was of course distinctive in his tremendous devotion to artistry. But for him artistry involved not so much the relish of sensuous loveliness or mere entertainment but rather the most effectively calculated ways and means of presenting his material in terms of literary architecture, structure and design, as well as in balancing of psychological cause and effect. He said that the artist in his small space must pack his materials "in the one way that is mathematically right," modelled on "the mechanical arts." Dramatic form or scenic method aimed at "the high dignity of the exact sciences, it was mathematical and architectural."In his youth when Poe and his attack on "the heresy of the didactic" was "on all lips," James recognized that Poe (author of *Eureka* based on Newtonianism) held the critic's "scales the highest" and pretended, more than anyone else, "to conduct the weighing process on scientific principles." James' own essay on "Criticism" was first entitled not the art but "The Science of Criticism." In his preface to *The Awkward Age* he tells how he calculated the illumination of his heroine's character by "seven lamps" or commentaries on her by that many friends, thus solving his problem of "point of view" in what he called a "triumphantly scientific" way. (He was much concerned with avoiding the unscientific "omniscience" of the author, and with engineering his stories so that they unfolded as they would have been realized or understood in the mind of participants or confidants whom he called "reflectors," so as to arrive at realism which he defined as "an immense and exquisite correspondence to life" and normal or scientific ways of getting information. "Really, universally," he said in his preface to *Roderick Hudson,* "relations stop nowhere, and the exquisite problem of the artist is eternally but to draw, by a geometry of his own, the circle within which they shall *appear* to do so."

James thought that a novelist's characters should be shown as gradually developing in accord with evolutionary theories of adaptation to environment and of heredity. (One recalls Nanda in *The Awkward Age* as inheriting her grandmother's qualities as opposed to her mother's, and Hyacinth Robinson as explained by his conflicting heritage in *The Princess Casamassima.*) James thought Balzac the "master of us all" and devoted an essay to him partly because of all historians of manners Balzac had "an unequalled intensity of vision, he saw his subject in the light of science as well, "in the light of the bearing of all its parts on each other. (Balzac said he derived his basic idea of the *Comédie Humaine* from observations in the *Jardin des Plantes* and its scientific teachings about environmental determinism.) James said that one cannot fully understand a man unless we know under what circumstances he grew up; and he criticised Cabot's biography of Emerson for not presenting him more fully in his contexture of his time, place, and race. Having reviewed Quatrafages on Darwin, the racist Gobineau, and Taine (on whom he wrote five essays), James very frequently used current evolutionary racial and atavistic theories to illuminate and motivate his distinctively "international" contrasts, as in "A Bundle of Letters" (1879). In this he has an arrogant German scientist urge his countrymen to war on the French because of his notions of his superior race. And in "The Last of the Valerii" James has an Italian husband of a modern American girl revert to his ancient pagan racial religion of blood sacrifice to Juno in a story rich in atavism.

Having followed the scientific Zola (on whom he wrote three critical essays) in dealing with the London slums in *Princess Casamassima,* James praised H. G. Wells as a novelist for his "scientific" recording of the British "lower middle" class which the unscientific Dickens treated as fantastic and George Eliot as picturesque. But James in 1872 praised the critic Sainte-Beuve for a "frankly provisional empiricism more truly scientific than M. Taine's premature philosophy" which tended to try to explain the larger group rather than the individual, as did Sainte-Beuve.

James' concern for the tragic and with evil is partly a reflection of current concern with the evolutionary struggle for existence. Thus in *English Hours* (p. 71) he says, "When you think of the small profits, the small jealousies, the long waiting and the narrow margin for evil days implied by this redundancy of shops and shopmen, you hear afresh the steady rumble of that deep keynote of English manners, overscored so often and with such sweet beguilement by our finer harmonies, but never extinguished—the economic struggle for existence." And in books such as *The Wings of the Dove,* with the dove, Milly, the dying heiress victimized by the "snake" Kate and her aunt the rapacious Mrs. Lowder, one sees that in his distinctive novels despite their "sweet beguilement" he has mainly translated this biological struggle for existence to high society and the quest of the mercenary marriage.

James' artistic idea of beginning with the facts but transmuting them into art with universal implications may also have been reinforced by scientific analogies. His Isabel Archer and Aunt Penniman are censured for living too much in illusions and being too indifferent to the rapacious instincts of others. Referring to the "struggle for existence," his "Madonna of the Future" says that in this hard world . . . one must take what comes," and the story satirizes the artist's procrastinating Platonic idealism. Indeed, in most of the passages where he talks of art transmuting the facts into symbolic universals it is noteworthy that he draws not upon Platonism or Coleridge but upon scientific analogies of re-combination. Thus in his quest of "this chemical transmutation for the aesthetic, the representational," he concludes that there can be no real art without the "crucible of the imagination, of the observant and recording and interpreting mind . . ." (*Letters,* II, 181–2). Just as the true scientist is interested in the facts mainly as they inductively establish a universal and abstract law, so James is interested in facts only in proportion as they can be used imaginatively in new combinations to body forth some universal truth of human nature. His father being a devotee of Swedenborg who was half mystic and half scientist, James still retained "In After Years" some faith in immortality as associated with the over-arching law of the conservation of energy and of the values of the human consciousness in terms of cosmic compensation.

Finally, James frankly admitted that his brother's Pragmatism (which drew in part on analogies with Darwin's "spontaneous variations") was "immensely and universally right," and Henry said "All my life I have . . . unconsciously pragmatized" (*Letters,* II, 83). He refers no doubt to his judging ideas and conduct in terms of practical consequences and in accepting an experimental pluralism and avoiding dogmatism. Thus "the day of dogmatic criticism is over and with it the ancient infallibility and tyranny of the critic. No critic lays down the law, because no critic received the law ready made."

James and Mark Twain appear to be poles apart, but H. S. Canby in *Turn West, Turn East* (1951) has found many interesting parallels. And Everett Carter in *Howells and the Rise of Realism* (1954) pp. 152–62, argues plausibly that the author of *Huckleberry Finn* in his central theme was reflecting the utilitarian Pragmatism which C. S. Peirce in 1878 called "a new name for some old ways of thinking." (See Philip Wiener, *Evolution and the Founders of Pragmatism.*) Mark Twain was led to revolt against his native Calvinism partly by his reading of spokesmen of the rationalistic Enlightenment such as Thomas Paine, whose *Age of Reason* rested upon an anti-clerical version of Newtonianism. His acquaintance (in popular versions) with the ideas of geological time also militated against *Genesis* and the concept of a special creation. His friend Macfarlane had taught him the popular version of current evolution even before Darwin, to whom he refers sympathetically a dozen times. In literary criticism Mark Twain is most noteworthy for his devastating attacks on the faulty observation and unnatural dialogue of Malory, Cooper and Scott (see Chapter 46 in *Life on the Mississippi*). Mark Twain attributed his own sharpness of observation and realistic knowledge of a great range of men and women to his experience in learning what he insisted on calling "the science of piloting." One should emphasize his own great care in the adaptation of his characters and their speech-shadings or vernacular to their environment, for his training gave him an uncanny sense of *place,* and all that it involves. And his heritage from Thomas Paine and the rationalistic Enlightenment, reinforced by reading Lecky, enabled him to write scorching satire on mediaeval feudalism and priestcraft in anti-Scott books such as *The Prince and the Pauper* (1882), and *The Connecticut Yankee* (1889), which holds up in contrast all the advantages of an inventive and technological order based on the science of his own industrial Hartford. In the eighteen-eighties Twain has many panegyrics on the idea of progress based on science, countered by ridicule of mediaevalism and tradition. If he evolved from the youthful gayety of his Western years to pessimism, from creating naturally good characters such as Colonel Sellers and Huck and Jim to his later view of *What is Man?* but something lower than a rat, this trend toward disillusion was caused not only by family disasters, bankruptcy from which he recovered, and a congenital tendency toward over-sensitivity, but by his responsiveness to the more cynical readings of Darwinism current in his day. "Extracts from Adams' Diary" (1893) is a sort of parable of Darwinian ideas of rapacity. He concludes in his *Notebook* (p. 255) in 1895 that "Nature's attitude toward all life is profoundly vicious, treacherous, and malignant." But his artistically-poor *American Claimant* (1892) is the key full-length document which in essence shows his turn against his earlier faith that the American situation and democratic form of government guarantee our superiority to Europe. He here adopts the idea that all men everywhere are a part of a malign nature actuated by a struggle for existence, modifying his view in *The Connecticut Yankee.* The English hero, who is disillusioned with America, discusses Darwin with "such enthusiasm"; even General Hawkins expatiates on "the glacial period, and the correlation of forces, and the evolution of the Christian from the caterpillar"; heredity and atavism are discussed—there's a "contribution" in every man "from every ancestor he ever had," man who thus has in him the blood of those who have committed a thousand crimes. "Don't you know the wounded deer is always attacked and killed by its companions and friends." *Puddin'head Wilson* (1894), about the interchange of a white and a negro baby, reflects current debates about heredity, racism, and environment. Mark Twain's critical essay "What Paul Bourget Thinks of Us" suggests sharply Taine's science-inspired doctrine that literature is determined by time, place, and race.

The American popularizer of Herbert Spencer in *Cosmic Philosophy* (1874), John Fiske had been persuaded by his friend Huxley to apply his talent for studying evolutionism to history-writing in which he included several provocative critical essays. Fiske introduced his *Century of Science* (1899) with a long dedicatory Epistle to Thomas Sergeant Perry, the realistic literary critic, calling him his "patron saint." He dedicated his *Myths and Myth-Makers* (1872) to his "dear friend" and neighbor Howells. And he as early as 1868 he had written an appreciative introduction for an American edition of Taine's *Philosophy of Art,* to be discussed later. Fiske devotes "Sociology and Hero-Worship" (opposed to Carlyle) to the Spencerian idea that great men, including authors, are a "product of the age," an idea he partly illustrates in his "Milton." In an essay on Gladstone's work on Homer, however, the language-problem leads Fiske to deny the idea of a folk-origin of the great epic, in spite of George Eliot's "clever" remark about such a view being counter to evolutionary views. In his essay on "Longfellow's Dante" (1867) he develops the idea that "the critical spirit of every age previous to our own ["nurtured in this scientific nineteenth century"] has been characterized by its inability to appreciate sympathetically the spirit of the past and bygone times," every translation of Dante being based on "some conscious or unconscious instinct of literary criticism" (*Unseen World,* p. 336). His essay on "Forty Years of Bacon–Shakespeare Folly" (1897) includes much on the era and conditions, which he also used elsewhere to explain the slowness of America's literary production. In an essay on Lessing Fiske says of the disciples of this literary critic (he mentions Sainte-Beuve)

> "they inaugurated the historical method of criticism, and they robbed the spirit of intolerance of its only philosophical excuse for existing. Hitherto the orthodox had been intolerant towards the philosophers because they considered them heretics . . . But henceforth to the disciple of Lessing, men of all shades of opinion were but the representatives and exponents of different phases in the general evolution of human intelligence, not necessarily to be disliked or despised if they did not happen to represent the maturest phase" which will undoubtedly itself "in due course of time be essentially modified or finally supplanted." (*Unseen World,* pp. 209, 207)

Evolution thus greatly advanced critical tolerance and objectivity, as in the case of Longfellow's presentation of Dante. Fiske's *Excusions of an Evolutionist* also led him to the idea that "poetry and music had their humble origin in tales about the dead hero, and rhythmical chants and dances in propitiation of his ghost" (p. 185), and he devoted several essays to the early evolution of language, one of which shows how prehistoric Aryan civilization can be partly reconstructed by means of a study of their language (p. 113–129). He was much interested in *Myths and Myth-Makers,* citing scholars such as Grimm, Müller, Kuhn, Bréal, Dasent, and Edward Tylor, the anthrolopogist, with some attention (pp. 238–40) to the beginnings of literature, from which he delighted in tracing the evolution of altruism which he regarded as the crowning development.

Another historian, Brook Adams, the iconoclastic author of *The Emanicipation of Massachusetts* (1887), wrote the suggestive "Natural Selection in Literature" (1899) contrasting the characters of Scott and Dickens as reflecting the conditions of the struggle for existence before and after the Industrial Revolution. "Natural selection operates on men as on other animals, favouring those whose qualities afford them an advantage over their rivals . . . Hence the intellectual variation between successive generations of the same race offers the most interesting of all fields of historical study," literature being one of the chief "channels through which the human intelligence finds expression." Adams sees civilization completely changed by "the consolidation of industries which resulted from the . . . introduction of the steam engine and kindred inventions." "The whole social equilibrium was reversed within . . . two generations, and the changes which ensued are stamped with equal clearness upon the census-book, the statue-book, and upon the writings of the novelist and poet." (Note the determinism assumed.) Thus Scott's characters are motivated commonly by martial honor or courage, and Dickens' by fear, as in *Oliver Twist.* The bulk of the essay is devoted to apt illustrations of this fact from the novels of the two chroniclers. "To appreciate Dickens as a social phenomenon, to comprehend the variation in intellectual types which his evolution indicated, one must go backward fifty years and consider the instincts and ideals of the species which was passing away, a species which found its most perfect reflection in the mind of Sir Walter Scott," contrasting his characters with those of Dickens, "the creation of the 'Industrial Revolution.' " For "the form in which the struggle for existence presented itself to the audience of Dickens and of Scott was . . . radically different, and stimulated nearly opposite intellectual qualities." In Adams' preface to the 1919 edition of *The Law of Civilization and Decay,* first published in 1896, he says "the last generation was strongly Darwinian . . ."

Another portent of the times was Kuno Francke, who as head of the German Department at Harvard and founder of its Germanic Museum, was influential in popularizing German ideals in America. His enthusiastic essay, "The Evolutionary Trend in German Literary Criticism" (*International Monthly,* II (1900), pp. 612–646), focused on "the Messiah toward whom the previous history of literary criticism is pointing," traces the roots of the Darwinian method in criticism back to Herder and suggests the method he used in his very influential *Social Forces in German Literature* (1896). Like Taine, he is to study literature (according to his preface) as "an expression of national culture," to "point out the mutual relation of action and reaction between these [intellectual] movements and the social and political condition of the masses from which they sprang or which they affected" and the "forces which determined the growth of German literature as a whole. . . . All literary development is determined by the incessant conflict of two elemental human tendencies: the tendency toward personal freedom and the tendency toward collective organization." In the spirited survey which constitutes the book, his sympathies are with a growing collectivism although he pays lip-service to balance; and he finds "in science, both mental and physical, a steadily widening influence exercised by the idea of organic evolution, whether this idea be applied by a Grimm, Hegel, Ranke, Alexander von Humboldt, Comte, Marx, Darwin, or Spencer" (p. 400). I need not comment on the military outcome of this focus on the accelerating "struggle between individualistic and collectivistic tendencies."

Jack London's literary ideas deriving from evolutionism are suggested in essays such as "The Phenomena of Literary Evolution" (*Bookman,* XII, 148–51, 1900) and "The Terrible and Tragic in Fiction" (*The Critic,* XLII, 539–43, 1903). His *Call of the Wild* (1903) in its story of the civilized dog in whom "instincts long dead become alive again" under the Alaskan aurora borealis as he reverts to a savage wolf is a parable of man's own atavism in his realization that conscience is a vain and futile thing and a "handicap in the struggle for existence." His *War of the Classes* (1903) illustrates how one variety of socialism substituted for the struggle for existence of individuals the struggle of the economic classes. Since London gave literary Darwinism through his romantic boisterousness such an appeal that the Russians report that they circulated 567 Russian editions, or 10,367,000 copies between 1918 and 1943 (LHUS, 1386), his work has much significance beyond its mere literary quality in helping to explain the image which the Russians now have of the American attitude.

We can perhaps best illustrate naturalistic theories from Frank Norris, celebrator of "The Responsibilities of the Novelist" to tell the harsh unvarnished truth about "the crude, the raw, the vulgar," about man's greed and lust considered as his basic animal heritage beneath the thin veneer given him by civilization. In a fight "the brute that in McTeague lay so close to the surface leaped instantly to life." His voice was "no longer human; it was rather an echo from the jungle," and his conduct is explained by "the foul sewer of heredity". But Ernest Marchand has dealt colorfully with the way Norris makes his characters reel back into the Brute (cf. Vandover becoming a wolf), and I refer you to his able study (pp. 101ff), involving also Norris' debt to Zola and his view of nature as "a vast, unconquered brute of the Pliocene epoch, savage, sullen, and magnificently indifferent to man." If at times Norris is not untouched by humanitarianism (cf. Cressler in *The Pit*), he also deals with economic rivalries in terms of the war between the classes and views the railroad interests as an "Octopus" crushing the farmers. And yet, inconsistent as he is, he can say (echoing Spencer?) that "Greed, cruelty, selfishness in humanity are short-lived; the individual suffers, but the race goes on . . . The larger view always and through all shams, all wickednes, discovers the Truth that will, in the end, prevail, and all things, inevitably, resistlessly work together for good." Perhaps his science-bred faith in progress accounts in part for his anti-traditionalism, his nativism, environmentalism, and vitalism. *The Responsibilities of a Novelist* develops the idea that "The survival of the fittest is as good in the evolution of our literature as of our bodies, and the best 'academy' for the writers of the United States is, after all, . . . to be found in the judgment of the people, exercised throughout the lapse of a considerable time." As if advised by Taine, one of Norris' characters strove for "a great song which should embrace in itself a whole epoch, a complete era, the voice of an entire people."

In "Literature" (1909) Harry Thurston Peck of Columbia tried to demonstrate how "The patient, laborious, and brilliant achievements of these four men—Stendhal, the writer of psychological fiction, Michelet, the master of historical imagination, and Comte and ["the brilliant, epoch-making"] Spencer with their application of scientific laws to social life as well as to the world of mind,—may be taken as having laid a basis for the scientific study of literature." (p. 10). Peck goes on to illustrate Sainte-Beuve's scientific approach in explaining individual writers, and he especially emphasizes Taine's evolutionary method (p. 12), along with many other critics. (Taine is "the most splendid historian of literature" of any country.) Yet Peck in this same lecture finally defines the function of criticism as merely helping "in various ways to stimulate the love of literature" (p. 37), and his own critical practice in *The Personal Equation* (1897), *What is Good English and Other Essays* (1898), and *Studies in Several Literatures* (1909), illustrates his dual interest in scientific *and* impressionistic criticism. In Peck's essay on Zola in 1892, later reprinted as an Introduction to *La Terre,* he outlined Zola's theories about the relevance of science to literature and then labelled them "preposterous." But by praising Zola's work admittedly based on these scientific ideas as "so wonderful, so overwhelming in the evidence of genius . . . as to be assured of an unquestioned immortality," Peck seems to accept indirectly those scientific ideas. He also finds Zola's use of heredity "admirably described, in Mayo Hazeltine's essay on Zola included in his *Chats about Books* (1883). This book is sympathetic toward writing "illustrating elemental traits of human nature, or as interpreting the pressure of a unique environment" (p. 351). Hazeltine had published well-informed and sympathetic essays on both Spencer and Darwin.

Although most of Dreiser's work lies beyond our period, we may note in passing that this "inconsistent mechanist" (as Eliseo Vivas calls him) wrote enthusiastic essays on Norris' *McTeague* and on the later cynical Mark Twain, and that Dreiser tells us that after reading Spencer and Huxley in 1897 on the struggle for existence he became obsessed with the "sharp contrast" between current idealistic literature devoted to "the noble maxims of the uplifters" and his own observations (in night police courts, etc.). This contrast led him to try to supply the need, as he saw it, for a literature devoted to "the coarse and the vulgar and the cruel and the terrible," and the idea that life is "wholly meaningless." Dreiser's superman Cowperwood, alternating between lust and greed, is essentially Jack London's Sea-Wolf in a tuxedo; and Dreiser tells us that "it is folly not to wish that the significant individual will . . . always do what his instincts tell him to do." (Mr. Charles Walcott finds some change of direction in Dreiser's work *beyond* our period.)

It will be recalled that H. L. Mencken, who championed Dreiser and other naturalists, prided himself on being a heckler of all humanitarians, on being an "orthodox" defender of the capitalistic survival of the fittest: "I am in favor of free competition in all human enterprises, and to the utmost limit." Mr. Mencken claimed that "Nietzsche got the law of natural selection from Darwin," and that by following the Darwinian scientific method "we have come as near to the absolute as it is *possible for human* beings to come." Perhaps Mencken's admiration for unfettered individualism is explained in part by his panegyric on Huxley as comparable to Aristotle; Huxley "worked that great change in human thought which marked the Nineteenth Century," who "flung himself upon authority" in the name of "the plain truth that sets men free." "No man has ever written more nearly perfect English prose." In Mencken's book on *Shaw* (1905), hostile to socialism, he says, "It will take the perspective of centuries to reveal to us the metes and bounds of Darwin's influence." (p. xi)

The naturalistic period, however, had less shrill critics such as H. W. Mabie, early defender of Whitman, author of a dozen volumes of mellow criticism. In 1892 Mabie found "The Significance of Modern Criticism" in the fact that the scientific spirit "could not rest in any isolated study of literary works; it must study literature as a whole, determine its rank and place, and interpret its significance in the totality of human development . . . The end of criticism is to this extent identical with the end of science; it is to discover and lay bare the fact, and the law behind it. Modern criticism has given us a new conception of literature. Studying comprehensively the vast material . . ., discovering clearly the law of growth behind all art, and the interdependence and unity of all human development, it has given us an interpretation of literature which is nothing less than another chapter in the revelation of life." Like Kuno Francke, Mabie traces this scientific criticism to Herder, who "substituted a natural and vital for an artificial and mechanical conception," thus starting "a tremendous . . . revolution" in which literature is seen as "conditioned on the development, the surroundings, and the character of the men who create it."

Vida Scudder in 1887 wrote a critical essay emphasizing the salutary "Effect of the Scientific Temper in Modern Poetry" as in (1) inculcating a faith in progress, (2) in the "Force-Idea" as the basis of hopefulness associated with endless change, "becoming," and character-growth, (3) in Unity as associated with a new sense of the interdependence of man and nature and God, of cause and effect, and (4) in the dignity of a realism based on the divine of the common and a new reverence for both facts and the laws which govern them. However, she thought even evolution involved "dangers" and that it could be perverted to the interests of the fatalistic, the materialistic, and the "stupid." (She refers to Swinburne and Whitman.) But in general she thinks that science has inspired in the Victorian age a "poetry of search" and "The Triumph of the Spirit." These ideas are expanded in her book *The Life of the Spirit in the English Poets* (1895). In her *Social Ideals* she honored George Eliot, friend of Spencer, as inspired by evolution to create a hero "formed, evolved, created by the special conditions of his own age," the result of the "interplay of two great natural forces, heredity and environment." (pp. 189, 191.)

W. M. Payne, editor of *The Dial* (Chicago), wrote an enthusiastic essay in 1900 on "American Literary Criticism and the Doctrine of Evolution" (*International Monthly,* II, 26–46; 127–53). Acknowledging Darwin's unrivalled influence, Payne rejected subjective criticism and called for an objective criticism "controlled by the doctrine of evolution as a guiding principle." Such criticism, he said, should place a work "in relation to its antecedents and its consequents," the "conditions under which the artist grew, the habits of the race, the opinions of his age, his physical and psychological peculiarities." This point of view was applied in Payne's long introduction to his widely used anthology of *American Literary Criticism* (1904), where he refers to the "masterly" Taine, Symonds, and Brunetière, and regretted that in America we have so far so few "thoroughgoing applications to literature of the evolutionary principle." (p. 28) In *Various Views* (1902), in an essay on Brunetière, who studied the evolution of forms in the light of Darwinism, Payne rebuked *The Nation* for an unsympathetic article on him and expressed his hearty "concurrence" with Brunetière's stress on objectivity, stress on law above caprice, framing hypotheses to be verified as in science, and his criterion of "the collective judgment of the best informed in a succession of generations," a "prescription" "much needed in this country" (pp. 207–214). *Little Leaders* (1902) contain his brief essays on Taine and J. A. Symonds, who aims in an evolutionary way to "place himself within the mind of the writer" as an individual, and he concluded, the "synthesis of the two . . . will produce the criticism of the future" (p. 232).

The individuality (which Taine neglected) in literary criticism was ably brought within the evolutionary frame of reference by Archibald Henderson's *The Changing Drama* (1914, p. 49ff), which centers on the influence of science, by supplementing Darwin with DeVries and using the analogy of the latter's theory of variations and "saltations."

John P. Hoskins attacks some of the earlier assumptions about writings competing like rival organisms, and develops this thesis: "In order to survive, a literary form must be assimilated by society, must demonstrate its utility by expressing better society's view of what is real and true in life." "Biological Analogy in Literary Criticism," *Modern Philology,* VI 407–34 (April, 1909) and VII, 61–82 (July, 1909); and "The Place and Function of a Standard in a Genetic Theory of Literary Development," *Pub. Mod. Lang. Assoc.,* XXV, 379–402 (1910). The latter article stresses the role of form and taste in competition for public assimilation.

J. Mark Baldwin applies the method of Darwinian biology to psychology and aesthetics, and interprets literary genius as a variation effective in proportion as it is capable of adjusting itself to its current social environment. "The valuable is that which has survived on account of its utility," he says in *Darwin and the Humanities* (1909). To Baldwin the ultimate reality is "just all the contents of consciousness so far as organized or capable of organization in aesthetic or artistic form." Tradition, interpreted as the current "community's sense of the fitness of thought in their rule of judgment," enables it to distinguish between a genius and a crank or eccentric. His views appear to be somewhere midway between those of C. C. Everett (who wrote much good criticism inspired by an idealistic interpretation of Spencer) and those of John Dewey, instrumentalist and relativist. (Dewey's aesthetic functionalism was not fully expressed until 1925, although his general philosophy may have influenced criticism earlier.)

Somewhat in line with E. C. Stedman's first chapter of *Victorian Poets* (1874), the influential Brander Matthews thought that evolution, one of the four major legacies of the nineteenth century, had "helped" authors (cf. Ibsen's use of "heredity" as like Greek fate), and had "wholly transformed" criticism. It must now view an author as "an organ of the society in which he had been brought up, since the material upon which he works is the whole complex of conceptions, religious, imaginative and ethical, which forms his mental atmosphere." While he acknowledged that "science fails if we ask too much," Matthews followed Taine in seeking to "relate a work of art . . . to its environment" and to see it as "a contribution of its species made by a given people at a given period." Naturally, therefore, such evolutionary concepts led him to urge (in "The Whole Duty of Critics", 1892), the kind of criticism which is relative, descriptive, and inspired by sympathetic appreciation. (His genial colleague at Columbia, W. P. Trent, wrote several essays involving about the same attitude toward science and criticism. See, *e.g.*, "Literature and Science" in *Greatness in Literature*, 1905.)

W. C. Brownell is not an historical but a judicial critic who finds "the true criterion . . . in the rationalizing of taste." He recognizes the scientific spirit (with democracy) as one of "the two supreme influences on the nineteenth century," as dominating its best intellects, and he censures Carlyle for his indifference to it. For to Brownell the "scientific spirit signifies poise between hypothesis and verification, between statement and proof, between appearance and reality," and it has been "a tonic force" on literature. For a critic to oppose science as hostile to art is "to waste one's breath," for science has given nature "new dignity"; she cannot be studied too closely, nor too long," for science increases our "sense of the immensity, the immeasurableness of things. Yet he finds Tennyson's use of science "unsatisfying." Because of "the scientific turn of her genius," George Eliot makes her plots depend on "what her characters think. The characters are individualized by their mental complexions, their evolution is a mental one." Brownell thinks that perhaps because of her "friendship with Mr. Spencer" and her "prolonged excursion into the realm of science," her characters "were data of an inexorable mental concatenation . . . [of] cause and effect, the law of moral fatality informing and connecting them. Since the time of the Greek drama this law has never been brought out more eloquently, more cogently, more inexorably, . . . more baldly." But at the same time she makes human responsibility perfectly plain. He quotes George Eliot as saying that Tito "was experiencing that inexorable law of human souls that we prepare ourselves for sudden deeds by the reiterated choice of good or evil that determines character," and he praises her "tonic of stoicism" and contagious "courage," noting that this derives not from religion (which is "quite neglected" in her work) but from her "scientific" reading to life.

There were at least four movements counter to evolutionary criticism, in America before 1910. The first involved the revival of Waverleyism at the end of the century, as well as attempts to justify a literature of entertainment and of escapism in time and place. (Cf. Marion Crawford's "The Novel—What is It?" (1893). Second, the evolutionists' revelation of the ruthlessness of the struggle for existence and supermanism led some writers (following the later Howells) to use this revelation as proof that to be effective democracy must be implemented by a "planned economy" to safeguard equality of opportunity, and hence, reacting against evolution, there developed a considerable demand for a literature of propaganda and social reconstruction. (See Bibliography in C. C. Regier's *Era of the Muckrakers,* and the bibliographies in *American Literature* by Lisle A. Rose.) Third, finding "something bleak and terrifying" in the isolated position of man since science has postulated him as an infinitesimal bubble on an unimportant planet, "a brother to the lizard," with "no purpose," Joseph Huneker represents the impressionistic critics who sought psychological compensation for this sense of littleness and thralldom to blind forces by trying to become *Iconoclasts* (1905), *Egotists* (1909), and anarchists in terms of capricious personal taste. Fourth, there is a more profound judicial group of critics who took high ground among the ancient Greeks. George Santayana thought that even Dante shows "loss in breadth" and Shakespeare a "notable loss in taste," and sought not to explain or to describe but to evaluate a literature of change by the yardstick of the unchanging "moral indentity of all ages," by "that element in the past which was vital and which remains eternal." He thinks that science can only lead to a "Poetry of Barbarism" as in Browning and Whitman, that "our knowledge is a torch of smoky pine." Conversely Santayana's *Three Philosophical Poets: Lucretius, Dante, and Goethe* (1910) are taken to represent beyond their "diversity . . . a unity of a higher kind." There is not time here to debate the question whether the "wisdom of the ages" is constant, whether, with slavery and the degradation of women, "the Homeric times" can actually be called "the sweetest and sanest that the world has ever known" and so used as a suitable yardstick for our best ideals today. But in admitting that the life of the mind is fantasy and that he is really a naturalist, Santayana* would appear

> "To hope till hope creates from its own wreck
> The thing it contemplates."

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* In Santayana's *Poetry and Religion* (1900) in the essay "Platonic Love in Some Italian Poets" he pays homage to "that pursuit of something permanent in a world of change, of something absolute in a world of relativity, which was the essence of the Platonic philosophy" (p. 137). Conversely, in another essay, he says, "Natural science, like pantheism, presents us with a universal flux, in which something, we know not what, moves, we know not why, we know not whither" (p. 241). He fears the coming of the "greatest calamity" as a result of people without religious or poetic imagination when they may "be reduced to confessing that while they had mastered the mechanical forces of Nature, both by science and by the arts, they had become incapable of mastering themselves . . ." (p. 116) And in "The Elements of Poetry" in this volume he concludes, "And just because the world built up by common sense and natural science is an inadequate world (a skeleton which needs the filling of sensation before it can live), therefore the moment when we realize its inadequacy is the moment when the higher arts find their opportunity" (p. 269). But in *The Sense of Beauty* (1896), pp. 20–1, he had insisted that "if we approach a work of art or nature scientifically, for the sake of its historical connexions or proper classifications, we do not approach it aesthetically . . . The scientific habit in him (the critic) inhibits the artistic." And he concludes: "Beauty

One of the most extensive if severe oppositions to the critics' use of science is that of Irving Babbitt and P. E. More. Associating science with "endless change and relativity," with Vareity as opposed to Unity in the Platonic sense, they urge a "reaction from scientific positivism" especially in criticism (Babbitt's *Masters of Modern French Criticism,* 1912, p. ix) and a critical evaluation of a given book by the yardstick of the supposedly fixed unity of mankind's memory (tradition) running through the ages. They accept Emerson's dualistic distinction between the "Law for man" and "Law for thing." The increasing allegiance to the latter at the expense of the former is blamed on the "Baconians," although Bacon is used as a vague symbol and may not be "a direct or even an indirect influence" (Babbitt's *Literature and the American College,* hereafter referred to as LC, 1908, p. 36). Trying to evaluate literature on the basis of an author's self-knowledge which he thinks should include free-will and responsibility as opposed to determinism, Babbitt finds a symbolic significance in the fact that to him "the significance of Bacon's moral breakdown lies in the fact that it had the same origins as his idea of progress" because "in seeking to gain dominion over things he lost dominion over himself" (LC, 39). In education Babbitt and More strenuously urge a turn from science to the ancient classicists such as Socrates ("Know thyself"), although Babbitt thinks even classical study has been perverted by German scholars who illustrate the fact that it is easier to be scientific in terms of "historical relativity" than to be civilized (LC, pp. 122, 138). Since Babbitt disparaged scientific criticism as dealing only with the facts of the past, disparaged what he called a pedantry of originality and the superstition of the 'document' newly discovered, he doubtless helped to discourage literary research by scientific methods. In *The New Laokoon* (1910, p. 210) he found Taine in his deterministic approach to literary criticism in terms of a "gigantic scientific formula" guilty of the most heinous scientism, and in his Introduction to Taine's *L'histoire de la Littèrature anglaise,* 1898, expanded in his *Masters of Modern French Criticism,* he accused Taine of "scientific fatalism." Babbitt's 1902 Introduction to Ernest Renan's *Souvenirs* (also reprinted and expanded in *Masters of Modern French Criticism,* pp. 257–297) praises his style, charm and knowledge, but centers on the fact that "so ardent a believer in

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therefore seems to be the clearest manifestation of perfection, and the best evidence of its possibility. If perfection is, as it should be, the ultimate justification of being, we may understand the ground of the moral dignity of beauty. Beauty is a pledge of the possible conformity between the soul and nature, and consequently a ground of faith in the supremacy of the good" (p. 270).

evolution" was led to emphasize as a critic historical change and relativity at the expense of the changeless. In his *Vie de Jésus* Renan, using his scientific philology, tried to explain many a miracle as a popular "distortion of some natural incident," and Babbitt (who later said he ranged himself "unhesitatingly on the side of the supernaturalists") exclaims, "As though, with our infinitesimal experience, we really knew whether the ordinary 'law' may not at times be superseded and held in abeyance by a higher 'law'!" (*Masters,* p. 275). Although he rejoices that in later life Renan was somewhat less hopeful about science (p. 280), Babbitt concludes that, especially in his literary disciples, "Renanism has . . . come to be synonymous with some of the most subtle forms of intellectual corruption the world has yet known" (p. 291). In 1889 Brunetière announced he was to seek help as a literary critic from the doctrines of Darwin and Haeckel, and he carried their method into the neglected area of the study of literary forms, writing books on the evolution of the lyric, the drama, and criticism itself as one of the forms. He tried to show (in his own words) "in virtue of what circumstances of time and place they originate; how they grow after the manner of living beings, adapting or assimilating all that helps their development; how they perish; and how their disintegrated elements enter into the formation of a new *genre.*" While Babbitt finds this "literary Darwinism" is "defensible" when expressed in only "general terms," he thinks Brunetière was "led astray by his love of logical symmetry" in "the working-out of his system." In such criticism Babbitt charges that "the sense of the individual is lost" and Brunetière disregards the author's "deliberate

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[1] As editor of the critical *Revue des Deux Mondes* after 1895, author of more than thirty volumes of criticism, and lecturer in America in 1897, Brunetière's critical theories were widely debated here. Long lists of American comments will be found under Brunetière in *The Reader's Guide* from 1890 to 1910. In his devotion to formal craftsmanship, scientific analogies, good taste, and George Eliot, he has some resemblance to the general position of Sidney Lanier. Morris Roberts' *Henry James' Criticism* (1929) pp. 45, 68–70, assumes parallels to Brunetière. W. M. Payne in the Chicago *Dial,* XXII. 299–301 (May 16, 1897) defended his critical theories. The introduction in C. D. Warner's *Library of the World's Best Literature* of 1897 (V, 2603–06) outlines his ideas of scientific criticism stressing forms and calls him "the foremost literary critic of the present day." C. E. Norton (*Letters,* 1913, II. 253) praised in 1897 his "keen and clear intelligence, his intellectual principles and discipline, his strong moral convictions . . ." His ideas of criticism were given wide currency by summary in *Methods and Materials of Literary Criticism* (Boston, 1899) by C. M. Gayley and F. N. Scott, who find that while he may "overwork the biological parallel," his work on *genres* is "helpful" and "admirable' (pp. 251–2; 65—see index for a host of other discussions). Bliss Perry's *Study of Fiction* (1902) refers to Brunetière frequently on the evolution of forms, finds him "fascinating reading" but thinks "popular caprice" may upset such theses (p. 331). Since Brunetière was a conservative, his criticism of Zola was much used by those Americans who thought Zola extreme; for a very useful bibliography of American criticism of Zola, year by year, criticism which usually debated the literary implications of science, see A. J. Salvan, *Zola aux États-Unis* (Providence, 1943), pp. 189–209, along with Salvan's interpretation.

act of his own will." (*Masters,* pp. 325–26), possibly forgetting that he, Babbitt, had just quoted approvingly Brunetière's exaltation of "intellect and will" in his criticism of Zola. Although Babbitt disparaged historical criticism as concerned with the changing Many in contrast to the quest of the One, he himself did some of his most stimulating critical work in discussions of the history of ideas such as are involved in genius, imagination, nature, imitation vs. originality, melancholy, etc. He was also stimulating in showing the cross-fertilization of ideas—religious, political, humanitarian, and literary. He claims that he does not wish to abandon science but to mediate between science and the "humanities" (LC, p. 170), but he also says he wished to center his whole attack on "pure utilitarians" and "scientific radicals" regarded as culture's two "enemies" (LC, p. 113).

Paul Elmer More, who published seven volumes of his *Shelburne Essays* before 1910, essentially shares his friend Babbitt's conviction that "the intellect is evidently dependent on intuition" and that "both the One and the Many as well as man's relation to them must forever elude final formulation" (*Masters,* 51, 371). But More, if superior in stylistic charm, was even more inclined to base his dualism on faith or unresolved "irrational paradox" (VIII, 249, in "Definitions of Dualism"; also 259, 297). To More art is the attempt of the subjective imagination to establish "the experience of the individual in tradition" of a highly selective kind which must embody "the inner check" intuitively perceived by individuals. Writing formally rises to a standard of excellence in so far as the artist's imagination is subject to the control of "the unvaried inner check" (VIII, 265), taste so checked being a universal canon. Criticism has thus a fixed criterion, and "in the understanding of dualism it possesses further a key to the main divergencies of thought and action, and a constant norm of classification." More adds that the true critic is ever "checking the enthusiasm of the living by the authority of the dead" (VIII, 265; VII, 219). More's "Criticism" centers on measuring any individual work of art by the "larger memory" of artistic excellence running through the ages. He argues that the "limitless impulses" in the heart of the romanticists is the counterpart of the "limitless forces" of sciene's self-creating universe ("Huxley" in VIII, 234); and he charges both science and the literature of the romantic nineteenth century not only with neglecting the inner check but with neglecting the changeless in preference to change. His 1910 essay on "Victorian Literature" uses this criterion: "If any one thing may be called certain in criticism, it is that the quintessence of poetical emotion . . . arises from the simultaneous perception in man's destiny of the ever-fleeting and of that which is *contrayr to mutabitie*" (VII, 263–4). These romantic writers mainly forgot dualism, he charged, tried to see the infinite within the changing stream of nature instead of apart from it, and neglected the inner check set above both instinct and reason. More then proceeds to dismiss romantic literature in a wholesale fashion as "a drift toward disintegration and disease" (VIII, ix). He cites Pater as an example of those romanticists who lifted beauty above truth, deified the sensuous flux, and lost the vision of the infinite as an ideal above changing nature (VIII, 115). Science and romanticism grew up together, and Darwin is said to have expressed the law of change in the animate world, that law which leaves no place for either a power outside of nature or a higher and lower principle within nature but finds order in variation itself (VII, 248). Although More disclaims determinism, he thinks evolutionism has reinforced romantic critical impressionism, carrying into art the law of change and supporting the idea that there is no principle of taste superior to the shifting pleasure of the individual (VII, 253). George Meredith is regarded as typifying the new order in portraying no deep underlying emotions and in emphasizing growth and change (VII, 262). Despite some recognition of free-will, Meredith is accused of over-emphasizing heredity and environment (II, 165–6) and of not distinguishing between body and spirit (II, 167–9). Scientific naturalism and the "constant immanence of this philosophy of change" dominate the form and substance of Victorian poetry (VII, 259). Swinburne's poems are embodied "motion" (III, 115). To Morris the world was merely a swift-moving succession of forms (VII, 259). The chief characteristic of Whitman's verse is a "sense of indiscriminate motion" (IV, 203), and his democracy was "part and parcel of his proclamation of the philosophy of change and motion" (VII, 259). Even Browning does not often strike the universal note, and there is no hint in him of a "break between the lower and the higher nature of man, or between the human and the celestial character" (III, 163). In the literature of the nineteenth century More finds little peace, because, he thinks, peace is not of the flux but "in another and purer atmosphere" (III, 255). The futile "Quest of the Century" was to seek to "discover fixed laws and an unshaken abiding place for the mind in the very kingdom of unrest . . ." (III, 264). If a critic aspires to agree with More about the One, difficulties present themselves, since he was reared a Calvinist, abandoned Christianity, sought in romanticism itself a "welcome refuge," tried to write out "a rationalistic system which was to be more consistent than Spencer's," and then turned Anglican and verged upon Roman Catholicism (Robert Shafer's sympathetic *Paul Elmer More and American Criticism*, New York, 1935, pp. 62–64). Which One is a reader to accept? And like Babbitt, More as an enemy of humanitarianism which might be implemented by science seems to eliminate charity from Christ's teachings: he tells us that Christ "never for a moment contemplated the introduction of a religion which should rebuild society . . . He nowhere intimates that the law and custom of the world can be changed; he accepts these things as necessary to the social system . . . Not a word falls from his lips to indicate that slavery should be abolished, or the hierarchy of government disturbed . . ." (I, 243–5). Since even the Fundamentalist presumably would believe in The One and in checking evil, and millions of such people produce no art, one wonders whether such critical criteria do not neglect many other very relevant yardsticks, such as, for example, matters of literary technique and form and craftsmanship. Perhaps it is not surprising that Stuart Pratt Sherman, the chief disciple of Babbitt and More, felt constrained finally to conclude regretfully, "they are both dogmatic and mystical, to an extent that makes it impossible for one to understand or follow them, to say nothing of expounding them." Such were the main ideas of those who opposed the influence of science on literary criticism.

What services did evolutionary criticism render? I must be brief. It helped us understand the practice of many socially significant writers, helped to provide a reading public capable of understanding them sympathetically as spokesman of the age which produced them. Evolutionary criticism helped to counteract subjective impressionism and a condescending judicial spirit which was scornful of anything less lofty than Plato, Dante and Shakespeare. Evolutionary criticism was conducive to objective investigation, especially in our graduate schools; accepting the existing books as like a "given" in geometry, the problem was "to prove" not how good they were but to explain historically what elements and influences entered into their development and *why* they had been fittest to survive competition with other books. If evolutionary criticism evaded the ultimate problem of yardsticks and evaluation, it did some good in correlating literature with other forms of expression of American civilization and in relating it to our social history, and thus arousing interest in it as an index to what Vernon Parrington called "The Main Currents of American Thought." And by going back to primitive beginnings and showing how ethical standards differed in different ages (cf. cannibalism, etc.) evolution helped to show us in how small a period in relation to time in geological terms the so-called "eternal values" have been dominant, helped us to understand precisely what "the wisdom of the ages" involved in the way of slavery, degradation, inquisitions, etc., and opened the door at least for experiment, more humane standards, and the free play of reason in a criticism which recognized the otherness of past ages. In recent years the use of evolutionary doctrines in literary criticism has decreased. But during the 1860–1910 period such doctrines played a part in literary criticism and graduate study which we will do well to remember. It is good, surely, to begin by ascertaining precisely what an individual poem or story means by itself. But having done that, there may still be wisdom in following the general program of the evolutionary critics and in connecting all the individual pieces of an author's work in genetic relation to his life and the civilization which produced him, and of which he is thus in some measure the illuminating spokesman.

To understand this trend more fully one needs to survey the American reaction to Taine.

II

Hippolyte Taine in America*

Beginning in the 1860's there was a strong movement in America, due mainly to the influence of Hippolyte Taine, to adapt the findings of the physical sciences to a theory of literary criticism in order that literature might be scientifically studied.[1] Taine's famous three-fold principle that a writer was determined by race, moment, and milieu seemed to encompass all the vagaries that went into the writing of art, so that for the first

* Grateful acknowledgement is made of the fact that in this section on Taine I have been greatly aided in getting the manuscript into its present form by John Rathbun, a Research Assistant generously provided for this purpose by The Graduate School of the University of Wisconsin. He deserves much credit.

[1] Taine's doctrines are still stimulating interest. See especially Winthrop Rice, "The Meaning of Taine's Moment," *Romanic Review*, XXX (Oct. 1939), 273–79; Chinard's preface to Taine's *Introduction á l'Histoire de la littérature anglaise* (Princeton, 1944); and Harry Levin's "Literature as an Institution," *Accent*, VI (1946), 159–68, reprinted in *Criticism: the Foundations*, ed by Schorer, Miles and McKenzie (1948). It should be noted too that contemporary scholars like Howard Mumford Jones, Barrés, Calverton, and Edmund Wilson think highly of Taine. Jones's *The Theory of American Literature* stresses the need for balance between Taine and Sainte-Beuve and the criticism of Croce and Eliot. Both Calverton and Wilson look to literature for evidence of social and moral forces in the age and men that produced it. Indeed, Wilson (*Triple Thinkers*, 1948, p. 261) argues that Taine is best on the connection between literature and social phenomena, yet holds that Taine responded artistically to art.

time art could be understood in relation not only to itself but in relation to its surroundings. In the matter of race, he accepted the doctrine of "progressive heredity" or acquired characteristics (following Lamarck and Spencer and in part Darwin, as opposed to Weismann and DeVries).[2] To Taine "termperament and character" were determined not only by environment but also by transmission through heredity. In his *History of English Literature* (Edinburgh, 1873, I, 18) he wrote:

> "Different climate and situation bring it [the human animal] various needs, and consequently a different course of activity; and still again, a different set of aptitudes and instincts. Man, forced to accomodate himself to circumstances [adapt himself to the environment], contracts a temperament and a character, corresponding to them; and his character, like his temperament, is so much more stable, as the external impression is made upon him by more numerous repetitions, and is transmitted to his progeny by a more ancient descent."

His definition of race as "the inherited and hereditary dispositions which man brings with him into the world and which, as a rule, are united with the marked differences in the temperament and structure" recognized both individual and national differences, thus giving his theory more latitude than it would otherwise have had. As Sholom Jacob Kahn points out,[3] Taine had worked out his method before Darwin but not his theory. Darwin's work provided scientific confirmation for the examination of the environment to discover the persistence of traits. "The theory of the great English naturalist," Taine wrote, "is nowhere more precisely applicable than in psychology."[4] Adapting Darwin along the lines of the Englishman's followers, Taine used race not merely as a biographical factor but as showing the quality of superiority in particular directions in a particular environment. This took his criticism out of the area of scientific neutrality by asserting that that literature was best which showed the best chance of surviving. In other words, a value judgment was implicit in his criticism.[5]

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[2] See John S. White, "Taine on Race and Genius," *Social Research*, X (Feb. 1943), 76–99; and F. C. Roe, "A Note on Taine's Conception of the English Mind," *Studies in French Language, Literature and History* (Cambridge, England, 1949). One should note that Taine differs from Buckle in that Buckle thinks race has no significance or influence, saying "original distinctions of race are altogether hypothetical." (*Hist. Civil. England*, I, 127).

[3] *Science and Aesthetic Judgment; a Study in Taine's Critical Method* (New York, 1953), pp. 43–44.

[4] Quoted by Kahn, p. 122, from Taine's *On Intelligence*, I, 81.

[5] Cf. Martha Wolfenstein, "The Social Background of Taine's Philosophy of Art," *Journal of the History of Ideas*, V (June, 1944), 332–358. Miss Wolfenstein's thesis

But in the general sense, Taine's method was to describe and classify rather than to evaluate. Literature was valuable as a document which told how previous generations lived. Only in this sense was it valuable as experience. "It resembles," Taine said, "those admirable apparatuses with their extraordinary sensitivity which physicians use to detect the intimate and delicate changes which take place in our bodies."[6] And elsewhere he wrote: "Whether facts are physical or moral matters not, they have always causes. There are causes for ambition, for courage, for truth, as for digestion, muscular movement, animal heat. Vice and virtue are products like vitriol and sugar."[7] Thus mind and the productions of mind were natural, or material, and consequently were susceptible to the same kind of measurement as developed in the natural sciences. The individual was subordinate to the masses. The masses determined literature, and in turn were mirrored in literature.[8]

Before turning to the American reaction to the various tenets of Taine, it is perhaps advisable to consider representative American criticisms of his over-all philosophy. During the latter half of the nineteenth century, there were in America a number of philosophical cross-currents, each vying for recognition. The transcendentalists, the personalists, the German idealists, the empiricists and pragmatists, all delivered themselves of their attitude toward Taine. The liberal Unitarian, James T. Bixby, who sought to orient evolution toward Christian and spiritual ends, argued against Taine's study of the mind as a physical organism, and held that there was a "chasm" between mind and matter which it would be better for science not to try to bridge.[9] Bixby distinguished between two great philosophical methods, the subjective and the objective, symbolized in the work of Socrates and Bacon respectively. He put himself on the side of Socrates, and thus found himself in essential disagreement with Taine's main assumption. The place of science was "a subordi-

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is that Taine attempted to study art as an historian and eliminate value-judgments, but in failing to do so, he attempted to formulate a theory of value which he was never able to coordinate successfully with his historical approach. Her article is valuable in showing how Taine combined his philosophical readings with the findings of science, and how he strove to overcome an ennervating relativism by appeal to science.

[6] Quoted in Stallman, *Critiques,* p. 428.

[7] Quoted by Edgar Pelham, *Art of the Novel* (1933), p. 232. It was statements like this that prompted Zola to call Taine "my master," despite Taine's explicit disavowal of the new school.

[8] Much of this attitude was based on Taine's pessimistic view of the individual, whom he thought fundamentally bad. He consequently embraced the idea of an elite and tradition. For orientation see Hilda Laura Norman, "The Personality of Hippolyte Taines." *PMLA,* XXXVI (1921), 529–550.

[9] Review of Taine's *On Intelligence, North American Review,* CXVII (Oct. 1873), 401–438.

nate one." "He who takes it as his sole or chief guide will fall into many errors."[10] No physical instrument had been devised which could truly reveal the operations of the mind; and even if there had, man would still find himself studying motion, not sensation. Taine's "bold push" to identify mind and matter was thoroughly inadmissible.

Bixby's essential point of view was repeated in the two essays on Taine of William Kingsley. Kinglsey was a Christian transcendentalist who believed firmly that "a mind with intuitions and beliefs must be pre-supposed."[11] He consequently deprecated Taine's "molecular theory" of the mind and identified Taine with the "associational psychology" of Alexander Bain and J. S. Mill.[12] In reviewing the English translation of *History of English Literature*,[13] Kingsley accused Taine of critical poverty in the latter's inability to form "value judgments." Taine could give only "literary impressions," and thus admitted implicitly that he could not realize the very function for which Kinglsey thought literary criticism existed.[14] He attacked Taine on two points: that Taine was writing his history not for love of English literature but only as a major illustration of his literary theory; and that Taine's theory of art, however useful and convenient, was basically wrong. To this end he pointed out Taine's espousal of the "development theory." "He . . . declares his belief in 'a pround evolution which extends from the formation of the solar system to that of modern man.' He accepts the nebular hypothesis of La Place; and the teachings of Mr. Darwin with regard to the 'origin of species.' "[15] Kingsley admitted the logic of Taine's position, that if the arts were products of the mind, and if the mind was material, then the arts were amenable to "rules." But he held that this theory was "nowhere proved"; the mind of man was not a machine. "The historian cannot proceed in his inquiries respecting the phenomena of the mind as the meteorologist and the chemist proceed in their inquiries respecting physical phenomena. It follows, accordingly, that this book, with all its originality, its sprightliness, and splendor of diction, for the purposes for which M. Taine has written it, must be declared to be a failure."[16]

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[10] *Ibid.*, p. 436.

[11] Review of Taine's *On Intelligence, New Englander Magazine*, XXXI (1871), 366–367.

[12] *Ibid.*

[13] *New Englander Magazine*, XXXI (1871), 542–578.

[14] *Ibid.*

[15] *Ibid.*

[16] *Ibid.*, p. 559. Kingsley disliked Taine's dispassionate method of approaching English literature and used Taine's method to "indict" him: ". . . if his feelings are such with regard to what we may call the externals of English life and society, it

More judicious and extended in his criticism of *History of English Literature,* the Rev. John Bascom, in 1873 of Williams College and soon to become president of the University of Wisconsin, argued against Taine's theory on the basis of morals and intuitions.[17] Bascom acknowledged that no other work on the subject had "excited so much attention, or received so favorable criticism"; and he praised its style as "clear, animated, highly figurative." He liked its unity and "decided effect."[18] But while Taine recognized "the relation of morals to English character," Bascom censured as "fundamental" the fact that as a determinist Taine "understands neither the origin nor the nature of the ethical sentiment, nor its relation to art."[19] The secondary physical causes of race, environment, and epoch were "efficacious" but "limited." Taine "disproportionately urged" the influence of merely "external conditions"; Bascom, as befitted an intuitionist and a clergyman, insisted that "the central impulse, the most pervasive sentiment in man is the ethical one," and he emphasized "personal power" and liberty of choice.[20]

Bascom felt that Taine erred in his indifference to ethical good and evil in art as well as in neglecting man's original intuitive apprehension. Taine limited literary criticism to mere description, as opposed to evaluation by ethical criteria. His psychological doctrine which Bascom quoted (to the effect that man is merely "a mental machine, provided with certain springs . . . affected by various circumstances") was attacked as "absurd". "It is not till we have mangled and dwarfed our mental science, that we can do this thing."[21] He argued that moral values *were* relevant to art, for it was precisely because actions transpired under moral law that they engrossed us. But as a professed liberal Bascom insisted that morality in art should "not curdle on the surface . . . not separate as a thin cream to be skimmed off," but should be unobtrusively organic with the whole work: it should be "as a fluid circulating in living cells, and imparting flavor and aroma to the entire plant."[22] Thus Bascom's criticism rested on substantial logic and on ancient principles which run through Emerson to Plato. While he was somewhat verbose and grandiloquent, he supported his case by well chosen quotations

is obvious that this French critic—with tastes formed under the influence of 'race,' 'circumstances,' and 'epoch'—must find it still more impossible to feel any sympathy with, or love for, English literature."

[17] *Bibliotheca Sacra,* XXX (1873), 628–647.
[18] *Ibid.,* pp. 628–9.
[19] *Ibid.,* pp. 629–30.
[20] *Ibid.,* pp. 631, 633.
[21] *Ibid.,* p. 641.
[22] *Ibid.,* p. 646.

from Taine and on the whole had an air of temperate and earnest persuasiveness and of rich humanity.

A somewhat different tack from Bascom's was taken in 1876 by the idealist philosopher, George Sylvester Morris, whose German-inspired philosophy was influential on John Dewey and Alfred Lloyd. Morris believed that the ideal was "the living truth of real things," and he argued that to be whole art must embody the ideal.[23] Like Bixby, he felt that there were two ways of looking at things: from without and from within. The former gave impressions, the latter caught the causes and true constitution of things. The former was the method of science, the latter of philosophy. "The positive [scientific] method, dealing only with phenomena, furnishes no knowledge of the real nature of things."[24] This was the method of Taine, not false, but incomplete. But Taine tried to identify "force" with "environment" and "development" with "cause" or "law," and consequently reduced his definitions to absurdity, thereby leaving the ground of "scientific accurate observation" for the field of philosophy and making a shambles of it all.[25]

William James's criticism of Taine followed along the main lines of his habitual criticism of the British empircists. In his review of *On Intelligence*,[26] James concluded that with all its shortcomings the book was "valuable." His main objection was that Taine avoided answering the philosophical problems he posed. More particularly, he found that Taine implicitly contradicted himself between the first and last sections of the book. In the first section, devoted to the psychological analysis of intelligence, Taine had embraced the nominalism of the British empiricists, that phenomena were concrete and universal concepts empty of content. Then in the section on the metaphysical analysis of intelligence Taine shifted. He forgot his former point of view and seemed "to admit to the fullest possible extent the reality of general qualities as such."[27] However, James softened his criticism on this point considerably, when he pointed out that Taine seemed to countenance a class of abstractions if they had some practical value; on the other hand, barren abstractions were always repudiated.[28]

> Nevertheless we find M. Taine constantly forgetting this point of view, and talking as if he found fault with the

[23] "The Philosophy of Art," *Journal of Speculative Philosophy*, X (Jan. 1876), 1–16.
[24] *Ibid.*, p. 15.
[25] *Ibid.*, p. 16.
[26] *Nation*, XV (1872), 139–141.
[27] *Ibid.*
[28] *Ibid.*

> illicit class of abstractions less for their barrenness than for the isolation and independent entity which their votaries ascribe to them—for their appearing "behind" the phenomenon, not in it. But the abstract character whose reality he admits must also be taken as independent of the concrete phenomena in which they appear; being "the same" in all, they are independent in each, and require M. Taine to provide a separate plane of being for them to subsist in anterior to their taking on the divers adventitious peculiarities which determine their appearance in their diverse concrete shapes. This he often ostensibly denies, but virtually admits in many places, and this admitted, his contempt for the phantoms of metaphysical illusion . . . is unjustifiable except on the mere ground of their uselessness.[29]

James was irritated too by Taine's *assuming* the truth of his theory without feeling the necessity of proving it philosophically or of treating exhaustively the "opposite" theories of Mill and Kant.[30] Again, he criticized Taine for showing superficial adhesion to the English empirical school but exhibiting basic dissent. Yet he acknowledged that the book had enjoyed an "unusually prompt success," and attributed it less to the pure psychology of the book than to Taine's fame in other fields. He found Taine "eminently" an artist, but he found him trumping up proof for his ethnic assertions, guilty of neglecting "scientific rigor," lacking in historical development. With all this, he still maintained that Taine's work on the intelligence was of strict stuff, "and had its author written nothing else, it would give him an honorable name and place in the brotherhood of thinkers, properly so called."[31] It was "the clearest and best account of the psychology of cognition with which we are acquainted," James wrote, and he felt that the book would play a leading role in the revival of empiricism in Germany. If not completely favorable, James's notice of Taine was important for the latter's popularity in America, bringing him much-needed recognition and a sort of prestige in being considered by a man of acknowledged intellect.

When T. S. Perry came to consider volume one of *L'Ancien Régime* his view was almost wholly different from James's. Where James had seen Taine as assuming a theory without offering concrete proof, Perry understood Taine's "method of work" to consist of the accumulation of "details and statistics" without dealing in "general principles and vague statements."[32]

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[29] *Ibid.*
[30] *Ibid.*
[31] *Ibid.*
[32] Review of *Les Origines de la France Contemporaine, Atlantic Monthly,* XXXVII (May, 1976), 627–629.

Like James, he found Taine's style "brilliant and picturesque," but felt that it was likely to pall. There was no relief to the color; the effect was to give equal importance to all events, so that there was no clue to the relative worth of the various causes.[33] Perry was in general agreement with scholars today that Taine did not apply his famed theory to his examination of the French Revolution; but while he apparently perceived Taine's conservatism, he found that Taine's study read "like the brief of an advocate of the Revolution."[34] He noted that the book did not "present a full picture of French life in the last century, and Taine's example would be a dangerous one for all historians to follow." Yet he held that "once in a while such an impassioned book performs a duty."[35] In regard to Taine, one should remember that Perry was in general sympathy with the principles of historical scholarship, and sought particularly in his studies of Russian literature to follow the historical method.

Such men as have been cited above were concerned primarily with the inner consistency of Taine's theory and of his ability to realize it in his critical work. Most reviewers of Taine, even while they had a philosophical orientation, were inclined to judge him on the merits of his accomplishment. F. J. Weir, for instance,[36] adopted something of the view of Bixby in holding that together Taine and Ruskin exhibited a complete critical theory, the one in studying the positive, objective phases of art in terms of physical causes, the other in linking the moral and subjective motives of art.[37] On the whole, he was greatly impressed with Taine's work, even while he questioned the "moral basis of his unique mind." He praised Taine's "vivid and forcible language" and his ability to penetrate to "the motives and causes of his subject."[38] The anonymous writer on "M. Taine and the Science of History" in the *New Princeton Review* was even more extravagant.[39] "Taine's historical method," he wrote, "may be summed up in one word; it is an *explanation* of history with reference to ends in view, not as they should have occurred according to an ideal aim, but as they did occur according to the nature of the actors and conditions which determined them."[40] Accordingly, Taine's method was both "psychological" and "scientific." It applied

[33] *Ibid.*
[34] *Ibid.*
[35] *Ibid.*
[36] Review of *Philosophy of Art in the Netherlands*, *New Englander Magazine*, XXX (Jan. 1871), 44–55.
[37] *Ibid.*
[38] *Ibid.*
[39] "M. Taine and the Science of History," *New Princeton Review*, III (May, 1887), 410–411. Two translations of Taine on Napoleon Bonaparte were also reprinted in this magazine, III (Mar. 1887), 145–163, and III (May, 1887), 289–305.
[40] *Ibid.*, p. 410.

psychological principles not only to individuals but to classes of people and to political parties. It was bound to "revolutionize" the writing of history. "The human mind is becoming more scientific, or, in other words, more precise, exacting, and comprehensive in its knowledge of motives and means, and demands a just intermingling of the inductive and deductive processes in the science of history. Thanks to M. Taine . . . the way is paved for it in his masterly works."[41]

Incidental references to Taine abound in the literature of the period. Emerson read his essay on Marcus Antoninus and pronounced his sentences in no need of mending; later, after having toured Egypt, he had dinner with Taine and Tourguéneff in Paris, and the next day Taine sent him an inscribed copy of *History of English Literature.*[42] Lyman Abbott cited Taine's work on the French Revolution as proof of the "yoke" democracy imposes on people.[43] Frederic Harrison praised Taine's study of the French Revolution as one of "enormous erudition," which pieced together every possible cause to bring out "every feature of the great crash."[44] William Payne, a very influential critic, wrote an essay on Taine and praised him for his "combination of picturesqueness, vivacity, and philosophical analysis" in his writing.[45] Frank Harris sat in on Taine's lectures at the University of Paris, and W. C. Brownell in his trip abroad met Taine and was favorably impressed.[46] Whitman, in his notes dealing with *Leaves of Grass,* refers to Taine and "his fine ensemble of the letter and spirit of English literature."[47] Burroughs in his work on Whitman has initial mottoes from Taine, Ruskin, and Sainte-Beuve.[48] And James Huneker observed, "In France criticism is an art, and I have long worshipped at the shrines of Sainte-Beuve, Taine, and A. France."[49]

Amongst recognized writers Taine was of course well known. Mark Twain referred to Taine at least four times, and Aspiz tells us that "Hippolyte Taine was a favorite of Mark Twain." Twain admitted that Taine's great history of the French Revolution *(Les Origines de la France Contemporaine),* along with Saint-Simon and Carlyle, had made him a "Sansculotte."[50] In

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[41] *Ibid.,* p. 411.
[42] *Letters to Emma Lazarus* (1939), p. 6; Ralph Rusk, *Life of Emerson* (New York, 1949), p. 473.
[43] *Christianity and Social Problems* (Boston, 1896), p. 111.
[44] *Choice of Books and Other Literary Pieces* (London, 1888), p. 401.
[45] *Dial,* XXIX (Oct. 16, 1900), 265.
[46] Van Wyck Brooks, *The Confident Years* (1952), p. 259, 398.
[47] *Complete Writings,* IX, p. 26.
[48] *Whitman, a Study.*
[49] *Iconoclasts* (1905), p. 214.
[50] *Letters,* II, p. 490.

1877 Twain wrote Mollie Fairbanks that he had been reading "some chapters in Taine's *Ancient Regime,*"[51] a book which includes much about how the nobles in going to the cities withdrew wealth from country districts and thus helped to cause famine among the peasants. In *The Gilded Age* he has Laura try to buy Taine's *Notes on England* which she characterizes as "a volume that is making a deal of talk just now [1873], and is very widely known . . ."[52] And Twain warmly praised Taine's *History of English Literature,* based on scientific determinism, and he called the author "the most poetry-saturated of poets and the Father of English literature! I call him the Father . . . because he made so many people read serious books which, without his advice and encouragement, they never would have tackled."[53]

At the hands of William Dean Howells Taine fared somewhat worse. Howells had only praise for Taine's style, the "picturesqueness" of his writing and the Emersonian overtones to his manner. But he felt that Taine's "distorted philosophy" destroyed the informative value of his books.[54] He wrote that Taine's *Ancient Regime* "is not true, on the whole, though probably it is not to be questioned in any particular. . . . Taine's facts are like testimony in a court of justice which, given without statement as to motive or intent, serve the advocate as material for working up the 'case as he likes . . .' "[55] In reviewing *Notes on England*[56] he felt pretty much the same way. He admitted to being deeply moved by Taine's style, and he thought that Taine, through his "facts," "guesses," and "lucky thrusts in the dark," had done much to bring out the complexities in English literary history. But his final conclusion was that "We read him with the greatest delight; and we leave him with penitential distrust."[57] Taine later had Howells's *Lapham* translated and published in France, and praised it highly.

On the other hand, Henry James, who entered more deeply into the study of French writing, recognized and valued Taine's philosophy as well as his artistic ability. James' book on Hawthorne, endeavoring to explain the fragile flowering of his great native gifts by the artistic poverty of the American environment, as well as the controversy with Howells in which James emphasized the fact that an American-born novelist could do

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[51] *Mark Twain to Mrs. Fairbanks,* ed. by Dixon Wecter (San Marino, Calif. 1949), p. 208.

[52] "Author's National Edition," II, p. 56–57.

[53] Henry W. Fisher, *Abroad with Mark Twain and Eugene Field* (New York, 1922), p. 138.

[54] Review of *Notes on England, Atlantic Monthly,* XXX (Aug. 1872), 240.

[55] "A French Poet of the Old Regime," *Atlantic Monthly,* XLI (Mar. 1878), 340.

[56] *Atlantic Monthly,* XXX (Aug. 1872), 240–242.

[57] *Ibid.,* p. 242.

better work abroad in an environment rich in tradition and "color," suggest the general influence of "the great and admirable Taine." If he "lacks saturation," James said of Taine in 1912, he "sees with a magnificent objectivity, reacts with an energy to match, expresses with a splendid amplitude, and has just the critical value, I think, of being so off, so *far* (given such an intellectual reach,) and judging and feeling in so different an air."[58]

In his four essays on Taine, James developed fully his likes and dislikes. He thought of him as essentially a philosopher and historian rather than as a critic. In his first essay on Taine in 1868,[59] James declared that he deserved a hearing insofar as a member of another "race" had taken the trouble to inquire into the English mind. He emphasized the picturesque quality of Taine's writing, and noted that his vehement and impetuous style pointed up the "possible futility" of his theory of "national and local influences."[60] However much the question might occur whether "the description covers all the facts," James was sure that "the theory makes incomparable observers, and that in choosing a traveling companion he cannot do better than take him from the school of M. Taine."[61] Taine studied man "as a plant or as a machine," and this led to a supreme accumulation of facts, and it was facts, rather than any petty "moralizing and sentimentalizing" that the reader should demand. ". . . we cannot help laying down our conviction that M. Taine's two volumes form a truly great production; great not in a moral sense, and very possibly not in a philosophical, but appreciably great as a contribution to literature and history."[62] Thus James admired Taine for the vigor and power of his intellect, his masterful pictorial style, the range and intelligence of his observations. His materialism and determinism interested him chiefly because of their results for his style. Although Taine's deterministic theory possibly did not explain all the facts, indisputably it seemed to inspire unsurpassed observation and description.

Several years later James was still thinking of Taine as an accurate observer, master of a great literary style, whose philosophical theorizing was vital if it did not explain all the facts. He held that Taine's originality did not lie in his famous three principles, but in the way in which he applied them.[63] Taine,

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[58] *Letters* (New York, 1920), II, 226, 245.
[59] Review of Taine's *Italy, The Nation,* VI (May 7, 1868), 373–4.
[60] *Ibid.,* p. 373.
[61] *Ibid.,* p. 374.
[62] *Ibid.,* p. 375.
[63] Review of *History of English Literature, Atlantic Monthly,* XXIX (Apr. 1872), 470.

James pointed out, differed from Sainte-Beuve in believing that truth is not difficult to ascertain, and his "premature philosophy" was therefore less "truly scientific."[64] In actual practice, says James, Taine played "fast and loose with his theory, and is mainly successful in so far as he is inconsequent to it . . . his best strokes are prompted by the independent personal impression."[65] His historical position was often insecure; he passed too quickly from general conditions to the particular case; and the result was "imperfect science." His strength was in his style—his eloquent statement and comprehensive expression.

Always, however, there was in Taine the "constant demand" for facts. He talked, observed, listened, and analyzed constantly; "as to the value of some of M. Taine's inferences there will be various opinions, but his manner is the right manner, and his temper is excellent."[66] Taine was "alternately" a philosopher and a historian, not a critic, for a critic noted "shades of difference," while Taine was "perpetually sacrificing shades to broad lines."[67]

It would be, however, a mistake to say that the popular reaction to Taine was completely favorable. *The New York Times* called him "specious and fanciful," and David Wasson ridiculed him as one of the "one-eyed seers of modern France" who preached the "gospel of no-belief."[68] Alfred Fouillée[69] condemned Taine's philosophy as "Spinozism superposed upon positivism," and spoke unfavorably of Taine's attitude toward man as "diseased and demented by nature." Similarly, Warner's *Liberary of the World's Best Literature* reproached him for his pantheism, naturalism, and fatalism, but also praised him in general.[70] H. W. Boynton[71] and Percy Bicknell[72] noted Taine's fondness for anonymity, his "inexorable" determinism, and his position as "spokesman of positivism." More restrained and perspicuous, T. S. Perry seconded James's contention that Taine was an "admirable observer," who, if not a "profound" philosopher, was necessarily accurate and "descriptive." Perry was especially dis-

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[64] *Ibid.*, p. 470.

[65] *Ibid.*

[66] Review of *Notes sur Angleterre, Nation*, XIV (Jan. 25, 1872), 58.

[67] *Notes and Reviews*, p. 104–6. In *French Poets and Novelists* (London, 1878), p. 190, James quotes Taine, "the apostle of the 'milieu' and the 'moment,' on George Sand, and proceeds in his essay to show how Taine was right in thinking her "an exceptionally good case for the study of the pedigree of a genius—for ascertaining the part of prior generations in forming one of those minds which shed back upon them the light of glory." James remarks that in her case "the operation of heredity" went on "very publicly." For further references to Taine, see *ibid.*, pp. 231, 235, 255.

[68] Wasson, *Essays* (Boston, 1888), p. 368.

[69] "The Philosophy of Taine and Renan," *International Quarterly*, VI, (Dec.–Mar. 1902), 260–280.

[70] Vol. XXIV (1897), 14399–14409.

[71] *Atlantic Monthly*, XCI (1903), 830–831.

[72] "The Taine Memoirs," *Dial*, XXXVII (1904), 104–107.

concerted with Taine's "tendency" to arrange "all the world in labelled compartments."[73] Such a tendency, he felt, substituted an unneeded simplicity for the natural complexity of the event.

Balancing these views were the more discriminating and favorable reviews of Taine's over-all theory by W. F. Rae and T. R. Loundsbury. In 1872 Rae presented a sympathetic interpretation of his deterministic doctrines of literature and sympathized with him for the persecution by contemporary reactionaries. Taine's study of Hegel and attendance at the School of Medicine and the Museum of Natural History, as well as hostility to the idealist Cousin, are considered by Rae among the influences which formed Taine's mind.[74] Rae shows that Taine's preface to a prize essay on Livy as early as 1854 embodied his cardinal ideas in relation to a discussion of Spinoza: in relation to nature man is only a small part of a whole; "man's inner being is subject to laws in the same way as the external world; moreover . . . there is a dominant principle, a ruling faculty, which regulates thought and imparts an irresistible and inevitable impulse to the human machine." The *History of English Literature* is presented as "the event of the day, and the illustration of the year"; his "rank among moderns writers [is] acknowledged to be very lofty." The reader is led to sympathize with Taine when a motion by the Bishop of Orleans, seconded by M. Cousin, led to his being refused a prize in the gift of the French Academy: it was charged that his *History* was "impious and immoral; that its author had alleged 'virtue and vice to be products like sugar and vitriol;' that he had denied the freedom of the will; that he had advocated pure fatalism, had deprecated the ecclesiastics of the middle ages, had eulogized the Puritans . . . had shown himself a skeptic in philosophy and a heretic in religion." Rae admired Taine's unity of purpose in expounding and illustrating his systematic method in criticism. Versatile as Taine was, everything he had written was both readable and pregnant with reflection, with a pleasant flavor of their own and "a stamp of originality."

The same year (1872) the *Nation*, edited by the very austere and influential E. L. Godkin, printed a somewhat more discriminating review by Yale's T. R. Lounsbury of Taine's *History*, and concluded that "he has written the best history of English literature that has yet been produced," its "crowning merit" being

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[73] Review of *Notes on England, Atlantic Monthly,* XXIX (Mar. 1872), 370–371.

[74] *Appleton's Journal of Literature, Science and Art,* VII (May 18, 1872), 542–544. Edward Youmans, disciple of Herbert Spencer, was the first editor of this periodical.

"catholic sympathy" without either aversion or preference.[75] Lounsbury disparages the kind of literary history which lists facts without dealing with principles, and prefers Taine's methods. "If it deal at all with names and dates, it is with the single purpose of setting in a clearer light the history of ideas. It is a scientific exposition of the changes that have taken place in the intellectual development of a people, the causes which have led to them, the results that have sprung from them. Its chief aim is to trace those principles of thought and action which, ruling the lives of men, have found expression in their literature. In this view the subject leaves the province of annals, and passes into that of philosophy. Literature is bound up with the national life, and in order to know the characteristic of the one it is essential to study closely the other. Race, climate, political institutions, manners, and customs, all become of importance, for these all affect the man, and necessarily leave their impress upon the work he produces." However, Lounsbury thought that Taine showed "a tendency to push the doctrine of race too far," to strain it "to its extremest limits." "It is in race and climate, indeed, that he finds the leading characteristics of English literature." Yet in dealing with leading authors, Lounsbury found Taine "always fresh, suggestive, striking, and what is even better, fully appreciative" and "not dull."

While there was some controversy over the idea of evolution, dependent upon one's philosophical position, most Americans recognized the fact that much of Taine's theory was indebted to contemporary findings in science. His idea of race, for instance, was founded on the tentative findings of ethnologists, and if Taine tended to identify nationality and race, it was a failing shared by many scientists. Taine's critical theory owed much of its popularity to its having been confirmed by Darwin's and Spencer's work, especially the biological confirmation of organic development of individual and social organisms. Sherwood Cummings argued that Taine's idea of race corresponded to Darwinian heredity; "surroundings" and "epoch" had reference to Darwinian environment. By surroundings Taine meant "education, career, condition, abode," while by epoch he meant the cultural heritage, the level of civilization into which the writer was born.[76] Taine, Cummings said, called race a "kind of lake, a deep reservoir [of inherited characteristics] wherein other springs

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[75] T. R. Lounsbury, *The Nation,* XIV (Jan. 4, 1872), 10–11.

[76] Taine's *History of English Literature,* translation by H. Van Laun (Edinburgh, 1873), I, 21, 21–25.

have, for a multitude of centuries, discharged their several streams."[77]

This idea was controverted by spokesmen of American conservatism such as Orestes Brownson, who argued that scientists should be opposed by all "sensible" men because their hypotheses were stated rather than proved; he indicted "the Huxleys, the Büchners, the Taines, the Darwins, the Spencers, the Tyndalls" for "their lack of science" rather than their specifically scientific findings.[78] But where Brownson found evidence of intellectual cheating, others found the very summit of scientific truth. William Payne in *American Literary Criticism* (1904, p. 28) connected science and the "masterly" Taine and praised his method of applying the findings of evolution to criticism. Taine's method was salutary, Payne thought, even if it minimized personality. Similarly, John Fiske contributed to his scientific prestige to popularizing Taine. In 1867 he wrote a sympathetic introduction to Taine's *Philosophy of Art,* pointing out specific examples of Taine's indebtedness to science. And in 1872 he edited a condensed edition of Taine's *History of English Literature,* in the preface writing that the book was "an admirable one for the student inasmuch as its brilliant speculations and lively criticisms tend to stimulate intellectual curiosity."[79] The preface of R. H. Stoddard to H. Van Laun's edition of *History of English Literature* nominated Taine's book as "the most acute, suggestive, critical, and thoughtful History of English Literature."[80] In *Gateways of Literature,* Brander Matthews pointed out the link between the racial soul and literature, and, while he admitted that there were other approaches to literature, argued that in the "potent influence of heredity and environment" critics had "grasped a true talisman of artistic appreciation" by perceiving "the race behind the individual."[81] The very influential W. C. Brownell, while he held tenaciously to the "ideal" in art, recognized the validity of Taine's approach, his knowledge of the plastic arts, and the need for critical disinterestedness.[82] And S. P. Sherman ranked Taine with Arnold, Sainte-Beuve, Ruskin, and Pater because of his distinctive contribution to literary criticism.[83]

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[77] *Ibid.,* I, p. 19.

[78] *Brownson's Views* (New York, 1893), p. 86.

[79] The *Atlantic Monthly* in reviewing Fiske's edition (XXXI, April, 1873, 500–501) praised his judicious editing and said that Taine's "ingenious criticism" would stimulate not only his followers but would provide a "method" for opponents who wished to "differ intelligently."

[80] *Op. cit.,* p. xiii.

[81] *North American Review,* CXC (1909), 677.

[82] *American Prose* (New York, 1923), 248, 295, 315.

[83] Introduction to Brownell *American Prose Masters* (New York, 1923), p. xxii.

Reading Taine for the first time was for many Americans tantamount to coming across a new gospel, especially for those to whom the findings of Darwin seemed to sum up centuries of scientific findings. Hamlin Garland's reminiscent *Son of the Middle Border* has told of his indebtedness to Taine in determining to write a book reflecting the frontier of his boyhood experiences. Longfellow when he closed *History of English Literature* pronounced it a "prodigiously clever book" and wondered how a Frenchman could so realize the peculiar English intellect.[84] Dreiser in *The "Genius"* put his hero, Eugene, to work reading Taine and Gibbon rather than puttering in the botany and physics laboratories. O. W. Holmes quoted Taine with relish that Cowper's "horrible malady of the nerves" had led to suicide, Puritanism, and madness.[85] But more important, it led E. C. Stedman to adopt Taine's method in writing *Poets of America* (1885) and *Victorian Poets* (1875), in so far as they relate to all but the greatest poets who transcend their time, place and race (see quote p. 000). And William James dropped Spencer's *Principles of Psychology* in his Philosophy 4 course at Harvard in order to have his students study Taine's *On Intelligence*. "A real science of man is now being built up out of the theory of evolution and the facts of archaeology, the nervous system and the senses," he wrote President Eliot.[87]

In noting Taine's merging of the individual into the group, Americans took divergent attitudes. Some saw his theory as sketching in the individual through analysis of the environment. Others held that an analysis of the individual gave unerringly a picture of the milieu, while others still held to the idea that the individual was somehow above his time and must be dealt with in terms of himself. These latter wrote meaningfully of genius and to some extent tended to elevate Sainte-Beuve over Taine as a critic.[88]

Members of the genteel tradition, like James Russell Lowell, Hamilton Wright Mabie, and Edmund Clarence Stedman, while they praised Taine's learning and professional devotion, and admitted that his whole view was not without grandeur, nevertheless argued that the view that genius was unique was equally true. Mabie pointed out that Sainte-Beuve centered on personality, and thus caught the complexity of the literary product. Mabie admitted that Taine interpreted literature "effectively,"

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[84] *Life,* (Boston, 1892), III, p. 195.
[85] *Holmes, American Writers Series,* p. 415.
[87] Quoted by Schneider, *History of American Philosophy,* p. 514.
[88] Even Sainte-Beuve criticized Taine for not considering the individual sufficiently. Cf. *Nouveaux Lundis,* VIII, 67–9.

but, he held, it was "somewhat coarsely" done in emphasizing environment and the "experience of the race."[89] Lowell repeatedly said that Taine assumed his "ethnological postulates" and then seemed "rather to shape the character of the literature to the race than to illustrate that of race by literature."[90] *The Critic*[91] published several articles both favorable and unfavorable to Taine; but it consistently held to the idea that too often his criticism was "misguided" through too small "allowance for the man of genius" and too eloquent praise for "the spirit of the age."[92] The *Atlantic Monthly* in 1871 had rich praise for *Art in the Netherlands* but accused Taine of generalizing "too far"; and it cautioned readers of Taine to read him with "friendly distrust."[93] As a "Christian socialist" (whose point of view he celebrated in *Murvale Eastman*) Tourgee insisted that realists and people like Taine, while right in part, erred grievously in leaving out of their calculation the "soul." Tourgee accused men like Taine of thinking of man as a result of "natural laws" of purely physical bearing, whereas the true picture was of natural laws both physical and mental.[94] Although Harvard's Lewis Gates, who trained writers such as Frank Norris, was mainly on the side of Sainte-Beuve and the aesthetic appreciators as against the scientific determinism of Taine, his essay on Taine paid tribute to his ability "to redeem literary criticism from being a paltry juggling with fine phrases and to give it a seriousness of purpose, dignity, and a recognized standing." He concluded that "in an age of *décadence,* when the descendants of the Romanticists and idealists are for the most part engaged in dilettante experiments on their senses and emotions, such materialism as Taine's is as healthy as sea air."[95] And W. C. Brownell wrote that Sainte-Beuve's critical method was far more "considerable" than "the fascinating historical and evolutionary framework within which Taine's brilliant synthesis so hypnotizes our critical faculty."[96]

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[89] *Study Fire* (New York, 1894), 2nd series, p. 156, 158. For Stedman's ideas consult *Victorian Poets* (New York, 1875), pp. 1, 410, 434, 194–6, 143.

[90] *Works,* V, p. 124. (Essay on "Rebellion.")

[91] "Certain Exclusion from the French Academy," XV (Jan. 24, 1891), 49; "Taine's *Modern Regime,*" XV (Apr. 1891), 205–206; "The Late M. Taine," XIX (Mar. 25, 1893), 183–4.

[92] "The Late M. Taine," p. 184.

[93] Volume XXVII (Mar. 1871), 396. G. M. Miller, *Historical Point of View in English Literary Criticism* (Heidelberg, 1913), p. 15, also praised Sainte-Beuve for including the individual.

[94] *Murvale Eastman* (New York, 1889), p. 113.

[95] *Studies and Appreciations* (New York, 1900), p. 204. It is quite possible that Taine encouraged Cable's interest in racism. And Louis Sullivan, the master of Frank Lloyd Wright, was influenced by Taine to call for an architecture in character with the American people. Cf. *Autobiography of an Idea* (New York, 1924), p. 233.

[96] *Criticism* (New York, 1914), p. 79.

As early as 1871 William Dean Howells read and reviewed for the *Atlantic Monthly* Taine's *Art in the Netherlands*, translated by J. Durand. His reaction was on the whole unfavorable. Taine's "love of generalization" went "too far."[97] He felt a "cheapness" in Taine's work. However, he did make a grudging concession which typified Howells's reverential and emotional attitude toward art at this time; Taine, he thought, could be read with less "friendly distrust" than "any other theorizer upon art."[98] Less than a year later his rejection was less conditional. Although he admitted to not having read all the *History of English Literature* he alluded to Taine's "jack-a-lantern" and "the sparkling errors of that ingenious gentleman." "M. Taine's method," Howells wrote, "does not take into sufficient account the element of individuality in the artist."[99] Still Howells expressed a preference for Taine, who worked from Greek life to Greek art, over Ruskin, who inferred Greek character from Greek art. Later in 1872 he commented on Taine's *Notes on England*, complimenting Taine on his "observation" of the physical aspects of English life, but also noting Taine's "distorted philosophy" and "inability to judge profoundly."[100]

On the other hand Walt Whitman was all on Taine's side in the controversy over the individual's relation to the group. In *Good-Bye My Fancy* (1891) Whitman concluded that no great piece of writing could be adequately considered without "weighing first the age, politics (or want of politics) and aim, visible forms, unseen soul, and current times" which produced it.[101] And in an article in *The Critic* for December 3, 1888, Whitman wrote: "If Taine, the French critics, had done no other good, it would be enough that he has brought to the fore the first, last, and all-illuminating point, with respect any grand production of literature, that the only way to finally understand it is to minutely study the personality of the one who shaped it—his origin, times, surroundings, and his actual fortunes, life, and ways. All this supplies not only the glass through which to look, but it is the atmosphere, the very light itself. Who can profoundly get at Byron or Burns without such help? Would I apply the rule to Shakespeare? Yes, unhesitatingly; the plays of the great poet are not only the concentration of a 1 that lambently played in

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97 *Atlantic Monthly,* XXVII (Mar. 1871), 396.
98 *Ibid.*
99 *Atlantic Monthly,* XXIX (Feb. 1872), 241.
100 *Atlantic Monthly,* XXX (Aug. 1872), 240–2. His earlier polite hostility to Tainism differs significantly from his later work (1891) in praising T. S. Perry's historical criticism (*Harper's,* LXXIV, Dec. 1886, 161) and his own argument that writers supply what "the nation likes, involuntarily following the law of environment." (*Harper's,* LXXXIII, Nov. 1891, 964).
101 *Complete Works of Walt Whitman* (New York, 1902), III, 284.

the best fancies of those times—not only the gathering sunset of the stirring days of feudalism, but the particular life that the poet led, the kind of man he was, and what his individual experience absorbed."[102]

The dispute over the relation of the individual and the community naturally led to arguments over free will *versus* determinism. Americans readily saw Taine's thorough-going determinism and especially noted that it was based on the "mechanical" philosophy of empiricism and positivism. Many critics of Taine, as we have seen above, adopted the time honored American position that even in the midst of necessity the individual had a modicum of self-determination. This was in reality even Whitman's position. But Taine's writings brought the discussion again into the open. Mark Twain admitted that his reading of Taine and Sainte-Simon and Carlyle had been "influenced and changed, little by little, by life and environment," so that his sympathies for various factions of the French Revolution had changed.[103] The *Sewanee Review* in tracing the evolution of French criticism emphasized the note of determinism and anti-individualism in Taine, and pronounced his theorizing "relentless and inadequate."[104] The Danish George Brandes, who was widely read in America, and who is generally regarded today as Taine's disciple, wrote that Taine "was and remained my greatly loved master and deliverer, even though I mistrusted his essential teachings." But Brandes himself thought his writings a protest against Taine because he approached the individual through the group rather than dismissing the individual in Taine's fashion.[105] The much respected Francis Gummere, in an essay on "Whitman and Taine" (1911), admitted to the general "rightness" of Taine's theory, but held tenaciously to the dual action of individual and group; "had he [Taine] seen the great dualism here, as one must see it in the universe, as play and interplay of centrifugal and centripetal forces, he would have achieved the whole instead of the half success."[106] Taine refused to accept the genius as an "independent force in poetry," and this had been his "fundamental error in poetics."[107]

One result of Taine's thought in America was to confirm the American tendency toward folk and regional literature. These

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[102] Quoted by Richard M. Bucke, M.D. *Walt Whitman* (Philadelphia, 1883), p. 12.
[103] *Letters* (Aug. 22, 1887), II, 490.
[104] "Evolution of French Criticism," III (Aug. 1895), 396, 397.
[105] V. W. Brooks in *Scenes & Portraits* (New York, 1954), p. 223, says that in meeting Brandes in London in 1913 the latter admitted to being heavily influenced by Taine. And Einar Haugen has told me that Brandes once admitted to being a "thorough-going determinist and positivist."
[106] Francis Gummere, *Democracy and Poetry* (Boston, 1911), p. 138.
[107] *Ibid.*, p. 139.

had had a long tradition in America, born of the frontier spirit as well as simple curiosity about various facets of the American character. Taine's theory put the philosophical imprimatur on such writing, so that Mark Twain, in answering Paul Bourget, argued that there could be no one American literature but a number of regional literatures, since a writer could know only that immediately about him. It was open admittance that the individual was determined not only by heredity but also by environment. In the final analysis Howells thought Taine's method of showing the influence of environment on art "admirably brilliant and effective," even though he felt it somewhat onesided.[109]

Besides these general incidents,[110] Taine's emphasis on environment prompted American artists like Hamlin Garland, Edward Eggleston, and Edward Bellamy to write their historical novels as direct expressions of American regional life. On his first trip to Boston Garland procured an expurgated volume of Taine and found there all his nascent speculations confirmed. "The American artist must grow out of American conditions and reflect them without deprecatory shrug or spoken apology," he later wrote.[111] In 1886 Garland wrote Whitman that he had begun writing an outline study of the "evolution of American Thought" and referred to Spencer, Taine and Whitman as main inspirations of his work.[112] In *A Son of the Middle Border* Garland sang the praises of the future and told how he derived "the principles which govern a nation's self-expression" from Taine, "pondering all the great Frenchman had to say of race, environment, and momentum,"[113] for, as Taine said, "every living thing is held in the iron grasp of necessity." Shortly after, Garland formulated his "great principle" underlying "a really vital and original literature": "American literature, in order to be great, must be national, and in order to be national, must deal with conditions peculiar to our own land and climate."

In view of Garland's statement that Edward Eggleston was "the father of us all," it is instructive to note Eggleston's intellectual odyssey from Methodist preacher to Darwinism and Tainism and the presidency of the American Historical Association. To Eggleston, Darwin and Taine were peculiarly fitted

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[109] *Atlantic Monthly,* XXIX (Feb., 1872), 241, quoted by Everett Carter, *Howells* (Phila., 1954), p. 97.

[110] See Everett Carter, *Howells and the Age of Realism,* pp. 98–101, for several other references to Taine in America.

[111] Quoted by Howard Mumford Jones, *Theory of American Literature* (Ithaca, 1948), p. 124.

[112] Traubel, *With Walt Whitman in Camden,* II, 160–162.

[113] *A Son of the Middle Border* (New York, 1914), p. 307, 387. See also *Roadside Meetings of a Literary Nomad* (New York, 1930), and "Sanity in Fiction," *North American Review,* CLXXVI (1903), 336–48.

to one another. He confessed to his brother that he had absolutely sloughed off all belief in a supernatural entertained in his days as a Methodist parson; and he referred to Darwin: "No matter what the subject under consideration, we later nineteenth century people are pretty sure to be brought face to face with the intellect that has dominated our age, modified our modes of thinking, and become the main source of all our metaphysical discomforts."[114] In his preface to *The Hoosier Schoolmaster* he confessed that he had read Taine's *Art of the Netherlands,* which was, as this pioneer in midwest regionalism said, "little else than an elucidation of the thesis that the artist of originality will work courageously with the materials he finds in his own environment. In Taine's view, all life has matter for the artist, if only he has eyes to see."[115]

Whereas Eggleston and Garland had seen Taine's work as meaningful primarily for literary work, Edward Bellamy was conscious of the social orientation of Taine's writing, and was among those Americans who praised Taine as a historian who brought clarity, vigor, and picturesqueness to the portraiture of the manners and morals of an age. What he saw in Taine was parallel to the social themes of his historical novel *The Duke of Stockbridge, A Romance of Shay's Rebellion* (1879) and his utopian novel *Looking Backward* (1888). Bellamy admired Taine's "broad philosophical grasp" and the way in which Taine was able to reduce the broad outlines of his theory to a complete analysis of complex historical incidents. In reviewing Taine's *Ancien Régime,* Bellamy emphasized throughout the "high excellence" with which Taine had brought to life a "particular historical epoch."[116] In keeping with his theory of historical development, Bellamy saw the period of which Taine wrote as "a unique form of human culture . . . very possibly never to be repeated." "The ancien regime was indeed a heap of popular degradation, misgovernment, and oppression. Add to this the rare fascination which the picture of a civilization so utterly different from our modern democratic era must possess, by very force of contrast, for modern readers, and it is evident that few themes present finer opportunities than this which M. Taine has essayed." Bellamy especially admired Taine's "methodical arrangement," his "sustained vigor of treatment," his manner

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[114] Quoted by Gohdes in Quinn's *Literature of the American People* (New York, 1951), p. 775.

[115] Preface to the Library Edition of *The Hoosier Schoolmaster* (New York, 1892), p. 8. For a fully documented study of Eggleston and his relation to regionalism, see William Peirce Randle, *Edward Eggleston, Author of the Hoosier School-Master* (New York, 1946), with extensive notes and bibliography.

[116] "Literary Notices," *Springfield Union,* April 29, 1876.

of creating "a vivid and complete tableau of the manners and morals of the epoch."[117]

If many Americans were not disposed to accept *en toto* Taine's theory of historical criticism, balking especially at his mechanistic determinism, they nevertheless found much of value and they adapted many of his principles to the writing of literary history.[118] The *Nation's* acute review of Taine's *History of English Literature*[119] is a fair example of what Americans liked and disliked about Taine's philosophy. There were two ways, it said, of looking at literature. One detailed the facts without relating them to principles; the other sought to relate literature to "the history of ideas." This latter

> is a scientific exposition of the changes that have taken place in the intellectual development of a people, the causes which have led to them, the results that have sprung from them. Its chief aim is to trace those principles of thought and action which, ruling the lives of men, have found expression in their literature. In this view, the subject leaves the province of annals, and passes into that of philosophy. Literature is bound up with the national life, and, in order to know the characteristic of the one it is essential to study closely the other. Race, climate, political institutions, manners, and customs, all become of importance; for these all effect the man, and necessarily leave their impress upon the work he produced.

The review went on to praise Taine for writing the best history so far produced and admitted that once given his premises one could hardly fail to agree with his conclusions. Taine's crowning merit lay in "catholic sympathy"—"the critical historian of literature has no business whatever with preferences or aversions." But at the same time the *Nation* felt there was always a "tendency" in Taine to push the doctrine of race too far, and Taine was, on the whole, too ready to see the English as a nation of

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[117] Among lesser statements see the *Nation* on Taine's "Naturalistic History," LXXXIV (May 9, 1907), 427–8; Willard E. Martin, Jr., "Two Uncollected Essays by Frank Norris," *American Literature,* VIII (1936), 190–98, where Norris admits flatly that he is a literary determinist of the school of Taine; and Eggleston's review of Taine's *Philosophy of Art in the Netherlands, Independent,* (Dec. 8, 1870), , in which Eggleston stresses the use of the common and familiar in the artist's own environment.

[118] There was of course dissension on the part of recognized leaders in American thought. As would be expected, Josiah Royce, spokesman of idealism, professed to find little merit in Taine's theory. In *Fugitive Essays* (1920, p. 372) he scored the "ambitious failures like the magnificently planned and hopelessly unsuccessful book of Taine," and despaired of anyone achieving what Taine set out to do. Similarly, J. E. Spingarn, the disciple of Croce, wrote (*Creative Criticism,* New York, 1917, p. 39) "We have done with the race, the time, the environment of a poet's work as an element in criticism."

[119] *Nation,* XIV (Jan. 4, 1872), 10–11.

"barbarians." But this reservation aside, Taine's theory was deemed worthy of emulation, and the magazine thought that if more and better literary histories were to be written, Taine's criteria would be necessary.

This seems to have been the case for many scholars. Amy Lowell in her preface to the book on Keats (1925) berated the "host of commentators" on Keats for failing to link him to his time and environment, and expressly stated that she had hoped to give immediacy to her story by re-creating the era of Keats, by bringing back "into existence the place, the time, and the society in which Keats moved." M. C. Tyler's literary history of revolutionary times also eschewed the treatment of belles lettres in a social vacuum. Tyler, who occupied a chair of history at Cornell and later at the University of Michigan and was one of the founders of the American Historical Association, owed his critical theory to both Sainte-Beuve and Taine, focusing on the individual in the manner of the former and bringing out the deep pattern of historical development in the manner of Taine. He thus avoided any explicit reference to all-encompassing determinism or necessity.[120] Montrose J. Moses's *Literature of the South* (1910) constantly stressed the relation of literature and environment. While he professed objective comparative criticism, he actually was environmental in his literary treatment, and began most of his chapters with sections on "Social Forces." Frederick Lewis Pattee's *History of American Literature, with a View of the Fundamental Principles Underlying its Development* (1896) and *Foundations of English Literature* (1899) both were presumably based on Taine's theory of race, moment, and milieu, even though he failed to develop these ideas sufficiently in the body of his material. The former was a school text which announced an ambitious program strongly influenced by Taine. The preface to the latter announced that literature was the "merely natural results of previous conditions" and connected literature and political history. The first chapter of the book was entitled "Physical Geography," where Pattee made some effort, largely unsuccessful, to trace out England's geographical position as a complement to its literature. Similarly, C. F. Richardson's history of American literature sought to develop the evolution of American thought, although, as Howard Mumford Jones points out, he was also affected by Matthew Arnold in his critical canon.[121] W. R. Thayer accepted Taine's main principles but

[120] See the references to Tyler in Howard Mumford Jones, *Theory of American Literature*, pp. 103, 107, 105, 142, which plays up these features of Tyler's history.
[121] *Ibid.*, p. 101.

added another, the consideration of "message" in a writer.[122] And E. C. Stedman's early writings also bear traces of Taine and Arnold. Stedman clung tenaciously to the ideal of the individuality of genius, and for this reason could not accept wholly Taine's ideas on necessity. But this did not prevent him from adapting Taine's general propositions to his writing of literary history. "The most important art of any period is that which most nearly illustrates its manners, thoughts, and emotions in imaginative language or form," he wrote.[123] The critic "must recognize and broadly observe the local, temporal, and generic conditions under which poetry is composed, or fail to render adequate judgment upon the genius of the composer."[124]

Barrett Wendell, whose *Literary History of America* (1900) is in many ways our most impressive example of Taine's method before Parrington, admitted that Taine was the "master" who had helped him toward the understanding of literature.[125] His *Temper of the Seventeenth Century* (New York, 1904) is built around grandiloquent concepts of how the Elizabethan age, like "any school of art . . . rises, flourishes, and decays." He chose to think of "human expression much as one thinks of physical phenomena throughout the living world. Wildly various and strong and individual as these may seem, they prove, in truth, nothing more various or individual than cumulative examples of how those great forces work which we begin to recognize as natural law. When we take whatever fragment we like from the beautiful, confused intricacy of nature, and study its parts in their relations, we find slowly growing in our minds an image of such deathless, inexorable order as the mere contemplation of fact at any given moment could never reveal. Astronomy has thus emerged into colossal truth; geology too; physics is following; biology and all the human facts which we may include within it stand ready for deathless words which shall flash newer and ever newer cosmic order into the midst of receding chaos. And even

[122] *Atlantic Monthly,* LXXX (Aug. 1897), 231.

[123] *Victorian Poets* (New York, 1917), p. 27.

[124] *Ibid.,* p. 4.

[125] *France Today* (New York, 1908), p. 293. He went on: "I had been disposed to think that of all the writers of nineteenth century France none had been more admirable than Taine, both in conscience and in influence. The fact that I had not always been persuaded to accept his conclusions—particularly in the matter of English literature—in no wise impaired my respect for him. He seemed always precise, always intelligent, and above all incessantly suggestive. The vigor of his thought and the animation of his style compelled you to more alert thinking than you could have done without him. Even when this cogitation led to results widely different from his own, accordingly, you gratefully acknowledged him as the master whose stimulating power had most truly helped you. There was never monument projected, I fancied, for which more general approval might have been assured." In the *Temper of the Seventeenth Century* (p. 30) Wendell echoed Taine when he wrote that Shakespeare was "the most complete recorded example of the natural law which governs the growth, the flourish, and the decline of the school of art."

we students of literature cannot, and should not, resist that truest imaginative impulse of our own time; we should be anachronisms if we were to content ourselves only to enjoy the splendidly confused creations of the art we love—if we did not eagerly strive to perceive and to define the relations in which they really stand to one another. In fine, as in all Nature else, phenomena appear inextricably intermingled."[126]

The complex and inquiring mind of Henry Adams also found in Taine food for intellectual consumption.[127] Max Baym has uncovered Adams's references to Taine and the impetus the latter gave to Adams's own speculations. While Adams was constantly seeking the precise generalization, his temperament was constantly warning him of the potential error in generalization, and for that reason he could not give intellectual asset to Taine's simplified and all-encompassing theory. But like Taine, Adams constantly sought for unity, and this unity was thought of in terms of mind, or, to be more exact, in terms of the essential monistic structure of the universe. Thus his interest centered on psychology and especially on the idea of race consciousness, in the manner of Herbert Spencer, Taine, and the later Jung. Like Taine, he clearly saw the need for the study of relationships rather than of things alone; and his speculations in the *Education* and *Chartres* were efforts to achieve unity in a universe in which unity was metaphysically impossible. Hence the need of a philosophy of history in terms of psychology. It was psychology that promised the only scientific means to establish a pattern of order in a universe in which order was not pre-existent. Adams owes his greatest debt to Taine in *Mont-Sainte-Michel and Chartres*. Here Adams felt he apprehended the subliminal psychological unity of a race, expressed in its architecture, its religion, its whole mode of living, even its philosophical systems. It was the unexpressed, even unconscious, aspirations and habitual modes of conduct for which Adams was searching. He cannot, then, be criticized, as some have done, for misrepresenting or misunderstanding Church doctrines and medieval social organization; he was simply not concerned with these features especially, or in isolation, and frequently in the book said so. But he was concerned with pinpointing for a moment in time the race, milieu and environment, and to this extent he owed much of his approach to Taine.

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[126] Pp. 48–49; see also pp. 30, 128, 57, 85.

[127] This paragraph is based chiefly on the findings of Max I. Baym, "The Approach to Taine," in *The French Education of Henry Adams* (New York, 1951). See also the admirable essay on Adams by Robert Spiller in *Literary History of the United States,* volume II.

In 1898 Irving Babbitt edited Taine's *Introduction a l'Historie de la littérature anglaise* and included a short essay later expanded in Babbitt's *Masters of French Criticism,* 1912, which sought to evaluate Taine's contribution in both the literary and philosophical spheres.[128] He noted that Taine's theory of the development of literature could be applied with almost perfect ease to the work of Taine himself, for the work showed "most accurately" the influence of scientific positivism. (p. iii) This "modern scientific spirit" was "hostile" to the old idealism, and sought to examine experientially and empirically even that data which religion denied it. Babbitt felt that such a spirit had its origin in Descartes rather than Bacon, for by reducing the phenomenal to a quantitative measure he had made it possible for his followers to more and more rule out the mind as qualitative or in any way determining. (p. iv) With Taine, the soul had become "a natural product." (p. v)

It was this idea, says Babbitt, that gives to Taine's work its "extraordinary unity," for all that work was done to prove the thesis. Taine was a naturalist and determinist, though Babbitt admits that nowhere did Taine "expressly" formulate the doctrine; and the doctrine itself Babbitt terms "scientific fatalism." (p. vi)

The "weakening" of the older order had been followed by such disorder and "intellectual and moral chaos" that Babbitt wondered if perhaps the price had not been too great for the "scientific knowledge of life." (p. vii) Taine and his followers (Babbitt includes Zola, despite Taine's disclaimer) "failed to respect sufficiently the mystery of personality," a mistake not made by Sainte-Beuve, who confessed: "We shall doubtless never be able to treat man in exactly the same way as plants or animals." (p. vii) Babbitt himself felt that in every man there was a "fraction," a "residuum of pure and abstract liberty," which runs counter to Taine's theory. And he drew some consolation from the idea that the "era of scientific positivism" was, or seemed to be, drawing to a close.

Yet Babbitt saw some good in Taine's approach. It had been a necessary reaction to the medieval divorce of man from his environment. (p. ix) Taine had "devoted extraordinary powers of analysis" to showing that man was in an iron ring of necessity. And man's institutions were likewise; that was why Taine had so opposed the French Revolution: the Revolution had sought to

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[128] Babbitt also wrote an introduction to Ernest Renan's *Souvenirs d'enfance et de Jeunesse* (Boston, 1902), v–xxxvii, in which he used nearly the same method. Without in the least overlooking his "shortcomings," Babbitt found six ways that Renan could "become our teacher," and he used the historical method to arrive at Renan's position in the society of his time and the impulses prompting him to write as he did.

uproot by force what required "a slow process of evolution." (p. ix) Thus "Naturalism has worked a far-reaching transformation in all departments of thought by its twofold use of historical sympathy and scientific analysis. In literary criticism, for instance, it will hardly be possible after Sainte-Beuve and Taine to return to the point of Boileau—to treat a book as though it had 'fallen like a meteorite from the sky,' and judge it by comparison with an aesthetic code, itself constructed on *a priori* grounds like a medieval creed." (p. x) Because of "the labors of the naturalists," views of relativist composition ruled out forever the notion of a stationary universe. "They are not likely to revert to the crude dualism, the mechanical opposition of the soul and body, the ascetic distrust of nature that marked the medieval period." (p. x)[129]

Through all this we can see that Taine was widely discussed by Americans, although they were not uncritical of his ideas. They found much to value in his literary theory, but when that theory was reduced to its bare metaphysical elements they often found themselves in disagreement. Only a few were willing to submerge the individual in the group to the extent that Taine was willing. And many of them shyed away from his evident positivism and his effort to interpret personality in terms of material response. Yet they admired the general scope of Taine's work, admired his style, and felt that the theory could be adapted to scholarly use in America. The year 1872 was somewhat a critical year for Taine; in this year the most reviews seem to have been written on him, and to a certain extent his future reputation rested on what they said. In the main these reviews were favorable, although subject to some of the reservations mentioned above. Freed from its doctrinairre elements, Americans were sympathetic to his views on national character, national psychology, race, the influence of environment and the moment. They adapted these views to both their critical theory and their literary theory; the latter found expression in novels of regionalism. The full measure of Taine's acceptance can be seen later in the century, however, once men like Pattee, Richardson, Tyler, Wendell, and Parrington began their writing of literary history. For these owed much to Taine's influence and show the extent to which his theories had been domesticated in America.

[129] Taine's theory is still discussed today. Edwin Greenlaw, *Province of Literary History* (Baltimore, 1931), felt it necessary to attack Taine's theory is being too facile and praised Grierson's *Cross-Currents* as corrective of Taine. Van Wyck Brooks, especially in *America's Coming of Age* (1915), employed a variant of the critical theory of Sainte-Beuve and Taine. (See Zabel, "The Americanism of V. W. Brooks," *Partisan Review,* VI, 1939, 69–85.) In his dedication to *Axel's Castle* (1934) Edmund Wilson described himself as being influenced by Vico, Herder, and Taine.

A GUIDE TO THE SUBFAMILIES AND TRIBES OF THE FAMILY ICHNEUMONIDAE (HYMENOPTERA) KNOWN TO OCCUR IN WISCONSIN[1]

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INTRODUCTION

The study of ichneumonids in Wisconsin was undertaken to obtain information necessary to make better use of them in combatting our insect foes. Ichneumonid larvae all parasitize insects or arachnids, either internally or externally. Because of the large number of economically important pests among their hosts, and the role which ichneumonids occupy in reducing their numbers, the family is of great benefit to man. Before methods can be developed to favor these insects by creating more desirable habitats, a knowledge of what is present and the ecology and habits of the various species is necessary. Acquiring a knowledge of what inhabits an area is thus the first step in a series designed to take greater advantage of parasitic insects.

Adults of the family may easily be distinguished from other Hymenoptera by the following characters. The flagellum has at least fifteen segments. The sides of the pronotum reach or cover the first pair of thoracic spiracles, and in winged forms extend to the tegulae. The first morphological segment of the abdomen is fused solidly to the third thoracic segment, forming the propodeum (which always bears a pair of spiracles). The trochanters of at least the hind pair of legs are apparently double. The forewing has a distinct stigma, the first cubital and first discoidal cells confluent (forming the discocubital cell), and, except in *Ophionellus,* two recurrent veins. The venter of the abdomen is never heavily sclerotized.

In this paper keys and other materials are presented to assist in placing the adult members of the family in their respective subfamilies and tribes. The taxonomic arrangement and nomenclature follow that given by Townes in the *Catalogue of Hymenoptera of America North of Mexico* by Muesebeck and others,

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published in 1951 as U. S. D. A. Agricultural Monograph No. 2. While the keys and other aids to recognition included apply to Wisconsin species, it is hoped that they will prove useful for adjacent areas also.

Of the 14 subfamilies, 49 tribes and 347 genera listed in the Catalogue at least 13 subfamilies, 39 tribes and 197 genera occur in Wisconsin. The Catalogue lists about 2500 species; Wisconsin has over 450 species, including a number of undescribed forms.

During a visit by the senior author to the Canadian National Collection, Division of Entomology, in Ottawa, the Philadelphia Academy of Sciences, and the United States National Museum in Washington, a large number of specimens from the collection of the Department of Entomology of the University of Wisconsin were compared with types or authoritatively named specimens, and many notes and sketches were made. Appreciation is expressed to those in charge for permission to study the ichneumonid collections in Ottawa, Philadelphia and Washington, respectively.

Mr. G. S. Walley and Miss L. M. Walkley kindly helped solve some of the difficulties which had been encountered, and also reviewed the manuscript.

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The characters used were selected after study of material in the Department of Entomology of the University of Wisconsin; an unpublished artificial key by Dr. H. K. Townes (1943) to the ichneumonid genera of the northeastern part of the United States; the notes and sketches mentioned above; Plectiscine specimens borrowed from the Canadian National Collection, and specimens from the Milwaukee Public Museum. Dr. Townes generously granted permission for the use of parts of his key, with or without modification.[3]

In addition to the Catalogue already mentioned, the following works were found to be very helpful.

BURKS, B. D. 1952. A review of the nearctic genera of the tribe Mesoleiini with descriptions of two new genera and a revision of the nearctic species of *Perilissus* and *Labrossyta.* Ann. Ent. Soc. Amer. 45:80–103.

PRATT, H. D. 1945. Taxonomic studies of nearctic Cryptini. Amer. Midland Nat. 34 (3):549–661.

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[3] The characters drawn from Townes' key are indicated by the underscored portions in the keys. (Many of the characters have been modified from the original wording or value in order to delimit them more exactly or to make them fit Wisconsin specimens.)

TOWNES, H. K. 1940. A revision of the Pimplini of eastern North America. Ann. Ent. Soc. Amer. 33:283–323.

TOWNES, H. K. 1944–45. A catalogue and reclassification of the nearctic Ichneumonidae (Parts I and II). Memoirs of the Amer. Ent. Soc. No. 11.

TOWNES, H. K., and TOWNES, M. C. 1949. A revision of the genera and of the American species of Tryphoninae (Parts I and II). Ann. Ent. Soc. Amer. 42:321–447.

EXPLANATIONS AND PROCEDURES FOLLOWED

The following points were among those considered while constructing the keys: Keys are needed most by people who wish to identify specimens in groups not well known to them, and for groups lacking relatively clear-cut, easily-recognizable distinguishing characters. Specimens (from series which rarely approximate the composition of those upon which the keys were based) are usually keyed out individually, and individually agree or disagree with the characters presented. Under these conditions, it is not usually known in advance to which group a specimen is most likely to belong, or how typical it is of its group. Therefore, to increase the certainty of correct identification and the ease of deciding to which side of a couplet a specimen should go, the characters have been delimited as exactly as possible, and the groups divided where necessary. (However, since the key is incomplete, and some exceptions are bound to occur, the user should not expect more than a very great majority of specimens to be correctly placed.) It is believed that the advantages of this approach will outweigh the disadvantages, such as the greater length of keys often necessitated by it.

Only those specimens which are close to the borderline for proportions given need actually be measured. For this purpose, an ocular micrometer with a scale graduated into 100 divisions is suggested. When taking measurements, the reference points should both be in view; if structures are obscured by dirt or other structures, appropriate measures should be taken to render them visible. (However, no dissections are required, although in some instances the genitalia may be retracted and thus require pulling out far enough to reveal the sex of these specimens.) Measurements should be taken to the closest micrometer scale division for parts which involve a large number of these divisions, and to the nearest half-division otherwise.

The magnifications used in finding the proportions were 45 X and 112.5 X (sometimes only 19.5 X), but those as low as 30 X and 75 X, with allowances for attendant differences in accuracy, should be satisfactory for most specimens.

All dimensions are maximum unless otherwise specified. Length of structures, except for appendages, is from front to rear; for each appendage, and each segment of segmented appendages, it is from base to apex. Width is from side to side, at right angles to length. Depth is from dorsal to ventral, perpendicular to both length and width. The length of the petiole (unless a dorsal view is specified) is the distance between the base of the sternite and the apex of the tergite (diagonally, not along the suture dividing the sternite from the tergite). The length of the abdomen is the dorsal median length. The reference points for measuring the length of the thorax are the anterior end of the pronotum and the most posterior part of the propodeum bordering the petiolar socket. The length of the head when measured from above is the median longitudinal dimension parallel to a line drawn from the dorsal margin of the foramen magnum to the dorsal margin of the antennal sockets (the reference line being held at right angles to the line of vision); when measured in side view, it is the maximum front-to-rear distance along a line parallel to the same reference line. To measure the length of the mandibular teeth, use as a base line a line through the point of divergence of the teeth at right angles to the longitudinal axis of the mandible. When counting the number of facets, use as a row either of the two directions in which the centers of the facets are closest together, preferably where the curvature of the eye is not strong.

The system of wing venation in figure 66 is that of Rohwer and Gahan, except that "areolet" is substituted for "second intercubital cell". The areolet is considered as present if the second intercubitus, or a bulla representing it, is present; if only one intercubitus is present, the areolet is considered as absent. Examine the upper surface of the second recurrent vein when counting the number of bullae.

Roman numerals with arabic numerals as superscripts, enclosed within square brackets, refer to plate and figure numbers respectively. The wing figures were drawn with the aid of a projectoscope, and the other figures by the use of a grid. Figures 1–46 pertain to the head, 47–130 to the thorax, and 131–155 to the abdomen. Head parts are labeled in figures 1 and 2, parts of the thorax in figures 51, 53, 56, and 66, and those of the abdomen in figures 131, 139 and 153. Except where otherwise noted, heads are drawn from a little above and to the front of a lateral view, looking approximately at the middle of the eye; and thoraces, abdomens and abdominal parts from a little above and slightly behind a side view. The simplest way to orient the head of a specimen for comparison with a drawing is to turn the specimen until the shape of its ocellar triangle matches that in the drawing. Orient the thorax with respect to the petiolar socket, and the abdomens with reference to the petiole or apex.

Information on the usual appearance (or habitus) to be expected in the various groups is to be found elsewhere than in the keys. Ordinarily, an idea of the habitus is obtained only after considerable experience with a group. Nevertheless, an attempt is made to indicate characters by which members of the groups are recognizable. It has appeared advisable to present this information in tabular form.

Table 1 is a series of comparisons of various characters throughout the subfamilies. Each character is divided into from two to five categories. In estimating the proportion within each subfamily falling into a particular category, the species were considered, rather than the genera.

Table 2 suggests the comparison of certain characters which are useful in distinguishing between any two of the subfamilies appearing in it.

Key to the Subfamilies[3]

(Collyrinae Not Known to be Present)

1. Wings absent [V^{52}]; **or** forewing shorter than 1.1 times the length of the thorax (venation may [V^{65}] or may not be abnormal) .... 2.
   Wings present; forewing longer than 1.1 times the length of the thorax .... 3.

2. (1) Thorax much wider than deep .... PLECTISCINAE
   Thorax not or only slightly wider than deep .... GELINAE

3. (1) Some or all of the segments within the central half of the flagellum distinctly compressed, at least 1.5 times as deep as wide [$I^{5,6}$]; spiracles within basal half of petiole; discoidella not joining nervellus within its anterior 0.25 (measured along nervellus) .... SCOLOBATINAE
   Flagellar segments less distinctly or not compressed, all less than 1.5 times as deep as wide [$I^{3,4}$]; **or** spiracles at or beyond the midlength of the petiole; **or** discoidella joining nervellus within its anterior 0.25 .... 4.

4. (3) Areolet present [$VIII^{114}$]; second recurrent vein with one bulla [$VIII^{114}$] .... 5.
   Areolet absent [$VIII^{106,113}$]; **or** second recurrent with two bullae [$VIII^{110,113}$] .... 9.

5. (4) Length of scape at point where apical rim is nearest to the base equal to or greater than the greatest dimension of the scape at right angles to its longitudinal axis (measure-

ments not necessarily in the same view) [III[44]]; occipital carina present [I[2]]; a ridge or carina or a combination of both extending almost directly from the antennal socket to the carina or ridge which closely borders the inner margin of the eye [III[44]] .... 6.

Length of scape at point where apical rim is nearest to the base less than the greatest dimension of the scape at right angles to its longitudinal axis [III[41]]; **or** occipital carina absent; **or,** if a ridge or carina is present between the antennal socket and the eye, it extends only to a deep ridge or carina which distinctly diverges from the inner margin [III[45]] .... 9.

6. (5) Males .... 7.

Females .... 8.

7. (6) Parameres elongated into styli more than five times as long as deep at their midlength [X[153]] ...........MESOCHORINAE

Parameres less than four times as long as deep at their midlength [X[152,155]] .... 9.

8. (6) Subgenital plate large, its opening V- or U-shaped, and its posterior and ventral margins in side view forming a distinct acute angle (about 40° to 60°) [X[133,147]]; ovipositor straight, slender [X[147]], exserted about 0.33 to 1.0 times the length of the petiole; dorsal valvulae about 5–15 times as long as deep at their midlength, and in side view with the dorsal and ventral margins parallel most of their length [X[147]] .............................MESOCHORINAE

Subgenital plate **or** ovipositor **or** dorsal valvulae of other conformation .... 9.

9. (4,5,7,8) Forewing less than 4 mm. long..........................10.

Forewing at least 4 mm. long...............................11.

10. (9) Labrum projecting more than half the median depth of the clypeus as a broad semicircular plate [III[35]]; stigma not more than 2.33 times as long as wide [VIII[113]]; propodeum with about 13 areas enclosed by carinae.ORTHOPELMATINAE

Labrum hidden or projecting less than half the median depth of the clypeus [III[32,33]]; **or** the stigma at least 2.5 times as long as wide [VIII[99–112]]; propodeum with any number of enclosed areas .... 11.

11. (9,10) Forewing not more than 7.5 mm. long......................12.

Forewing at least 7.5 mm. long.............................23.

12. (11) Mandibular teeth subequal in length; tip of ventral tooth pointed; apex of dorsal tooth much broader than that of ventral tooth, and truncate, concave or angularly notched [III[38]] .... 13.

Mandibular teeth otherwise [III[32,36,43]] ....14.

13. (12) Petiole less than twice as long as wide at its midlength, much broader than deep, and with parallel or subparallel sides [X[135]] ................................DIPLAZONINAE

Petiole more than twice as long as wide across middle [X[133,134]] and of any shape [X[139–143]]........................14.

14. (12,13) Occipital carina absent; mandible narrow (in relation to the size of the head) [III^{36}], its basal width not greater than the combined diameters of a row of six contiguous eye facets; center of apex of sternite of petiole at or in front of the middle of the petiole.............ORTHOCENTRINAE

Occipital carina present (may be incomplete); **or** mandible wider [III^{31,33,39}], its basal width greater than the combined diameters of a row of six contiguous eye facets; **or** center of apex of petiolar sternite within the apical half of the petiole ....15.

15. (14) Second recurrent with one bulla.................................16.

Second recurrent with two bullae................................19.

16. (15) Center of apex of petiolar sternite at or in front of the middle of the petiole; femora stout, those of the middle and hind legs not more than 3.5 times as long as their greatest transverse dimension ....17.

Center of apex of petiolar sternite within the apical half of the petiole; **or** middle or hind femora slenderer............24.

17. (16) Areolet absent [IX^{120}], or present and petiolate [IX^{119}] or subpetiolate anteriorly; discoidella joining nervellus within its posterior three-fourths (measured along nervellus) [IX^{119,120}]; hind tibia with two apical spurs the shorter of which is not more than two-thirds the length of the longer [V^{56}], or with only one apical spur [V^{61}]..................18.

Areolet present and sessile anteriorly; **or** discoidella joining nervellus within its anterior fourth [VIII^{103}]; **or** the shorter of the two apical spurs of the hind tibia more than two-thirds the length of the longer [V^{59}]........................24.

18. (17) Postero-lateral margin of the mesoscutum (between the anterior end of the carina bordering the side of the pre-scutellar depression and the posterior end of the carina bordering the lateral margin of the mesoscutum) bordered by a distinct complete carina with vertical sides (which may be running along the crest of a slight ridge) [IV$^{49-51}$]; hind tibia with two apical spurs ....24.

Postero-lateral margin of the mesoscutum not or only incompletely bordered by a carina (a low rounded ridge, or a carina interrupted for part of its length by such a ridge, may be present, or both may be absent. Examine from several angles, as reflections from some angles may give the illusion of a carina that does not exist.) [IV^{48}]; **or** hind tibia with one apical spur.....................METOPIINAE

19. (15) Basal width of mandible not greater than the combined diameters of a row of ten contiguous eye facets; hind tibia with two small spurs, the longer not more than five times the length of the apical or subapical fringe of setae (which may be dense and conspicuous) on the inner side of the hind tibia [V^{59}] ....20.

Basal width of mandible greater than the combined diameters of a row of ten contiguous eye facets; **or** hind tibia without spurs, with one spur [V^{61}], or with two spurs the longer of which is more than five times the length of the apical or subapical setae (which may or may not form a fringe) on the inner side of the hind tibia...............................36.

20. (19) Sternaulus (which may be only a shallow depression posteriorly) crossing a line drawn from the ventral end of the mesopleural suture to the most posterior point of the backwardly-pointing angulation on the prepectal carina just above the origin of the sternaulus [reference points for line are a and b in V[54]]; **or** the second intercubitus present at least as a bulla and the two intercubiti separated anteriorly by more than the width of the first intercubitus [VII[87]] ....GELINAE

Sternaulus absent, or present and not crossing the reference line described above (prepectal carina may lack the angulation above the origin of the sternaulus) [IV[49], V[54]]; areolet absent [VII[97]], or with two intercubiti which meet or are separated anteriorly by at most the width of the first intercubitus ....21.

21. (20) Thorax at least twice as long as deep [IV[47]]; **or** abdomen beyond petiole with shallow to deep grooves or furrows on at least tergites 2 and 3 (if not distinct, examine from several angles; these grooves or furrows should not be confused with striations or other sculpturing which may be present) [X[136]] ....PIMPLINAE

Thorax less than twice as long as deep [IV[48–51]], V[52]]; abdomen beyond petiole without grooves or furrows, or with only faint suggestions of elongate depressions on the second but not on the third tergite (tergites 2 and 3 may be variously sculptured or have s l i g h t non-elongate depressions) [X[133–135,137–143]] ....22.

22. (21) Face and at least half of mesopleurum granular or coriaceous; stigma not more than 2.5 times as long as wide [VII[85]] ....GELINAE

Face or mesopleurum or both smooth or with different sculpture than that described above; **or** stigma more than 2.5 times as long as wide [VII[97]]................PLECTISCINAE

23. (11) Second recurrent with one bulla...............................24.

Second recurrent with two bullae...............................34.

24. (16,17,18,23) Spiracles within apical half of petiole [X[134,137,144]].......25.

Spiracles at or before the midlength of the petiole [X[131,135,145]]..31.

25. (24) Abdomen beyond petiole almost entirely smooth and highly polished; lateral carina or fold on the second tergite incomplete, with the parts of the tergite above and below the fold thin and of the same consistency; lateral margin of second tergite not bent under sharply to form a carinate fold [X[141]] ....OPHIONINAE

Abdomen beyond petiole largely sculptured; **or** the second tergite with a complete lateral fold or carina (the tergite may or may not be bent under sharply) which divides the tergite into parts of unlike thickness or consistency [X[131–140,142,143]]....26.

26. (25) Third abdominal segment compressed, at least twice as deep as wide [X^{134}]; **or** face **and** mesoscutum granular or granular-punctate; **or** forewing with a **single** intercubitus which joins the cubitus **more** than half the length of the intercubitus beyond the junction of the second recurrent with the cubitus [IX^{130}] ....27.

Third abdominal segment less than twice as deep as wide [X^{139}]; face and mesoscutum not or not both granular (or granular-punctate); forewing either with two intercubiti or with a single one joining the cubitus **less** than half the length of the intercubitus beyond the junction of the second recurrent with the cubitus [VI^{77}]..........................36.

27. (26) Areolet present and sessile, with the intercubiti separated anteriorly by more than twice the width of the first intercubitus [VII^{89}] ....36.

Areolet absent [$IX^{123,127}$], or present and with the two intercubiti meeting or separated by at most the width of the first intercubitus [$IX^{121,122,124}$] ....28.

28. (27) Third abdominal segment less than twice as deep as wide [X^{139}]; sternaulus distinct for at least half the length of the mesopleurum [IV^{51}]; mesosternum without a complete transverse carina in front of the middle coxae..............36.

Third abdominal segment distinctly compressed, at least twice as deep as wide; **or** sternaulus either absent or less than half the length of the mesopleurum [IV^{49}]; **or** mesosternum with a complete transverse carina in front of the middle coxae [V^{53}] ....29.

29. (28) Spiracles within apical 0.4 of petiole [X^{134}]........OPHIONINAE

Spiracles at or in front of the apical 0.4 of the petiole.........30.

30. (29) In side view, sclerotized portion of petiole rather straight on the basal half or more, with the dorsal and ventral margins parallel or only slightly diverging; apical portion of petiole deepest, with a moderately abrupt but smoothly curved dorsal convexity (ventral margin opposite may also increase in convexity) which includes the spiracles [X^{137}]..OPHIONINAE

In side view, sclerotized portion of petiole rather straight or slightly to moderately convex dorsally, with the greatest depth at approximately its midlength; **or,** if a dorsal convexity is present at or near the apex, it does not include the spiracles but is well separated from them by a flat or concave portion [X^{145}] ......................SCOLOBATINAE

31. (24) Middle tibia with one apical spur; **or** middle of dorsal margin of face projecting between the antennal sockets (above the plane of the frons) [II^{16},III^{31}]..................METOPIINAE

Middle tibia with two apical spurs; dorsal margin of face not projecting between the antennal sockets ....32.

32. (31) Petiole with a basal concavity above (lateral bordering carinae may or may not be present) [$X^{132,136}$]; thorax not elongate, less than twice as long as deep [IV^{48-51}]...................33.

Dorsum of petiole flat or convex basally above (ignore lateral bordering carinae which may be present) [$X^{131,144}$]; **or** thorax elongate, at least twice as long as deep..............36.

33. (32) Discoidella present, joining nervellus within its anterior fourth (measured along nervellus) [$VIII^{103}$]; **or** abdominal tergites 2 and 3 with two or more oblique grooves or furrows [X^{136}] ....BANCHINAE

Discoidella absent, or present and joining nervellus within its posterior three-fourths; abdomen beyond petiole without grooves or furrows (carinae, various sculpturings, or slight non-elongate depressions may be present)..................34.

34. (33) Costula absent [IV^{49},V^{55}]; **and** apical transverse carina strong (distinct, well-developed) at least within its central half [V^{55}] ....35.

Costula present [V^{51}]; **or** apical transverse carina absent or interrupted within its central half..........................36.

35. (34) Opening of scape strongly oblique to the longitudinal axis of the scape [I^{12}, III^{37}], with the longitudinal side of the "apical triangle" more than 0.8 times as long as its base;[4] females with ovipositor exserted beyond subgenital plate more than twice the greatest depth of the sixth abdominal tergite [X^{132}] ....BANCHINAE

Opening of scape not strongly oblique to the longitudinal axis of the scape [III^{38-40}], the longitudinal side of the "apical triangle" not being more than 0.8 times the length of its base; females with ovipositor exserted beyond subgenital plate less than twice the greatest depth of the sixth abdominal tergite [X^{149}] ....58.

36. (19,23,26,27,28,32,34) Areolet absent [$VIII^{99}$]; abdominal tergites 2 and 3 each with two distinct oblique grooves or furrows diverging posteriorly from near the center of the base of the tergite (other grooves or furrows may also be present); occipital carina complete, joining the hypostomal carina at the base of the mandible [III^{33}].................BANCHINAE

Areolet present; **or** abdominal tergites without such oblique grooves; **or** occipital carina incomplete or not joining the hypostomal carina at the mandible.........................37.

37. (36) Spiracles within basal 0.4 of petiole...........................50.

Spiracles at or beyond basal 0.4 of petiole...................38.

38. (37) Spiracles within the central 0.2 of the petiole [$X^{136,143,145}$].......39.

Spiracles at or beyond the basal 0.6 of the petiole [$X^{134,141}$].....42.

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[4] To obtain this proportion view scape perpendicular to its major axis. Rotate until the point on the apical rim nearest to the base [point **d** in I^{6}] is visible at one side, and the point farthest from the base (point **e**) is also visible. Pass an imaginary line (line **ab**) along the scape from the midpoint of its base to the midpoint between points **d** and **e**. Measure the width (line **cd**) of the scape at right angles to line **ab**. Line **cd** is referred to as the base of the "apical triangle". Next measure the distance between points **c** and **e**; this line represents the longitudinal side of the "apical triangle". Divide the length of line **ce** by the length of line **cd**.

39. (38) Areolet absent, or, if present, petiolate or subpetiolate anteriorly; or mesoscutum elongate, at least 1.33 times as long as wide .... 40.
Areolet present, with the two intercubiti not meeting anteriorly; mesoscutum less than 1.33 times as long as wide.....42.

40. (39) Sternaulus present for at least half the length of the mesopleurum [IV[51]]; or areolet absent but with the radius and cubitus indicating by slight angular bends that the second intercubitus would not, if it had been present, meet the first intercubitus anteriorly (this character with a number of exceptions in Wisconsin specimens in the University collection) [VII[84,85]] .... 41.
Sternaulus absent or present for less than half the length of the mesopleurum; areolet present, or absent and the radius and cubitus lacking these slight angular bends [VI[78]]........50.

41. (40) Areolet absent; thorax elongate, at least twice as long as deep [IV[47]] ....PIMPLINAE
Areolet present; or thorax less than twice as long as deep.....42.

42. (38,39,41) Center of apex of petiolar sternite at or in front of middle of petiole..43.
Center of apex of petiolar sternite beyond middle of petiole....44.

43. (42) Petiole with a deep lateral groove or pit basad of the spiracle [X[143]]; or abdominal tergites 2 and 3 with grooves or furrows making their contour irregular [X[136]].................50.
Petiole without a lateral groove or pit basad of the spiracle [X[139,141]]; abdominal tergites 2 and 3 without grooves or furrows [X[139,141]] ....44.

44. (42,43) Sternaulus and areolet both absent...........TRYPHONINAE
Sternaulus or areolet or both present..........................45.

45. (44) Second recurrent with one bulla...........................46.
Second recurrent with two bullae..............................47.

46. (45) Dorsal tooth of mandible less than 1.5 times as long as ventral tooth [II[19,23], III[41]]; or propodeal spiracle with its longest diameter more than 1.5 times its shortest diameter; or propodeum with prominent projections................GELINAE
Dorsal tooth of mandible at least 1.5 times as long as ventral tooth [II[28]]; propodeal spiracle with its longest diameter at most 1.5 times its shortest diameter; propodeum without projections ............................ICHNEUMONINAE

47. (45) Propodeal spiracle with its maximum diameter more than 1.5 times its minimum diameter..............ICHNEUMONINAE
Propodeal spiracle with its maximum diameter at most 1.5 times its minimum diameter.................................48.

48. (47) Sternaulus absent or present for less than half the length of the mesopleurum; stigma more than 2.5 times as long as wide ......................................ICHNEUMONINAE
Sternaulus distinct for more than half the length of the mesopleurum; or stigma at most 2.5 times as long as wide.......49.

49. (48) Junction of discoideus with subdiscoideus not farther from the posterior than from the anterior end of the second recurrent [V^{66}]; dorsal tooth of mandible more than 1.5 times as long as ventral tooth [II^{28}]...............ICHNEUMONINAE

Junction of discoideus with subdiscoideus farther from the posterior than from the anterior end of the second recurrent [VII^{85}]; **or** dorsal tooth of mandible not more than 1.5 times as long as ventral tooth [$II^{19,23}$, III^{41}]..........GELINAE

50. (37,40,43) Middle tibia with one apical spur..........TRYPHONINAE

Middle tibia with two apical spurs..........................51.

51. (50) Thorax elongate, at least 1.9 times as long as deep..PIMPLINAE

Thorax not elongate, less than 1.9 times as long as deep......52.

52. (51) Abdominal tergites 2 and 3 with shallow to deep oblique or transverse grooves or furrows (or both) [X^{136}]; propodeum with not more than five enclosed areas...........PIMPLINAE

Either or both of these tergites without such grooves or furrows [$X^{137-143}$]; **or** propodeum with more than 5 enclosed areas ....53.

53. (52) Males ....54.

Females ....55.

54. (53) Two adjacent segments near the midlength of the flagellum each with a large dorsal notch...............PLECTISCINAE

Flagellar segments without notches.........................56.

55. (53) Ovipositor exserted beyond subgenital plate more than twice the length of the petiole and more than the total length of the abdomen; ovipositor slender, with a small distinct subterminal dorsal notch, but lacking a subterminal dorso-ventral swelling; subgenital plate not ending in an elongate median projection; center of apex of petiolar sternite in front of middle of petiole..................PLECTISCINAE

Ovipositor exserted beyond subgenital plate either less than twice the length of the petiole or less than the total length of the abdomen; **or** ovipositor without a subterminal dorsal notch **or** with a subterminal dorso-ventral swelling; **or** apex of subgenital plate ending in an elongate median projection [X^{148}]; **or** center of apex of petiolar sternite at or beyond middle of petiole...56.

56. (55) Opening of scape strongly oblique to the longitudinal axis of the scape [$I^{8,12}$], with the longitudinal side of the "apical triangle" (see footnote 4) more than 0.8 times as long as its base ....57.

Opening of scape not strongly oblique to the longitudinal axis of the scape [III^{38-40}], the longitudinal side of the "apical triangle" being not more than 0.8 times the length of its base ....58.

57. (56) Mesoscutum with transverse ridges or striae; **or** tarsal claws each with a bristle with an expanded tip reaching from the base to the apex of the claw (as these bristles appear to break off easily, the presence of even one is sufficient to place the specimen here); **or** hamuli of hindwing more than 8 [VI[77]] ....PIMPLINAE

Mesoscutum without transverse ridges or striae; tarsal claws lacking a bristle with an expanded tip; hamuli not more than 8 [VI[80-82]] ....TRYPHONINAE

58. (35,36) Outer apical margin of fore tibia with a small to minute tooth or spine (may be hidden among apical bristles) [V[60]]. ....SCOLOBATINAE + a very small part of TRYPHONINAE

Outer apical margin of fore tibia without a tooth or spine.....59.

59. (58) Petiole so strongly curved that in side view its ventral margin opposite the spiracles lies above a line drawn from the base of the sternite to apex of the tergite (diagonally, not along the suture dividing the sternite from the tergite) [X[144]]; maxillary palpus slightly longer than the depth of the head ....SCOLOBATINAE

Petiole less strongly curved; **or** maxillary palpus shorter than the depth of the head.....................................60.

60. (59) Face and clypeus separated by a distinct depression or groove [II[17,20-22]] (the distance from the bottom of the depression or groove to a line joining the highest points on the face and clypeus more than the combined diameters of two contiguous eye facets. View in profile, against a light if facial pubescence interferes); **or** propodeum without longitudinal carinae ....TRYPHONINAE

Face and clypeus indistinguishably fused [III[43]], or separated only by a very shallow depression or groove (if a depression or groove is present, the distance from its bottom to a line joining the highest points on the face and clypeus not exceeding the combined diameters of two contiguous eye facets); propodeum with longitudinal carinae...............61.

61. (60) Labrum large, projecting beyond the clypeus more than 0.4 times the basal width of the mandible........TRYPHONINAE

Labrum small, hidden or projecting beyond the clypeus less than 0.4 times the basal width of the mandible ....SCOLOBATINAE

Code for Table 1 (terms used are followed by roughly corresponding percentages in brackets): r = rarely (up to 5, but more than 0); s = sometimes (5–20); o = often (20–50); m = majority (50–70); **u** = usually (70–90); **N** = nearly always (90–99); **A** = always (99–100). *Dash means "none". **Dash means "none" except where category limits overlap, when it means "other categories fit better".

Notes on Subfamilies

PIMPLINAE [I[4,7–12], II[24,25], IV[47], V[57,62], VI[67–77], X[131,136,148]]: Forewing 1.5–32 (usually 4–15) mm. long. The habitus appears to be of two major kinds. In one type the abdominal tergites have an irregular contour from grooves and elevations,[5] the thorax is of average or heavyset build, and the propodeum usually has less than six enclosed areas. In the other the abdominal tergites are of even contour, the thorax is usually elongate or subelongate, and the propodeum often has more than six enclosed areas. In this subfamily, if a transverse ridge is present on the clypeus, it tends to be near the base of the clypeus.

TRYPHONINAE [I[14], II[17,20–22], V[61], VI[78–82], VII[83], X[143]]: Forewing 2–16 (usually 3–14) mm. long. The propodeum tends to be without enclosed areas or to be more or less completely areolated (the areola and basal area are frequently confluent, however). If the clypeus has a transverse ridge, the ridge tends to be near the middle.

GELINAE [I[3], II[15,19,23], III[41], IV[51], V[52,65], VII[84–90], X[141,152]]: Forewing 0–16 (usually 2.5–10) mm. long. Sexual dimorphism, especially in structure, often marked. Usually there is a distinct angle between the major axis of the petiole and that of the rest of the abdomen. The propodeum is often somewhat blocky or concave behind (more often in females than in males).

ICHNEUMONINAE [II[18,28,29], III[46], V[66], VII[91–96], X[139]]: Forewing 2–20 (usually 3.5–13) mm. long. Sexual dimorphism in color and structure great in a large part of the subfamily. The major axes of the petiole and of the rest of the abdomen are at a distinct angle to each other. The propodeum (especially in females) frequently is concave behind, and usually is more or less completely areolated. The apex of the abdomen of the female is very characteristic for nearly the whole subfamily, and is almost diagnostic in itself. Ventrally the apex (in side view) is obliquely truncate or subtruncate (the tergites in this portion being longer than the sternites), with the straight ovipositor extending to or slightly beyond the apex of the abdomen. The dorsal and ventral margins of the dorsal valvulae are parallel or subparallel most of their length.

BANCHINAE [II[30], III[33,37,42], V[55], VIII[99–103], X[132]]: Forewing 2.5–12 (usually 3–10) mm. long. Most species fall into two major categories. In the first, the abdominal tergites are made irregular

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[5] Most species with this character belong in the subfamilies Pimplinae and Banchinae. Nearly all of those species in other subfamilies which have the tergites irregular may easily be distinguished by other characters.

in contour by grooves,[5] the petiole usually has lateral carinae extending from the spiracles to the apex, and the propodeum has a very variable number of carinae (the apical transverse carina is nearly always present). In the second, the abdominal tergites lack such grooves, the petiole rarely has lateral carinae reaching from the spiracles to the apex, and the propodeum has no carinae or vague carinae or one strong transverse carina (and sometimes some longitudinal carinae behind it).

SCOLOBATINAE [I[5,6], III[39,40,43,45], V[60,64], VIII[104–112], X[144,145,149]]: Forewing 2–21 (usually 4–12) mm. long. The second intercubitus, when present, tends to be interstitial or subinterstitial with the second recurrent.

ORTHOPELMATINAE [III[35], V[54], VIII[113], X[140]]: Forewing 1.5–4 (usually 2–3.5) mm. long. Petiole rather slender, and little wider at the apex than at the spiracles. Abdomen in dorsal view long-ovate to rectangular-oval.

PLECTISCINAE [III[32,34], IV[49], V[59], VII[97,98]]: Forewing 1.5–8.5 (usually 1.5–3.5) mm. long. Most species have long slender legs and long wings. The head does not usually cap the thorax closely.

ORTHOCENTRINAE [III[36], IX[115,116], X[142]]: Forewing 1–5 (usually 1.5–3.5) mm. long. The shape of the head and the venation of the forewing are both very characteristic (see illustrations). The legs are usually rather stout. The whole body may be greatly compressed.

DIPLAZONINAE [III[38], IX[117,118], X[135]]: Forewing 2–7 (usually 3–5.5) mm. long. Over-all appearance very characteristic. Generally rather compact, with the head fitting rather closely to the thorax.

METOPIINAE [III[31], IV[48], V[56], IX[119,120], X[138]]: Forewing 2.5–12 (usually 3.5–10) mm. long. Legs usually rather stout. Face usually strongly convex, bulged, or raised somewhat like a shield.

OPHIONINAE [I[1,2,13], II[16,26,27], IV[50], V[53,58,63], IX[121–130], X[134,137,154,155]]: Forewing 1.5–26 (usually 2.5–16) mm. long. Mesosternum in a large part of the subfamily with a complete pre-midcoxal transverse carina (this carina is rarely complete in the other subfamilies). Apex of propodeum frequently produced distinctly behind the hind coxal cavities (rarely more than slightly produced in the other subfamilies). Abdomen often conspicuously compressed.

MESOCHORINAE [III[44], VIII[114], X[133,147]]: Forewing 1.5–10 (usually 2–5) mm. Over-all appearance very characteristic. The veins enclosing the areolet are usually of equal or subequal length, giving it a rhombic or subrhombic appearance.

Key to Tribes of Pimplinae[3]

(Brachycyrtini Not Known to be Present)

1. Mesoscutum with strong transverse ridges or striae over most or all of its surface; mandibles bidentate [II[25]] .... 2.

Mesoscutum without transverse ridges or striae; **or** mandibles unidentate [I[8,9]] .... 3.

2. (1) Propodeum without areas enclosed by carinae..........RHYSSINI

Propodeum with areas enclosed by carinae.............PIMPLINI

3. (1) A strong bristle with an expanded or broadly spatulate tip reaching from the base to the apex of each claw (as these bristles are apparently easily broken off, the presence of even one is sufficient to place specimen here); areolet present [VI[80]] ....THERONIINI

Tarsal claws without a basal bristle having an expanded or spatulate tip; **or** areolet absent............................ 4.

4. (3) Eye distinctly emarginate on inner margin subopposite the antennal sockets [I[10]] mesoscutum more than 1.33 times as long as wide; areolet present, large, with the intercubiti separated anteriorly by more than twice the width of the first intercubitus [VI[69]] ....LABENINI

Eye with at most a broad, shallow, concave curve on inner margin; **or** mesoscutum less than 1.33 times as long as wide; **or** areolet absent [VI[70]], or present and with the intercubiti meeting or separated anteriorly by not more than twice the width of the first intercubitus [VI[74]] .... 5.

5. (4) Thorax at least twice as long as deep [IV[47]]; **or** center of apex of petiolar sternite within apical third of petiole....... 6.

Thorax less than twice as long as deep [IV[48–51]]; center of apex of petiolar sternite at or in front of apical third of petiole .... 7.

6. (5) Opening of scape strongly oblique to the longitudinal axis of the scape [I[8,12]], with the longitudinal side of the "apical triangle" (see footnote 4) more than 0.8 times as long as its base; **or** the span of the occipital carina in dorsal view less than 0.67 times the greatest width of the head ....POEMENIINI

Opening of scape not strongly oblique to the longitudinal axis of the scape [I[9]], the longitudinal side of the "apical triangle" not being more than 0.8 times the length of its base; span of occipital carina in dorsal view more than 0.67 times the greatest width of the head.....................XORIDINI

7. (5) Propodeum with at least six areas enclosed by carinae; hamuli of hindwing more than 8 [VI[77]] ....ACAENITINI

Propodeum with not more than five areas enclosed by carinae; **or** hamuli not more than 8 [VI[68,69]] .... 8.

8. (7) Distance between the eyes at the level of the anterior margin of the antennal sockets equal to or greater than the shortest distance between the eyes dorsally [I^{12}]; mesopleural suture opposite mesopleural pit straight or very broadly and shallowly curved or with a localized bend toward the pit [IV^{47,51}] .... EPHIALTINI

Distance between the eyes at the level of the anterior margin of the antennal sockets equal to or less than the shortest distance between the eyes dorsally [I^{7}]; mesopleural suture with a localized bend toward the pit [IV^{48}] .... 9.

9. (8) Females .... 10.

Males .... 11.

10. (9) Ovipositor deeper (at least in part) within the central half than in the apical quarter [X^{136}] .... POLYSPHINCTINI

Ovipositor not deeper within central half than within apical quarter [X^{150}] .... PIMPLINI

11. (9) Eyes hairy (may be inconspicuously so) ...... POLYSPHINCTINI

Eyes not hairy .... 12.

12. (11) Areolet present, closed at least by a bulla [VI^{67}]; or flagellum with three consecutive segments near its middle modified on the outer side to form two conspicuous notches [I^{4}] .... PIMPLINI

Areolet absent [VI^{70}]; flagellum without such notches .... POLYSPHINCTINI + a very small part of PIMPLINI

NOTES ON THE TRIBES OF PIMPLINAE

PIMPLINI [I^{4,7}, V^{57,62}, VI^{67,68}]; POLYSPHINCTINI [I^{11}, VI^{69,70}]; EPHIALTINI [I^{12}, VI^{71}, X^{146}]; POEMENIINI [I^{8}, VI^{72}]; RHYSSINI [II^{25}, VI^{73}]; THERONIINI [II^{24}, VI^{74}]; LABENINI [I^{10}, VI^{75}, X^{131}]; XORIDINI [I^{9}, IV^{47}, VI^{76}]; ACAENITINI [VI^{77}, X^{148}].

In dorsal view, head subquadrate and genae subequal in length with eye in Xoridini and part of Poemeniini; rarely both in the other tribes. Opening of scape slightly to moderately strongly oblique to the longitudinal axis of the scape in Xoridini, a large part of Polysphinctini, and a very small part of Pimplini; strongly to very strongly oblique otherwise.

Thorax elongate in Xoridini, Labenini, and most Poemeniini; subelongate in Acaenitini, Rhyssini, and the rest of Poemeniini; rather heavyset in Ephialtini (especially in females); approaching subelongate in some of Polysphinctini; and of other conformation in the remainder. Coxae elongate in Labenini, part of Xoridini and Rhyssini and Poemeniini, and a small part of Acaenitini and Polysphinctini. Tarsi, especially apically, and more so in females than in males, somewhat stouter in nearly all of Polysphinctini than usual for the subfamily. Tarsal claws each with a basal tooth (usually large) [V[62]] in females of Polysphinctini, most Pimplini, and part of Ephialtini; with a tooth (not necessarily basal) in both sexes of part of Acaenitini. Propodeum with at most five areas enclosed by carinae in Ephialtini and Rhyssini, nearly all of Pimplini, Polysphinctini and Poemeniini, and a small part of Theroniini, and possibly rarely in the other tribes also; otherwise with more than five areas enclosed by carinae.

Petiole little wider than deep in Poemeniini, Labenini and Xoridini; considerably wider than deep in the other tribes. Petiole with at most a trace of a pit or groove laterally basad of the spiracle in Poemeniini, Labenini, nearly all Xoridini, part of Acaenitini, and rarely in the other tribes; remainder with a pit and/or groove present. Petiole with at most a trace of a basal concavity above in Poemeniini, Labenini, Xoridini, part of Acaenitini, and rarely in the other tribes; a large one in most Pimplini, Ephialtini and Theroniini; and a small to large one in the rest. Abdominal tergites 2 and 3 (or more) irregular in contour (often less distinctly so in males) in Pimplini, Polysphinctini, and most Theroniini; more vaguely irregular in Ephialtini and some of Poemeniini; and even in contour (may be striate) otherwise. Second abdominal sternite of female with a distinct longitudinal median groove or carina (the latter in some dried specimens at least) and a pair of tubercles projecting from the sides of the groove somewhere along its length in Rhyssini. Subgenital plate of female very strongly produced in Acaenitini. Ovipositor usually less than half the length of the abdomen and inconspicuous in Polysphinctini; longer and often very conspicuous in the rest; moderately long and rather stout in Ephialtini.

Key to Tribes of Tryphoninae

(Stilbopini, Phrudini, and Boethini Not Known to be Present)

1. Mid-tibia with one apical spur....................... CTENISCINI

   Mid-tibia with two apical spurs............................... 2.

2. (1) Hind tibial spurs large, the longer more than six times the length of the apical or subapical setae (which may form a distinct fringe) on the inner side of the hind tibia; propodeum without longitudinal carinae .... PHYTODIETINI

   Hind tibial spurs smaller, the longer not more than six times the length of the apical or subapical setae (which may form a distinct fringe) on the inner side of the hind tibia [V[59]]; or propodeum with longitudinal carinae .... 3.

3. (2) Labrum large, projecting beyond the clypeus more than 0.4 times the basal width of the mandible, and exposed even when the mandibles are closed [II^{22}]...............ADELOGNATHINI

Labrum hidden or projecting beyond the clypeus less than 0.4 times the basal width of the mandible, and not exposed when the mandibles are closed [II^{20,21}]............................. 4.

4. (3) Areolet absent [VI^{80}]; prespiracular portion of petiole at least 1.6 times as long as its narrowest width..............ECLYTINI

Areolet present [VI^{82}]; or prespiracular portion of petiole less than 1.6 times as long as its narrowest width................. 5.

5. (4) Distance between most lateral points of mandibular cavities in cranium more than 1.2 times the distance between the eyes at the level of the anterior margin of the antennal sockets [II^{17}]; longer hind tibial spur not more than three times the length of the apical or subapical setae on the inner side of the hind tibia [V^{59}] ..............................GRYPOCENTRINI

Distance between most lateral points of mandibular cavities in cranium less than 1.2 times the distance between the eyes at the level of the anterior margin of the antennal sockets; or longer hind tibial spur more than three times the length of the apical or subapical setae on the inner side of the hind tibia ....TRYPHONINI

NOTES ON THE TRIBES OF TRYPHONINAE

ADELOGNATHINI [II^{22}, VI^{78}]; PHYTODIETINI [I^{14}, VI^{79}]; ECLYTINI [II^{21}, VI^{80}]; GRYPOCENTRINI [II^{17}, VI^{81}]; TRYPHONINI [VI^{82}]; CTENISCINI [II^{20}, V^{61}, VII^{83}, X^{143}].

Ocelli large, their diameters greater than the post-ocellar line and more than twice as great as the ocell-ocular, in a large part of Phytodietini and some Eclytini. Occipital carina complete and joining base of mandible adjacent to or separately from the hypostomal carina in Grypocentrini and some Adelognathini; joining hypostomal carina barely posterior to the base of the mandible in some Eclytini; otherwise incomplete or joining hypostomal carina distinctly posterior to the base of the mandible.

Tarsal claws conspicuously pectinate in Phytodietini [V^{58,63}], and part of Tryphonini and Ctenischini; moderately pectinate in part of the latter two tribes; and slightly [V^{64}] or not [V^{57}] pectinate in the rest.

Spiracles within the apical half of the petiole in Adelognathini, part of Eclytini, and rarely in the remainder; at or in front of the midlength of the petiole otherwise. Ovipositor straight or nearly so in Adelognathini, Phytodietini, Eclytini, and part of Grypocentrini, Tryphonini, and Ctenischini; upcurved in part of Grypocentrini and Tryphonini; and downcurved in part of

Tryphonini and Cteniscini. Ovipositor often not exserted in Cteniscini. Ovipositor may carry one egg in part of Cteniscini, Grypocentrini and Tryphonini, and very rarely in part of Eclytini; several eggs in part of Tryphonini.

KEY TO TRIBES OF GELINAE

(Sphecophagini Not Known to be Present)

1. Apterous [V52] ....GELINI

   Wings present (may be greatly reduced in size)............... 2.

2. (1) Forewing not more than 1.1 times the length of the thorax (venation may be abnormal [V65])........................... 3.

   Forewing longer than 1.1 times the length of the thorax........ 5.

3. (2) Basal transverse propodeal carina absent..............APTESINI

   Basal transverse propodeal carina present at least laterally posterior to the spiracles .... 4.

4. (3) Longitudinal propodeal carinae present..................GELINI

   Longitudinal propodeal carinae absent............MESOSTENINI

5. (2) Second recurrent vein with two bullae; face of male without white or yellow markings (may be ferruginous)........GELINI

   Second recurrent with one bulla; face of male with or without white or yellow markings.................................. 6.

6. (5) Junction of discoideus with subdiscoideus farther from the posterior than from the anterior end of the second recurrent [VII84,85]; face of male without white or yellow markings ....GELINI

   Junction of discoideus with subdiscoideus not farther from the posterior than from the anterior end of the second recurrent vein [VII86–90]; face of male with or without white or yellow markings .... 7.

7. (6) Propodeum with longitudinal carinae.......................... 8.

   Propodeum without longitudinal carinae.......................10.

8. (7) Second abdominal tergite longitudinally strongly striate or aciculate, or distinctly and fairly uniformly punctate; second segment of maxillary palpus more than 1.2 times as long as its greatest dimension at right angles to its longitudinal axis, and with its sides nearly straight to moderately strongly convex, any expansion not being angular in outline ....GELINI

   Second abdominal tergite smooth, granular, or sculptured differently from that described above; **or**, if punctate, second segment of maxillary palpus less than 1.2 times as long as its greatest dimension at right angles to its longitudinal axis, and with one side angularly expanded.................. 9.

9. (8) (Distinguishing characters not clearly defined; if in doubt, try both the following tribes.)
   Males only: longitudinal carinae of propodeum confined to faint traces between the basal and apical transverse carinae; areolet present or absent.......................MESOSTENINI
   Males and females: longitudinal carinae more extensive or stronger or both; areolet present..................APTESINI

10. (7) (Distinguishing characters not clearly defined; if in doubt, try both the following tribes.)
   Females only: basal transverse propodeal carina weak or absent; apical transverse propodeal carina strong; areolet present ....APTESINI
   Males and females: basal transverse propodeal carina strong or moderately strong; apical transverse propodeal carina variable, may be strong to partly absent medially; areolet present or absent ....MESOSTENINI

Notes on the Tribes of Gelinae

GELINI [I^{3}, $II^{15,19}$, IV^{51}, V^{52}, VII^{84-86}, $X^{141,152}$]; APTESINI [III^{41}, V^{65}, VII^{87}]; MESOSTENINI [II^{23}, VII^{88-90}].

Second recurrent as in the first part of couplets 5 and 6 in the key above in nearly all Gelini, and as in the second part of these couplets in some Gelini and in the other tribes. Propodeal areolation complete or with several enclosed areas in most Gelini and Aptesini, and rarely in Mesostenini.

For additional notes on the tribes Aptesini and Mesostenini (which intergrade somewhat), see Pratt's work indicated in the references in the introduction.

Key to Tribes of Ichneumoninae

(Ischnojoppini, Acanthojoppini, and Eurylabini Not Known to be Present)

1. Basal half of petiole flat above, and wider than deep ....PRISTICERATINI
   Basal half of petiole either not flat above or not wider than deep.. 2.

2. (1) Propodeal spiracle circular or not more than 1.5 times as long as wide .... 3.
   Propodeal spiracle with its longest diameter more than 1.5 times its shortest diameter .... 4.

3. (2) Propodeum with a distinct projection in the region of the apex of each second lateral area..................PRISTICERATINI
   Propodeum without distinct projections................ALOMYINI

4. (2) Propodeum at the region of the areola or base of the areola greatly elevated, with the upper surface of the elevation polished (may also be somewhat punctate); areolet may be petiolate or subpetiolate anteriorly [VII[96]] ....TROGINI
Propodeum at the region of the areola or base of the areola not elevated or not polished; areolet sessile anteriorly [VII[94]]..... 5.

5. (4) Mandible not more than 2.5 times as long as broad across base of its teeth [II[29]]; malar space (shortest distance between eye and base of mandible) more than 0.8 times the length of the mandible [II[29]] ..............................LISTRODROMINI
Mandible more than 2.5 times as long as broad across base of its teeth [II[28]]; or malar space less than 0.8 times the length of the mandible [II[28]]........AMBLYTELINI, ICHNEUMONINI

Notes on the Tribes of Ichneumoninae

ALOMYINI [II[18], VII[91]]; PRISTICERATINI [VII[92]]; LISTRODROMINI [II[29], VII[93]]; AMBLYTELINI [II[29], V[66], VII[94], X[139]]; ICHNEUMONINI [VII[95]]; TROGINI [III[46], VII[96]].

Except for distinguishing the very close tribes Amblytelini and Ichneumonini from each other, the tribes are fairly easy to separate using the characters in the key and over-all appearance. Because of the few specimens in some of these tribes present in the collection of the Department of Entomology, and the extremely complex and variable nature of a large part of the subfamily, however, further notes at this point would be applicable to only a few species and would be of little help.

Key to Tribes of Banchinae

(Neorhacodini Not Known to be Present)

1. Abdominal tergites 2 and 3 (or more) each with two or more deep grooves; areolet absent [VIII[99,100]]....................... 2.
Abdominal tergites without such grooves; or areolet present [VIII[101–103]] .... 3.

2. (1) Abdominal tergites 2 and 3 each with only two deep grooves, these diverging posteriorly from near the central portion of the anterior margin of the tergite (traces of transverse grooves may be present)...........................GLYPTINI
Abdominal tergites 2 and 3 each with at least four deep grooves, two oblique and two transverse or approximately transverse ....LYCORINI

3. (1) Discoidella joining nervellus within its anterior fourth (measured along nervellus) [VIII[103]].......................BANCHINI
Discoidella joining nervellus within its posterior three-fourths [VIII[101,102]] ....LISSONOTINI

Notes on the Tribes of Banchinae

GLYPTINI [III[33], VIII[99]]; LYCORINI [III[42], VIII[100]]; LISSONOTINI [III[37], V[55], VIII[101,102], X[132]]; BANCHINI [II[30], VIII[103]].

Opening of scape slightly to moderately strongly oblique to the longitudinal axis of the scape in Glyptini, Lycorini, and most of Banchini; strongly to very strongly oblique in Lissonotini and the rest of Banchini. Occipital carina complete and joining hypostomal carina at the base of the mandible in nearly all of Glyptini and a small part of Lissonotini and Banchini; not joining hypostomal carina or joining it posterior to the base of the mandible in the rest.

Propodeal carinae absent or present only as short traces in Lycorini, and part of Banchini; with the apical transverse carina present (some other less conspicuous carinae may be behind it; any other carinae appear only as short traces) in Lissonotini, and part of Glyptini and Banchini; and with additional or other carinae in the rest of Glyptini and Banchini. Propodeal spiracle with its maximum diameter not more than 1.5 times its minimum diameter in Glyptini, Lycorini, a large part of Lissonotini, and a small part of Banchini; more than 1.5 times its shortest diameter in the rest of Lissonotini and Banchini.

Ovipositor more than half the length of the abdomen in Glyptini, Lycorini, and nearly all of Lissonotini; less than half the length of the abdomen in Banchini and the rest of Lissonotini.

Key to Tribes of Scolobatinae

(Scolobatini Not Known to be Present)

1. Some or all of the segments within the central half of the flagellum distinctly compressed, at least 1.5 times as deep as wide [I[5,6]] .... EUCERATINI

   Flagellar segments all less than 1.5 times as deep as wide [I[3,4]] .... 2.

2. (1) Petiole long, with pre- and post-spiracular portions each more than twice as long as width of petiole at the spiracles; petiole strongly curved, so that in side view its ventral margin opposite the spiracles lies above a line drawn from the base of the sternite to the apex of the tergite (diagonally, not along the suture dividing the sternite from the tergite) [X[144]]; maxillary palpus slightly longer than the depth of the head .... CALLIDIOTINI

   Petiole relatively shorter in front of or behind the spiracles or in both places; or the petiole less strongly curved in side view; or the maxillary palpus shorter than the depth of the head .... 3.

3. (2) Maximum depth of eye more than 12 times the malar space (shortest distance between the eye and the base of the mandible) [III[40]]; inner dorsal longitudinal margin of hind wing cavity in metanotum (do not use the ventral margin next to the membrane of the wing) carinate [IV[51]], with the anterior portion of this carina produced dorsally so that its depth is at least 0.6 times the length of the carina (make measurements from the mesad side) and at least 0.25 of its depth projects above the transverse carina anterior to it ....CTENOPELMATINI

Maximum depth of eye not more than 10 times that of the malar space [III[45]]; **or** the inner dorsal margin of the hind wing cavity not carinate or with a carina that is not as deep anteriorly (the greatest depth in the anterior part either less than 0.6 times the length of the carina or less than 0.25 of its depth projects above the transverse carina in front of it) .... 4.

4. (3) Hind femur not more than 4.5 times as long as its greatest transverse dimension; propodeum with both longitudinal and transverse carinae in addition to those outlining the petiolar area .... 5.

Hind femur more than 4.5 times as long as its greatest transverse dimension; **or** propodeum without both longitudinal and transverse carinae, excluding carinae that may outline the petiolar area ....10.

5. (4) Petiole in dorsal view more than 4.5 times as long as the narrowest width of the postpetiole; petiole without a pit or groove laterally basad of the spiracle [X[145]]; central third or more of the apical margin of clypeus concave......PIONINI

Petiole in dorsal view less than 4.5 times as long as the narrowest width of the postpetiole; **or** petiole with a pit or groove laterally basad of the spiracle [X[136,143]]; **or** apical margin of clypeus truncate or convex.................... 6.

6. (5) Apical margin of clypeus convex [III[40,45]].................... 7.

Apical margin of clypeus truncate or concave in central third or more [III[39]] ....10.

7. (6) Eyes more than 1.1 times as far apart dorsally as ventrally; **or** females with ovipositor strongly upcurved.........PIONINI

Eyes not more than 1.1 times as far apart dorsally as ventrally; females with ovipositor straight or nearly so........ 8.

8. (7) Petiole in dorsal view not more than twice as long as wide; mandibular teeth approximately equal in size and shape ....PIONINI + perhaps a very small part of EURYPROCTINI

Petiole in dorsal view more than twice as long as wide; **or** dorsal mandibular tooth narrower at base than ventral tooth, and not more than 0.75 times as long as ventral tooth .... 9.

9. (8) Petiole with a pit or groove laterally basad of the spiracle ....MESOLEIINI + a small part of PIONINI

Petiole without a pit or groove laterally basad of the spiracle (carinae may border edges of petiole)........EURYPROCTINI

10. (4,6) Petiole with a pit or groove laterally basad of the spiracle ....MESOLEIINI
Petiole without a pit or groove laterally basad of spiracle (carinae may border edges of petiole)........EURYPROCTINI

NOTES ON THE TRIBES OF SCOLOBATINAE

EUCERATINI [I[5,6], VIII[104]]; PIONINI [III[43], VIII[105,106]]; CTENOPELMATINI [III[40], V[64], VIII[107]]; MESOLEIINI [III[39,45], VIII[108,109], X[149]]; EURYPROCTINI [V[60], VIII[110,111], X[145]]; CALLIDIOTINI [VIII[102], X[144]].

The tribes Euceratini, Mesoleiini, Euryproctini and Callidiotini are nearly always easy to separate from each other, and the characters in the key may largely or entirely separate the tribe Ctenopelmatini from the other tribes. The tribe Pionini resembles both the tribes Mesoleiini and Euryproctini; a few Mesoleiine females with the ovipositor upcurved, which are not yet represented in the University of Wisconsin entomology collection, may go into the tribe Pionini in the key.

KEY TO TRIBES OF OPHIONINAE

1. Abdomen beyond petiole almost entirely smooth and highly polished; lateral carina or fold on the second tergite incomplete, with the parts of the tergite above and below the fold thin and of the same consistency; lateral margin of second tergite not bent under sharply to form a carinate fold [X[141]] ....TERSILOCHINI
Abdomen beyond petiole largely sculptured; **or** the second tergite with a complete lateral fold or carina (the tergite may or may not be bent under sharply) which divides the tergite into parts of unlike thickness or consistency [X[131–140,142,143]].......... 2.
2. (1) Mid-tibia with two apical spurs; discoidella present; one intercubitus present, joining the cubitus more than half the length of the intercubitus beyond the junction of the second recurrent with the cubitus [IX[130]]..........................OPHIONINI
Mid-tibia with one apical spur; **or** discoidella absent; **or** two intercubiti present; **or** one intercubitus present which joins the cubitus less than half the length of the intercubitus beyond the junction of the second recurrent with the cubitus [IX[123,125]] .... 3.
3. (2) Whole propodeum (metapleura may be included also) with numerous (over 30) irregular areas set off by strong irregular ridges [IV[50]], the majority of which exceed in height 1.5 times the diameter of an eye facet (small rugosities may be present within these areas); profile of metapleura from dorsal view distinctly convex, not continuous with the lines formed by the sides of the mesothorax ....ANOMALINI

Propodeum with about 13 (or fewer) areas set off by the usual propodeal carinae [IV[51]] (the areas may contain rugosities of much shorter dimensions than the regular carinae, or certain localized parts, as the petiolar area, may contain rugosities subequal in height with the regular carinae), or, if covered with a network of small areas and ridges, the height of a great majority are not more than 1.0 times the diameter of an eye facet; profile of metapleura from dorsal view straight or nearly straight, and continuous or nearly continuous with the lines formed by the sides of the mesothorax.............. 4.

4. (3) Junction of mediella with nervellus more than 0.95 times as far from the junction of the subcostella and radiella as from the junction of the intercubitella and radiella (measure distances **between** the veins) [IX[124,125]]......................CREMASTINI

Junction of mediella with nervellus not more than 0.95 times as far from the junction of the subcostella and radiella as from the junction of the intercubitella and radiella [IX[121–123]] ....PORIZONINI

NOTES ON THE TRIBES OF OPHIONINAE

PORIZONINI [II[26], IX[117,124,128], X[137,155]]; CREMASTINI [I[13], IX[121,125], X[154]]; TERSILOCHINI [II[27], IX[129]]; ANOMALINI [II[16], IV[50], IX[118,122,126], X[134]]; OPHIONINI [I[1,2], V[53,58,63], IX[130]].

Face and clypeus distinctly or fairly distinctly separated in Cremastini and Tersilochini, part of Anomalini and Ophionini, and a small part of Porizonini; vaguely separated in most of the rest; not separated in part of Porizonini and Anomalini, and a small part of Ophionini. In dorsal view, span of occipital carina more than 0.7 times the greatest width of the head in nearly all Anomalini, part of Ophionini, and a very small part of Porizonini. Head black in Porizonini, part of Tersilochini, and rarely in the other tribes; otherwise in part or entirety other colors, as ferruginous, yellow, etc.

Tarsal claws conspicuously pectinate in Ophionini [V[58,63]]; distinctly but much less conspicuously pectinate in part of Porizonini and Cremastini, and a small part of Anomalini; slightly [V[64]] or not [V[57]] pectinate in the rest. Areolet present in most of Porizonini and a small part of Cremastini; otherwise absent. Hind wing as in the first part of couplet 4 in Cremastini and Tersilochini; as in the second part of the same couplet in the other tribes, but a very small part of Porizonini and Anomalini near the borderline. Maximum diameter of propodeal spiracle not more than 1.5 times its minimum diameter in all or most of Tersilochini, most of Cremastini, a large part of Porizonini, and a small part of Anomalini; in the rest more than 1.5 times its minimum diameter. Propodeum of part of Ophionini as well as all of Anomalini as in the first part of couplet 3; as in the second part of the same couplet, or without carinae or smooth, in the remainder.

Third abdominal segment at least twice as deep as wide in Anomalini, nearly all Ophionini and Cremastini, and part of Tersilochini and Porizonini; otherwise less compressed, but in these the depth usually subequal to or greater than the width. Ovipositor much less than the length of the abdomen in Ophionini, Anomalini, and part of Porizonini; about as long as or longer than the abdomen in Tersilochini, Cremastini, and the rest of Porizonini.

List of Subfamilies, Tribes and Genera Known to Occur in Wisconsin

PIMPLINAE

Pimplini
- Scambus
- Calliephialtes
- Pimpla
- Iseropus
- Tromatobia
- Zaglyptus
- Delomerista
- Perithous

Polysphinctini
- Laufeia
- Schizopyga
- Polysphincta
- Hymenoepimecis
- Oxyrrhexis
- Zatypota

Ephialtini
- Coccygomimus
- Ephialtes
- Itoplectis

Poemeniini
- Diacritus
- Poemenia
- Neoxorides

Rhyssini
- Rhyssa
- Megarhyssa
- Rhyssella

Theroniini
- Theronia

Labenini
- Labena
- Grotea

Xoridini
- Xorides
- Odontocolon
- Aplomerus

TRYPHONINAE

Adelognathini
- Pammicra
- Adelognathus

Phytodietini
- Phytodietus
- Netelia

Eclytini
- Eclytus
- Neliopisthus
- Hybophanes

Grypocentrini
- Idiogramma

Tryphonini
- Polyblastus
- Ctenochira
- Monoblastus
- Tryphon

Ctenisciini
- Acrotomus
- Eudiaborus
- Exenterus
- Smicroplectrus
- Exyston

GELINAE

Gelini
- Bathythrix
- Mastrus
- Otacustes
- Ethelurgus
- Stiboscopus
- Isdromas
- Phobetes
- Haplaspis
- Gelis
- Myersia
- Hemiteles
- Endasys
- Eriplanus
- Phygadeuon
- Stilpnus
- Atractodes
- Mesoleptus

Aptesini
- Cubocephalus
- Aptesis
- Megaplectes
- Schenkia
- Giraudia
- Polytribax
- Rhembobius

Mesostenini
- Christolia
- Trachysphyrus
- Pycnocryptus
- Mesostenus
- Polycyrtus
- Trychosis
- Idiolispa
- Gambrus
- Hoplocryptus
- Agrothereutes
- Ischnus
- Chromocryptus
- Lymeon
- Echthrus
- Helcostizus
- Acroricnus
- Messatoporus

ICHNEUMONINAE

Alomyini
- Phaeogenes
- Diadromus

Rhexidermus
Colpognathus
Dicaelotus

PRISTICERATINI
Platylabus
Ectopius

LISTRODROMINI
Neotypus

AMBLYTELINI
Hoplismenus
Melanichneumon
Cratichneumon
Aoplus
Ectopimorpha
Chasmias
Pseudamblyteles
Amblyteles
Pterocormus

ICHNEUMONINI
Ichneumon
Protichneumon

TROGINI
Catadelphus
Conocalama
Trogus

BANCHINAE

GLYPTINI
Glypta

LYCORINI
Toxophoroides

LISSONOTINI
Amersibia
Arenetra
Lampronota
Lissonota
Pimplopterus
Syzeuctus
Diradops

BANCHINI
Exetastes
Ceratogastra
Banchus

SCOLOBATINAE

EUCERATINI
Euceros

PIONINI
Rhorus
Pion

CTENOPELMATINI
Ctenopelma
Xenoschesis
Homaspis

MESOLEIINI
Opheltes
Perilissus
Absyrtus
Oetophorus
Labrossyta
Lathrolestes
Mesoleius
Lamachus

EURYPROCTINI
Dialges
Mesoleptidea
Hypamblys
Ipoctoninus
Anisotacrus
Hadrodactylus

CALLIDIOTINI
Callidiotes

ORTHOPELMA-TINAE
Orthopelma

PLECTISCINAE
Cylloceria
Dallatorrea
Eusterinx
Megastylus
Proclitus
Plectiscidea
Aperileptus

ORTHOCENTRINAE
Orthocentrus
Neurateles
Mnesidacus
Stenomacrus

DIPLAZONINAE
Diplazon
Zootrephus
Promethes
Syrphoctonus
Enizemum

METOPIINAE
Metopius
Pseudometopius
Chorinaeus
Periope
Colpotrochia
Triclistus
Hypsicera
Exochus

OPHIONINAE

PORIZONINI
Cymodusa
Campoplex
Idechthis
Casinaria
Campoletis
Bathyplectes
Dusona
Nepiera
Phobocampe
Horogenes
Hyposoter
Olesicampe

CREMASTINI
Dimophora
Pristomerus
Zaleptopygus
Cremastus

TERSILOCHINI
Tersilochus

ANOMALINI
Aphanistes
Barylypa
Gravenhorstia
Labrorychus
Atrometus
Therion
Heteropelma

OPHIONINI
Thyreodon
Ophion
Enicospilus

MESOCHORINAE
Astiphromma
Mesochorus

TABLE I — SUBFAMILY CHARACTERISTICS

Character	Category	Fig.	Pimp.	Tryph.	Gel.	Ichn.	Banch.	Scol.	Orthop.	Plect.	Orthoc.	Diplaz.	Metop.	Oph.	Mesoch.
* Separation of Face and Clypeus	Distinct	7-10	N	N	m	o	m	m	A	N	-	A	-	s	-
	Vague	26, 28, 29	r	r	o	m	o	o	-	r	r	-	o	u	r
	Absent	31, 36, 43	r	-	s	s	r	s	-	-	N	-	u	s	N
* Depression From Antennal Socket to Anterior Tentorial Pit	Distinct	23, 35	o	m	o	s	s	s	A	o	-	s	-	s	-
	Vague	27, 37	o	o	m	m	N	o		s	s	u	-	N	A
	Absent	7, 31	s	s	o	o		m	-	o	N	s	A		
* Facial Convexity	Slight to moderate	27-30	N	u	u	u	N	N	A	N	r	A	o	N	A
	Strong	15	r	s	s	o	s	r	-	s	N	-	o	s	-
	Bulged	31, 36	-	-	-	-	-	-	-	r		-		o	-
	Other	—	r	-	-	-	-	-	-	-	r	-	o	o	-
* Surface of Clypeus	Convex	18, 20	s	N	N	o	N	m	A	u	A	-	u	A	A
	Partly flat	28, 29	s	s	s	m	s	o	-	s	-	s	s		
	Other	7, 38, 46	u	r	r	s	s	s	-	s	-	N	-	-	-
* Apical Margin of Clypeus	Lobed	7, 35, 46	u	o	-	s	o	o	A	r	-	A	o	-	-
	Toothed	16, 25	s	-	s	s	-	s	-	-	-	-	-	s	-
	Convex	19-21	s	m	m	o	u	o	-	m	N	-	o	N	N
	Truncate	—	s	o	o	m	s	o	-	s		-	o		
	Other	—		r	r	s	r	r	-	s	r	-	-	-	s
* No. of Eye Facets Equalling Basal Width of Mandible	6 or under 6		r	-	r	-	-	-	-	A	A	-	-	r	r
	Over 6		N	A	N	A	A	A	A		-	A	A	N	N
	10 or under 10		s	r	o	r	A	r	A	N	-	s	s	N	N
	Over 10		u	N	m	N		N		s	-	N	N		

TABLE I (CONT.)

Character	Category	Fig.	Pimp.	Tryph.	Gel.	Ichn.	Banch.	Scol.	Orthop.	Plect.	Orthoc.	Diplaz.	Metop.	Oph.	Mesoch.
** Ratio Length Dorsal Mandibular Tooth to Ventral Mandibular Tooth	2 or over 2		s	o	s	N	r	-	-	o	m	-	s	r	-
	1 or over 1		N	N	N	N	N	o	-	N	-	-	A	N	-
	About 1		m	o	N	r	u	o	A	r	-	A		u	A
	Under 0.75		r	-	-	-	-	s	-	r	o	-	-	-	-
	1 tooth		s	-	-	-	-	-	-	-	r	-	-	-	-
** Ratio Length Shortest Side of Scape to Maximum Transverse Diameter	Under 1		u	u	u	N	N	o	r	s	-	s	u	o	-
	About 1		s	o	s	r	s	u	-	u	-	u	o	N	-
	1 or over 1		s	s	s	r	r	m	N	-	A	u	s	o	A
	Under 1.5		A	A	A	A	A	A	A	A	r	A	A	A	-
	1.5 or over 1.5		-	-	-	-	-	-	-	-	N	-	-	-	-
* Obliqueness of Opening of Scape	Slight	15-18	m	m	o	s	o	A	A	u	A	N	u	N	A
	Moderate	7, 11													
	Moderately Strong	20, 30			o	N			-		-	r	o	r	-
	Strong	23, 41	o	o	o		u	-	-	s	-	-	-	-	-
	Very Strong	8, 12				s		-	-		-	-	-	-	-
* Flagellum	Filiform	9	A	A	u	o	A	N	N	N	N	A	N	A	A
	Incrassate	3	-	-	o	o	-	-	r	r	r	-	s	-	-
	Submoniliform	—	-	-	s	o	-	-	-	-	-	-	-	-	-
	Part Flattened	5, 6	-	-	-	r	r	r	-	-	-	-	o	-	-
	Part D-cross-section	—	-	-	r		-		-	-	-	-	-	-	-
* Special Modifications of ♂ Flagellum	None	—	N	A	o	s	A	N	A	o	A	u	A	A	A
	Tyloids	3	-	-	m	u	-	-	-	o	-	o	-	-	-
	Notches	4	r	-	-	-	-	-	-	o	-	-	-	-	-
	Projections	6	-	-	-	-	-	-	-	o	-	-	-	-	-
	Other	—	-	-	-	-	-	-	-		-	-	-	-	-

TABLE I (CONT.)

Character	Category	Fig.	Pimp.	Tryph.	Gel.	Ichn.	Banch.	Scol.	Orthop.	Plect.	Orthoc.	Diplaz.	Metop.	Oph.	Mesoch.
* General Build of Thorax	Average	51, 54	m	N	u	m	N	A	A	N	N	N	o	u	A
	Heavyset	50	r	r	s	s	s	-	-	r	-	s	o	s	-
	Subblocky	48	s	-	s	o	-	-	-		-	-	o	-	-
	Elongate	47	o	-	-	r	-	-	-	-	r	-	-	-	-
	Deep	49	r	r	-	-	-	-	-	s		-	-	-	-
* Latero-posterior Margin of Mesoscutum (See Couplet 18)	Carina complete	47, 49-51	m	A	N	u	A	A	A	A	N	A	o	A	A
	Carina incomplete or absent	48, 52	o	-	s	o	-	-		-	r	-	m	-	-
* Ratio Length of Sternaulus to Length of Mesopleurum	0-0.5	49, 54	N	N	s	N	A	A	A	A	A	A	u	N	N
	Over 0.5	51	r	r	u	r	-	-	-	-	-	-	o	r	r
* Outer Margin of Apex of Fore Tibia	Not toothed	—	N	N	N	A	A	s	A	A	A	A	u	N	N
	Toothed	60	r	r	r	-	-	u	-	-	-	-	o	r	r
* Fore-, Mid-, Hind-Tibial Spurs	1-2-2		A	u	A	A	A	A	A	A	A	A	m	N	A
	1-1-0; 1-1-1		-	s	-	-	-	-	-	-	-	-	-	-	-
	1-2-1		-	-	-	-	-	-	-	-	-	-	o	-	-
	1-1-2		-	-	-	-	-	-	-	-	-	-		r	-
* Ratio Length Longer Hind Tibial Spur to Length Inner Apical or Subapical Tibial Setae	Over 5	59	o	m	m	N	N	u	-	s	-	A	A	N	A
	5 or under 5	—	u	o	o	r	r	o	A	N	A			r	-
* Ratio Length Shorter Spur to Length Longer Spur of Hind Tibia	Over 0.67	59	N	m	m	A	A	u	A	-	N	N	A	o	N
	0.67 or under 0.67	56	s	o	o			o	-	-	r	r	-	u	s
	Over 0.6	59	-	m	u	-	-	-	-	A	A	A	-	-	A
	0 or 1 spur	61	-	s	-	-	-	-	-	-	-	-	-	r	-

TABLE I (CONT.)

Character	Category		Fig.	Pimp.	Tryph.	Gel.	Ichn.	Banch.	Scol.	Orthop.	Plect.	Orthoc.	Diplaz.	Metop.	Oph.	Mesoch.
* Tarsal Claw	Simple		57	N	o	N	N	m	u	A	N	A	A	N	u	m
	Toothed		62	m	-	-	r	-	-	-	r	-	-	r	-	-
	Pecti-nate	Slightly	64	s	o	s	r	o	o	-	-	-	-	r	r	o
		Distinctly	58, 63	-	o	-	-			-	-	-	-			
* No. of Bullae in Second Recurrent	1			r	o	o	r	N	m	-	-	N	A	A	A	A
	2			N	u	m	N	r	o	A	A	r	-	-	-	-
* Areolet	Petiolate to subpetiolate		71, 74	m	m	-	r	u	m	-	o	s	A	s	m	N
	Absent		70	o	o	o	-	o	o	A	m	m		m	o	-
	Sessile		69, 75	s	r	u	N	r	-		-	o	-	o	r	r
	Sessile by position		87, 91	-	r	o	-	-	-		r		-	-	-	-
* Ratio Length 1st Intercubitus to Distance From 1st Intercubitus to 2nd Recurrent	Under 1			u	o	N	r	o	o	A	s	o	u	o	N	o
	About 1			o	o	m	o	o	o	-	s	u	m	m		u
	Over 1			s	m	s	N	m	m	-	u	s	s	o		o
	No 2nd recurrent			-	-	r	-	-	-	-	-	-	-	-	r	-
* Anterior End of 2nd Recurrent Within	Apical 0.3 areolet		79, 82	u	o	s	-	u	o	A	o	o	u	o	s	-
	Apical 0.3-0.5 areolet		71, 75			N	A		o						o	A
	Basal 0.5 areolet		87, 91	-	o					-	r	-	s	r		
	Undeterminable part of areolet		78	o	s	s	-	o	o	-	m	m	s	m	o	-
	Cell outside areolet		77	r	r	-	-	-	-	-	-	-	-	-	s	-
* Discoidella Joining Nervellus	Within anterior 0.25			s	-	-	-	o	-	-	-	-	-	-	-	-
	Within posterior 0.75			u	A	N	A	m	A	-	m	o	A	A	o	s
	Not joining			-	-	s	-	-	-	A	o	m	-	-	m	u
* Ratio Maximum Diameter to Minimum Diameter of Propodeal Spiracle	About 1			o	m	o	s	o	o	A	o	A	A	m	m	N
	1.5 or under 1.5			m	m	m	s	u	m	-	N	A	A	u	u	-
	Over 1.5			o	o	o	u	o	o	-	r	-	-	o	o	-

TABLE I (CONT.)

Character	Category	Fig.	Pimp.	Tryph.	Gel.	Ichn.	Banch.	Scol.	Orthop.	Plect.	Orthoc.	Diplaz.	Metop.	Oph.	Mesoch.
* Propodeal Carinae	None or traces		o	o	s	-	o	o	-	s	r	m	r	s	-
	Longitudinal+Transverse		o	m	m	A	o	o	A	u	u	o	u	u	A
	Most or all Longitud.		o	r	-	-	o	o	-	r	s	-	o	-	-
	Most or all Transverse		r	-	o	-	-	-	-	r	-	-	-	-	-
	Otherwise		r	-	s	-	r	-	-	-	-	s	-	s	-
* Ratio Length to Width of Abdomen Beyond Petiole	Under 2	—	r	r	m	s	-	r	-	r	-	r	-	-	r
	About 2-4.5	135-139	u	m	m	u	N	u	A	N	o	N	N	u	N
	Over 4.5	131, 134	o	o	s	r	o	s	-	-	m	r	r	o	s
* Sides of Petiole From Base to Apex (Seen From Above)	Parallel to subparallel		m	o	r	-	N	s	A	s	o	A	o	r	-
	Divergent		o	m	o	r		u	-	u	m	-	m	r	A
	Base subparallel, apex divergent		-	r	m	N	-	s	-	r	-	-	r	N	
	Other		-	r	r	-	r	r	-	r	-	-	r	-	-
* Dorsal Basal Concavity of Petiole	Large	135, 136	o	o	-	-	u	o	-	r	A	A	N	-	r
	Small	140	o	o	s	s	s	o	A	N				A	N
	Vague	—					-	s			-	-	r		
	Absent	134	o	s	u	u	-	o	-	r	-	-	-		s
* Dorsal Longitudinal Carinae of Petiole	Strong	138	s	o	r	r	-	r	-	s	-	o	o	-	-
	Weak	142	u	o	o	m	u		A	s	A	o	m	-	-
	Trace	—						N		u				-	s
	Absent	134	s	o	u	o	s					o	r	A	N
* Shape of Petiole in Side View (Ventral Margin Especially)	Straight	132, 145	u	m	s	-	N	A	-	o	N	A	N	u	A
	Arched	143, 144	o	o	o	s	s		A	m	r	-	r		
	Geniculate	137, 139	-	-	m	N	-	-	-	-	-	-	-	s	-
	Upcurved	131	r	-	-	-	-	-	-	-	-	-	-	s	-

TABLE I (CONT.)

Character	Category	Fig.	Pimp.	Tryph.	Gel.	Ichn.	Banch.	Scol.	Orthop.	Plect.	Orthoc.	Diplaz.	Metop.	Oph.	Mesoch.
** Spiracles of Petiole Within	Basal 0.5		N	N	-	-	A	u	A	-	A	A	N	-	-
	Basal 0.6		A	N	-	-	-	A	-	A	-	-	A	-	A
	Basal 0.4-0.6		-	-	-	-	-	u	-	A	-	-	-	-	A
	Apical 0.6		-	-	A	-	-	-	-	-	-	-	-	-	-
	Apical 0.5		-	r	-	A	-	-	-	-	-	-	-	A	-
* Lateral Pit or Groove Basad of Spiracle in Petiolar Tergite	Present	133, 135	m	N	-	-	N	m	A	u	A	s	N	o	A
	Vague	—	s	s	-	s	r	s			-	N			-
	Absent	137, 145	s		A	N	-	o		o	-	s	r	m	-
** Ratio Depth to Width of Abdominal Segment 3	Under 1	136, 139	N	m	u	N	u	u	A	m	o	u	N	o	N
	About 1	137	r	s	s	r	-	o	-	-	u	-	-	-	-
	Over 1	141, 142	-	o	s	r	o	o	-	o	m	o	r	u	s
	2 or over 2	134	-	o	r	-	-	r	-	r	r	r	-	o	?
** Ratio Length of Ovipositor to Length of Petiole	Under 0.5		r	o	s	s	o	u	-	s	u	s	o	o	s
	0.5 or over 0.5		N	m	N	u		o	-	u		N	m	m	u
	About 1		s	o	-	o	s	r	-	-		u	-	-	-
	Over 1		u	o	N	o	m	r	A	m	s	s	o	o	r
** Ratio Length of Ovipositor to Length of Abdomen	Under 0.25		s	o	s	u	o	N	-	r	N	u	u	o	o
	Over 0.5		u	r	N	-	-	r	N	m	r	-	r	o	-
	About 1		o	-	o	-	s	-	s	-	-	-	-	-	-
	Over 1		m	-	s	-	m	-	m	m	r	-	-	s	-
* Ovipositor With	Dorsal notch: Present	132, 135	-	o	o	s	A	N	-	m	s	A	u	u	N
	Dorsal notch: Small	132, 150	-	o	o	s	A	s	-	m	s	-	-	o	u
	Ridges	131	u	o	u	N	-	r	A	s	r	-	-	-	s
	Neither	139-142	s	o	s	r	-	r		o	N	-	o	o	s
	Both	149, 150	-	s	o	s	-	r	-	s	r	-	-	-	s

TABLE 2 — STRUCTURES USEFUL IN SEPARATING SUBFAMILIES

	Gelinae	Tryphoninae	Pimplinae
Ichn.	Wings; sternaulus; mandibles; propodeum; apex of ♀ abdomen.	Petiole; areolet.	Abdomen (especially petiole); areolet.
Gel.		Petiole; areolet; sternaulus; head color with some combinations of these characters.	Petiole; areolet; sternaulus; 2nd recurrent; abdomen posterior to petiole; tarsal claws.
Tryph.			Claws; abdomen; clypeus; tibial spurs; proportion of thorax; sculpture of genae and mesoscutum; ovipositor; no. of hamuli.

	Banchinae	Scolobatinae	Plectiscinae	Ophioninae
Scol.	Fore tibiae; abdomen (including petiole); propodeum; scape; hind wing; ovipositor.			
Plect.	2nd recurrent; hind tibiae; mandibles; ♂ antennae.	Mandibles; hind tibiae; ovipositor; ♂ antennae.		
Oph.	Abdomen (especially petiole); propodeum; mesosternum.	Abdomen (especially petiole); propodeum; mesosternum.	2nd recurrent; propodeum; mesosternum.	
Pimp.	2nd recurrent; junction of hypostomal and occipital carinae; ovipositor.	Scape; abdomen; claws; proportion of thorax; antennae; sculpture of mesoscutum and genae; ovipositor.	Hind tibiae; mandibles; abdomen; proportion of thorax; antennae; ovipositor.	2nd recurrent; petiole; propodeum.
Tryph.	2nd recurrent; hind wing; propodeum; abdomen; ovipositor.	Tibiae; antennae; separation; of face and clypeus; petiole.	Mandibles; hind tibiae; ♂ antennae; ovipositor.	2nd recurrent; petiole; abdomen; areolet; propodeum; mesosternum.
Gel.	Petiole; areolet.	Petiole; areolet; sternaulus.	2nd recurrent; hind tibiae; sternaulus; areolet; stigma; sculpture of face and mesopleurum; ♂ antennae; petiole.	2nd recurrent; abdomen; areolet; propodeum; mesosternum; sculpture of face and mesoscutum.
Ichn.	Petiole; areolet; 2nd recurrent.	Petiole; areolet.	Mandibles; hind tibiae; ♂ antennae; ovipositor.	2nd recurrent; areolet; propodeum; mesosternum; sculpture of face and mesoscutum.

PLATE I

Heads and Head Appendages

Fig. 1. OPHIONINAE, OPHIONINI, Ophion bilineatus ♀.

Fig. 2. OPHIONINAE, OPHIONINI, Enicospilus sp. ♂. Head from beneath.

Fig. 3. GELINAE, GELINI, Endasys sp. ♂. Several segments near middle of left flagellum from outer side and slightly above and in front. Fig. 3B diagrammatic cross-section of a segment in fig. 3A.

Fig. 4. PIMPLINAE, PIMPLINI, Zaglyptus incompletus ♂. Same as fig. 3, without diagrammatic cross-section of a segment.

Fig. 5. SCOLOBATINAE, EUCERATINI, Euceros sp. ♀. Same as Fig. 3.

Fig. 6. SCOLOBATINAE, EUCERATINI, Euceros sp. ♂. Same as Fig. 4.

Fig. 7. PIMPLINAE, PIMPLINI, Scambus sp. ♀.

Fig. 8. PIMPLINAE, POEMENIINI, Neoxorides borealis ♀.

Fig. 9. PIMPLINAE, XORIDINI, Xorides sp. ♀.

Fig. 10. PIMPLINAE, LABENINI, Grotea sp. ♂.

Fig. 11. PIMPLINAE, POLYSPHINCTINI, Laufeia slossonae ♂.

Fig. 12. PIMPLINAE, EPHIALTINI, Itoplectis conquisitor ♀. Fig. 12B left scape of fig. 12A, showing "apical triangle".

Fig. 13. OPHIONINAE, CREMASTINI, Zaleptopygus sp. ♂.

Fig. 14. TRYPHONINAE, PHYTODIETINI, Netelia sp. ♂.

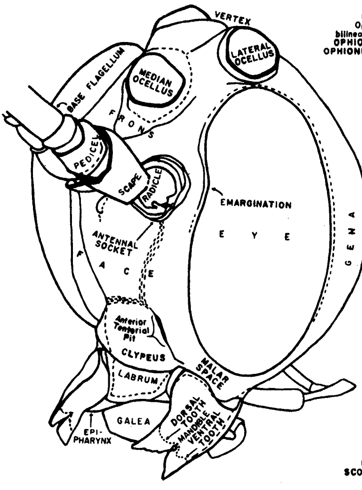


FIG. 1 Ophion bilineatus ♀ OPHIONINI OPHIONINAE

FIG. 2 Enicospilus sp. ♂ OPHIONINI OPHIONINAE

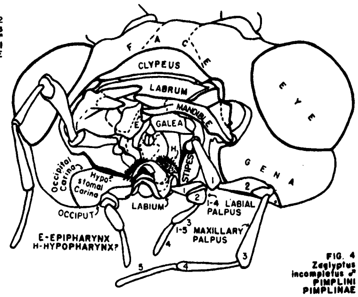


FIG. 4 Zaglyptus incompletus ♂ PIMPLINI PIMPLINAE

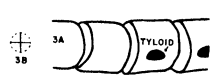
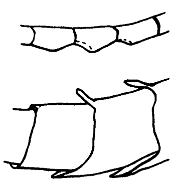


FIG. 3 Endasys sp. ♂ GELINI GELINAE



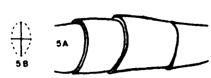


FIG. 5 Euceros sp. ♀ EUCERATINI SCOLOBATINAE

FIG. 6 Euceros sp. ♂ EUCERATINI SCOLOBATINAE

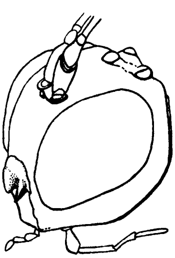


FIG. 7 Scambus sp. ♀ PIMPLINI PIMPLINAE

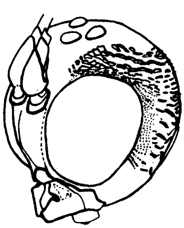


FIG. 8 Neoxorides borealis ♀ POEMENINI PIMPLINAE

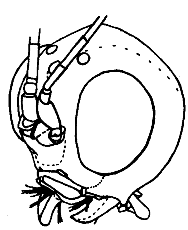


FIG. 9 Xorides SP. ♀ XORIDINI PIMPLINAE

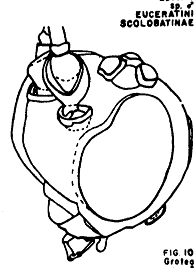


FIG. 10 Grotea sp. ♂ LABENINI PIMPLINAE

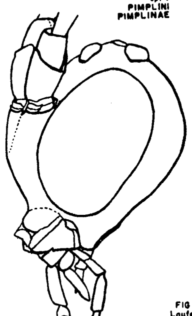
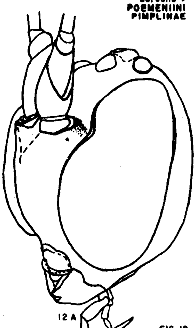


FIG 11 Laufeia slossonae ♂ POLYSPHINCTINI PIMPLINAE



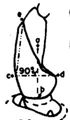


FIG. 12 Itoplectis conquisitor ♀ EPHIALTINI PIMPLINAE

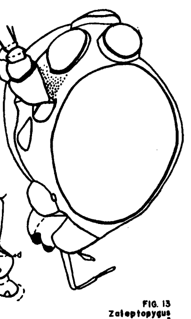


FIG. 13 Zaleptopygus sp. ♂ CREMASTINI OPHIONINAE

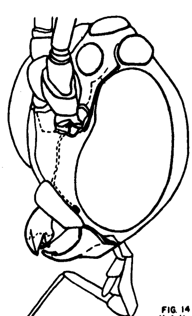


FIG. 14 Netelia sp. ♂ PHYTODIETINI TRYPHONINAE

PLATE II

Heads

Fig. 15. GELINAE, GELINI, *Endasys* sp. ♂.

Fig. 16. OPHIONINAE, ANOMALINI, *Barylypa* sp. ♀.

Fig. 17. TRYPHONINAE, GRYPOCENTRINI, *Idiogramma comstockii* ♀.

Fig. 18. ICHNEUMONINAE, ALOMYINI, *Dicaelotus* sp. ♂.

Fig. 19. GELINAE, GELINI, *Gelis* sp. ♂.

Fig. 20. TRYPHONINAE, CTENISCINI, *Exyston variatus* ♀.

Fig. 21. TRYPHONINAE, ECLYTINI, *Neliopisthus semirufus* ♂.

Fig. 22. TRYPHONINAE, ADELOGNATHINI, *Adelognathus* sp. ♀.

Fig. 23. GELINAE, MESOSTENINI, *Mesostenus gracilis* ♂.

Fig. 24. PIMPLINAE, THERONIINI, *Theronia hilaris* ♂.

Fig. 25. PIMPLINAE, RHYSSINI, *Rhyssella nitida* ♀.

Fig. 26. OPHIONINAE, PORIZONINI, *Campoplex* sp. ♀.

Fig. 27. OPHIONINAE, TERSILOCHINI, *Tersilochus* sp. ♂.

Fig. 28. ICHNEUMONINAE, AMBLYTELINI, *Pterocormus* sp. ♂.

Fig. 29. ICHNEUMONINAE, LISTRODROMINI, *Neotypus* sp. ♀.

Fig. 30. BANCHINAE, BANCHINI, *Exetastes angustoralis* ♂.

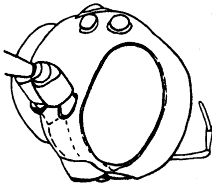


FIG. 15
Endasys
sp. ♂
GELINI
GELINAE

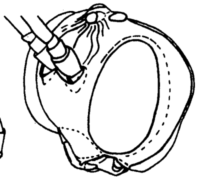


FIG. 16
Barylypa
sp. ♀
ANOMALINI
OPHIONINAE

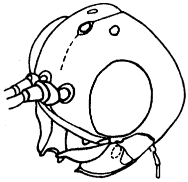


FIG. 17
Idiogramma
comstockii ♀
GRYPOCENTRINI
TRYPHONINAE

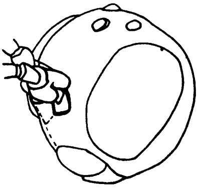


FIG. 18
Dicaelotus
sp. ♂
ALOMYINI
ICHNEUMONINAE

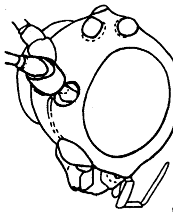


FIG. 19
Gelis
sp. ♂
GELINI
GELINAE

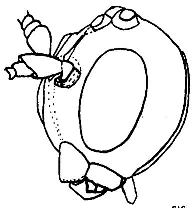


FIG. 20
Exyston
variatus ♀
CTENISCINI
TRYPHONINAE

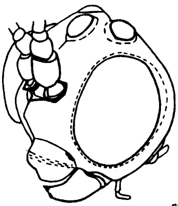


FIG. 21
Neliopisthus
semirufus ♂
ECLYTINI
TRYPHONINAE

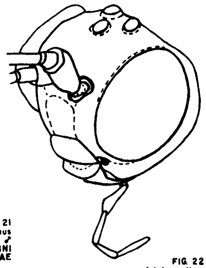


FIG. 22
Adelognathus
sp. ♀
ADELOGNATHINI
TRYPHONINAE

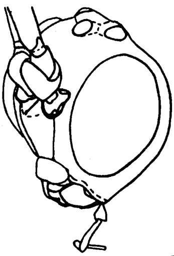


FIG. 23
Mesostenus
gracilis ♂
MESOSTENINI
GELINAE

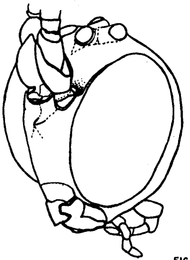


FIG. 24
Theronia
hilaris ♂
THERONIINI
PIMPLINAE

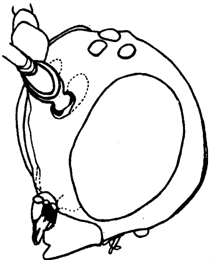


FIG. 25
Rhyssella
nitida ♀
RHYSSINI
PIMPLINAE

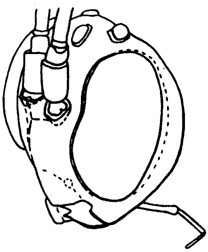


FIG. 26
Campoplex
sp. ♀
PORIZONINI
OPHIONINAE

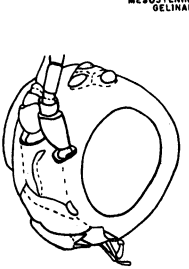


FIG. 27
Tersilochus
sp. ♂
TERSILOCHINI
OPHIONINAE

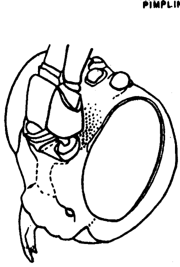


FIG. 28
Pterocormus
sp. ♂
AMBLYTELINI
ICHNEUMONINAE

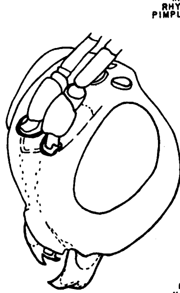


FIG. 29
Neotypus
sp. ♀
LISTRODROMINI
ICHNEUMONINAE

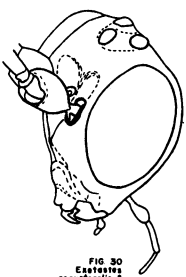


FIG. 30
Exetastes
angustoralis ♀
BANCHINI
BANCHINAE

PLATE III

Heads

Fig. 31. METOPIINAE, *Exochus* sp. ♀.

Fig. 32. PLECTISCINAE, *Plectiscidea* sp. ♂.

Fig. 33. BANCHINAE, GLYPTINI, *Glypta* sp. ♀ .

Fig. 34. PLECTISCINAE, *Cylloceria* sp. ♀ .

Fig. 35. ORTHOPELMATINAE, *Orthopelma mediator* ♂ .

Fig. 36. ORTHOCENTRINAE, *Orthocentrus stigmatias* ♂ .

Fig. 37. BANCHINAE, LISSONOTINI, *Pimplopterus* sp. ♂ .

Fig. 38. DIPLAZONINAE, *Diplazon laetatorius* ♀ .

Fig. 39. SCOLOBATINAE, MESOLEIINI, *Lamachus* sp. ♀ .

Fig. 40. SCOLOBATINAE, CTENOPELMATINI, *Xenoschesis cinctiventris* ♀ .

Fig. 41. GELINAE, APTESINI, *Cubocephalus* sp. ♀ .

Fig. 42. BANCHINAE, LYCORINI, *Toxophoroides* sp. ♀ .

Fig. 43. SCOLOBATINAE, PIONINI, *Rhorus* sp. ♀ .

Fig. 44. MESOCHORINAE, *Astiphromma pectorale* ♂ .

Fig. 45. SCOLOBATINAE, MESOLEIINI, *Opheltes glaucopterus* ♀ .

Fig. 46. ICHNEUMONINAE, TROGINI, *Conocalama brullei* ♀ .

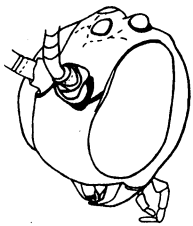


FIG. 31
Exochus
sp. ♀
METOPIINAE

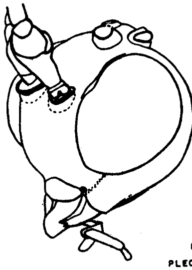


FIG. 32
Plectiscidia
sp. ♂
PLECTISCINAE

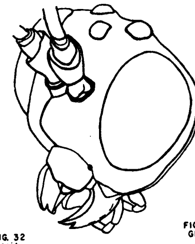


FIG. 33
Glypta
sp. ♀
GLYPTINI
BANCHINAE

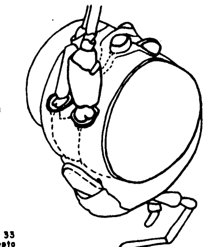


FIG. 34
Cylloceria
sp. ♀
PLECTISCINAE

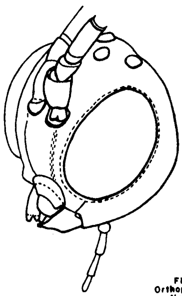


FIG. 35
Orthopelma
mediator ♂
ORTHOPELMATINAE

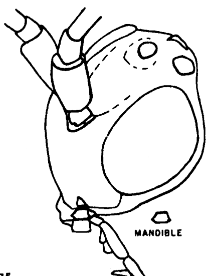


FIG. 36
Orthocentrus
stigmatias ♂
ORTHOCENTRINAE

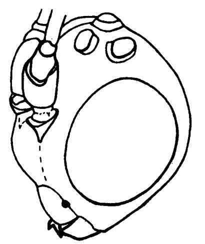


FIG. 37
Pimplopterus
sp. ♂
LISSONOTINI
BANCHINAE

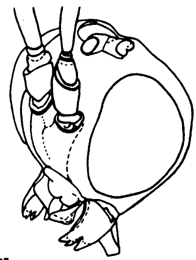


FIG. 38
Diplazon
laetatorius ♀
DIPLAZONINAE

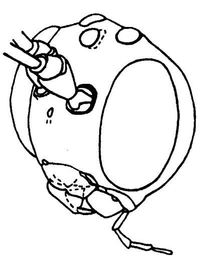


FIG. 39
Lamachus
sp. ♀
MESOLEIINI
SCOLOBATINAE

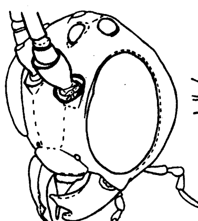


FIG. 40
Xenoschesis
cinctiventris ♀
CTENOPELMATINI
SCOLOBATINAE

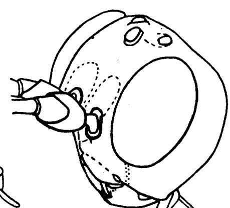


FIG. 41
Cubocephalus
sp. ♀
APTESINI
GELINAE

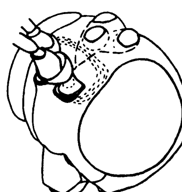


FIG. 42
Toxophoroides
sp. ♀
LYCORINI
BANCHINAE

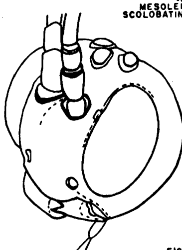


FIG. 43
Rhorus
sp. ♀
PIONINI
SCOLOBATINAE

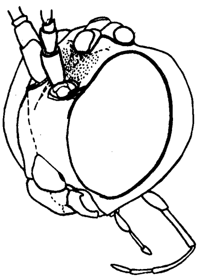


FIG. 44
Astiphromma
pectorale ♂
MESOCHORINAE

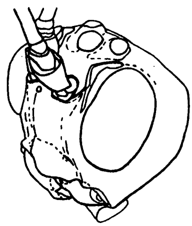


FIG. 45
Opheltes
glaucopterus ♀
MESOLEIINI
SCOLOBATINAE

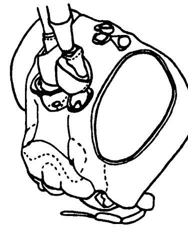


FIG. 46
Conocalama
brullei ♀
TROGINI
ICHNEUMONINAE

PLATE IV

Thoraces

Fig. 47. PIMPLINAE, XORIDINI, Xorides humeralis ♀.

Fig. 48. METOPIINAE, Hypsicera femoralis ♀.

Fig. 49. PLECTISCINAE, Aperileptus sp. ♀.

Fig. 50. OPHIONINAE, ANOMALINI, Therion morio ♀.

Fig. 51. GELINAE, GELINI, Bathythrix peregrina ♀.

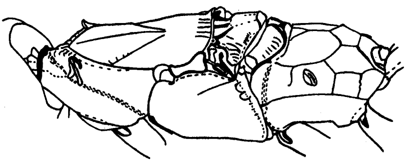


FIG. 47
Xorides
humeralis ♀
XORIDINI
PIMPLINAE

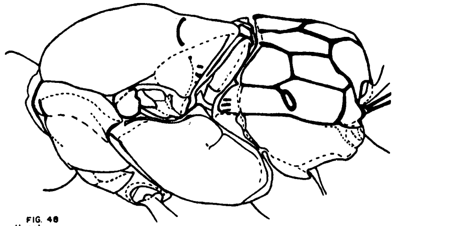


FIG. 48
Hypsicera
femoralis ♀
METOPIINAE

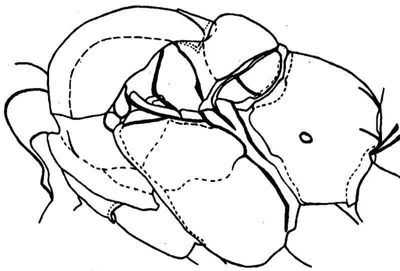


FIG. 49
Aperileptus
sp. ♀
PLECTISCINAE

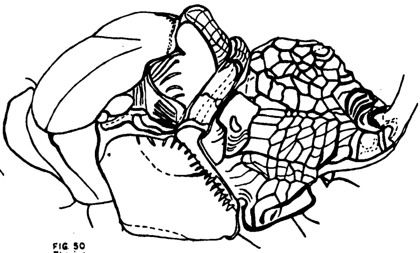


FIG. 50
Therion
morio ♀
ANOMALINI
OPHIONINAE

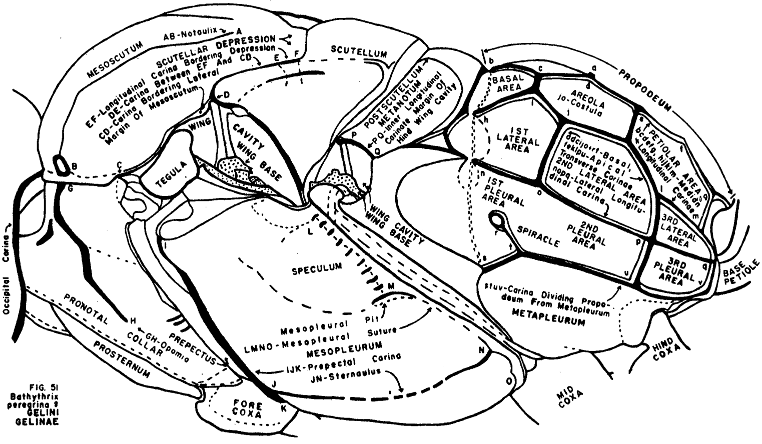


FIG. 51
Bathythrix
peregrina ♀
GELINI
GELINAE

PLATE V

Thoraces and Thoracic Parts

Fig. 52. GELINAE, GELINI, Gelis sp. ♀ .

Fig. 53. OPHIONINAE, OPHIONINI, Enicospilus sp. ♂ . Thorax from beneath, to the left and behind.

Fig. 54. ORTHOPELMATINAE, Orthopelma mediator ♂. Mesopleurum from side view.

Fig. 55. BANCHINAE, LISSONOTINI, Pimplopterus sp. ♂ . Propodeum from the side, above and slightly behind.

Fig. 56. METOPIINAE, Hypsicera femoralis ♀ . Left hind leg from outer side.

Fig. 57. PIMPLINAE, PIMPLINI, Pimpla irritator ♂ . Outer left hind tarsal claw from outer side.

Fig. 58. OPHIONINAE, OPHIONINI, Ophion bilineatus ♂ . Same as Fig. 57.

Fig. 59. PLECTISCINAE, Plectiscidea sp. ♂ . Apex of left hind tibia from inner, slightly to the front and end view.

Fig. 60. SCOLOBATINAE, EURYPROCTINI, Ipoctoninus uniformis ♀ . Apex of left fore tibia from inner side.

Fig. 61. TRYPHONINAE, CTENISCINI, Smicroplectrus sp. ♀ . Apex of left hind tibia from outer front view.

Fig. 62. PIMPLINAE, PIMPLINI, Pimpla irritator ♀ . Outer left hind tarsal claw from outer side.

Fig. 63. OPHIONINAE, OPHIONINI, Ophion bilineatus ♀ . Same as Fig. 62.

Fig. 64. SCOLOBATINAE, CTENOPELMATINI, Homaspis sp. ♀ . Same as Fig. 62.

Fig. 65. GELINAE, APTESINI, Aptesis sp. ♀ . Right wings.

Fig. 66. ICHNEUMONINAE, AMBLYTELINI, Aoplus cincticornis ♂. Right wings.

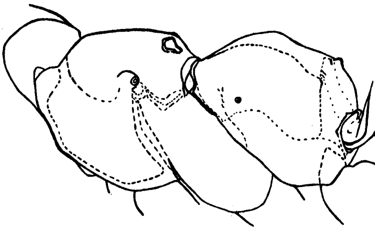


FIG. 52
Gelis
sp. ♀
GELINI
GELINAE

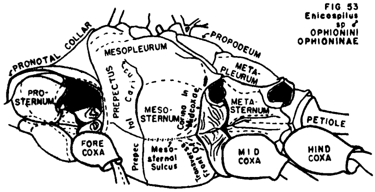


FIG 53
Enicospilus
sp ♂
OPHIONINI
OPHIONINAE

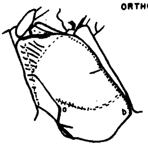


FIG. 54
Orthopelma
mediator ♂
ORTHOPELMATINAE

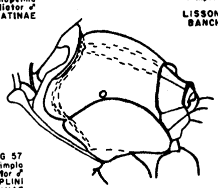


FIG. 55
Pimplopterus
sp. ♂
LISSONOTINI
BANCHINAE

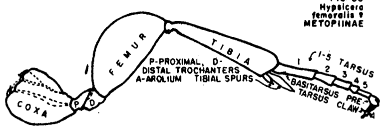


FIG 56
Hypsicera
femoralis ♀
METOPIINAE

FIG 57
Pimpla
irritator ♂
PIMPLINI
PIMPLINAE

FIG. 58
Ophion
bilineatus ♂
OPHIONINI
OPHIONINAE

FIG. 59
Plectiscidea
sp. ♂
PLECTISCINAE

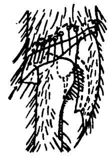


FIG. 60
Ipoctoninus
uniformis ♀
EURYPROCTINI
SCOLOBATINAE

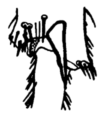


FIG. 61
Smicroplectrus
sp. ♀
CTENISCINI
TRYPHONINAE

FIG 62
Pimpla
irritator ♀
PIMPLINI
PIMPLINAE

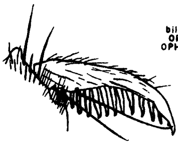


FIG. 63
Ophion
bilineatus ♀
OPHIONINI
OPHIONINAE

FIG. 64
Homaspis
sp. ♀
CTENOPELMATINI
SCOLOBATINAE

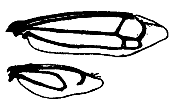


FIG 65
Aptesis
sp ♀
APTESINI
GELINAE

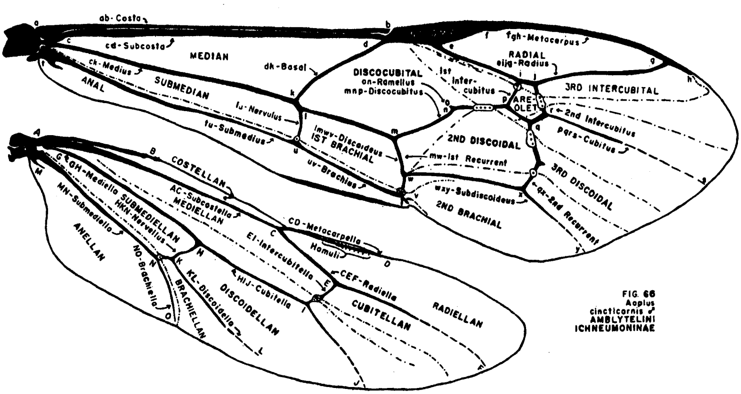


FIG. 66
Aoplus
cincticornis ♂
AMBLYTELINI
ICHNEUMONINAE

PLATE VI

Right Wings

Fig. 67. PIMPLINAE, PIMPLINI, Calliephialtes sp. ♀.

Fig. 68. PIMPLINAE, PIMPLINI, Zaglyptus sp. ♀ .

Fig. 69. PIMPLINAE, POLYSPHINCTINI, Laufeia sp. ♀ .

Fig. 70. PIMPLINAE, POLYSPHINCTINI, Polysphincta sp. ♀ .

Fig. 71. PIMPLINAE, EPHIALTINI, Itoplectis conquisitor ♀.

Fig. 72. PIMPLINAE, POEMENIINI, Diacritus muliebris ♀ .

Fig. 73. PIMPLINAE, RHYSSINI, Megarhyssa macrurus ♂.

Fig. 74. PIMPLINAE, THERONIINI, Theronia hilaris ♀ .

Fig. 75. PIMPLINAE, LABENINI, Labena grallator ♂.

Fig. 76. PIMPLINAE, XORIDINI, Odontocolon mellipes ♀ .

Fig. 77. PIMPLINAE, ACAENITINI, Arotes amoenus ♂.

Fig. 78. TRYPHONINAE, ADELOGNATHINI, Adelognathus sp. ♀.

Fig. 79. TRYPHONINAE, PHYTODIETINI, Netelia sp. ♂ .

Fig. 80. TRYPHONINAE, ECLYTINI, Neliopisthus densatus ♂ .

Fig. 81. TRYPHONINAE, GRYPOCENTRINI, Idiogramma comstockii ♀.

Fig. 82. TRYPHONINAE, TRYPHONINI, Polyblastus pedalis ♀ .

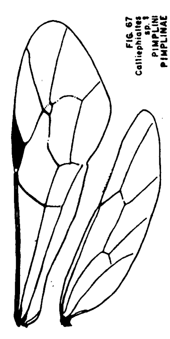


FIG. 67 Calliephialtes sp. ♀ PIMPLINI PIMPLINAE

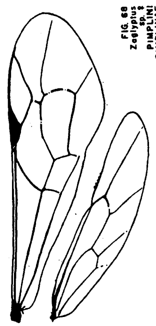


FIG. 68 Zaglyptus sp. ♀ PIMPLINI PIMPLINAE

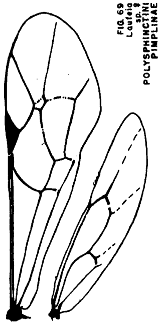


FIG. 69 Laufeia sp. ♀ POLYSPHINCTINI PIMPLINAE

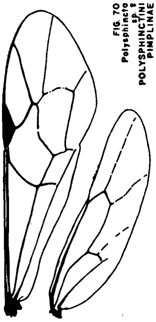


FIG. 70 Polysphincta sp. ♀ POLYSPHINCTINI PIMPLINAE

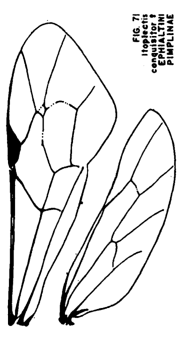


FIG. 71 Itoplectis conquisitor ♀ EPHIALTINI PIMPLINAE

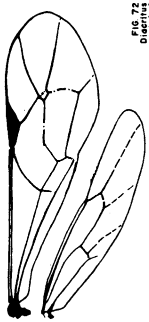


FIG. 72 Diacritus muliebris ♀ POEMENIINI PIMPLINAE

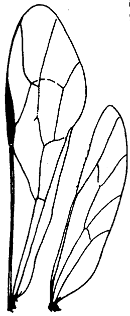


FIG. 73 Megarhyssa macrurus ♂ RHYSSINI PIMPLINAE

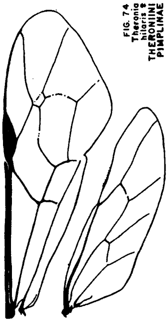


FIG. 74 Theronia hilaris ♀ THERONIINI PIMPLINAE


FIG. 75 Labena grallator ♂ LABENINI PIMPLINAE

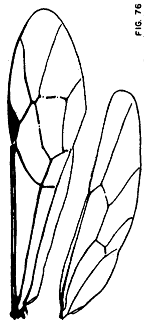


FIG. 76 Odontocolon mellipes ♀ XORIDINI PIMPLINAE

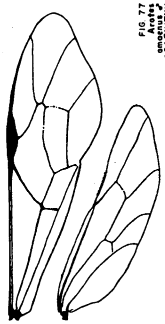


FIG. 77 Arotes amoenus ♂ ACAENITINI PIMPLINAE

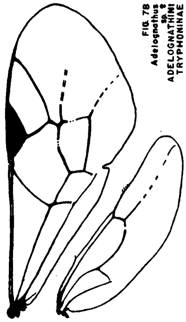


FIG. 78 Adelognathus sp. ♀ ADELOGNATHINI TRYPHONINAE

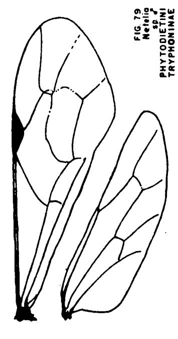


FIG. 79 Netelia sp. ♂ PHYTODIETINI TRYPHONINAE

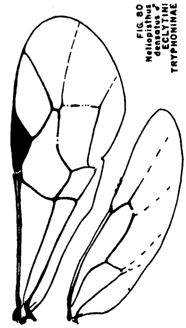


FIG. 80 Neliopisthus densatus ♂ ECLYTINI TRYPHONINAE

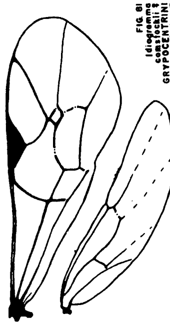


FIG. 81 Idiogramma comstockii ♀ GRYPOCENTRINI TRYPHONINAE

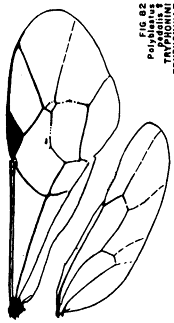


FIG. 82 Polyblastus pedalis ♀ TRYPHONINI TRYPHONINAE

PLATE VII

Right Wings

Fig. 83. TRYPHONINAE, CTENISCINI, Exenterus canadensis ♀.

Fig. 84. GELINAE, GELINI, Haplaspis sp. ♀.

Fig. 85. GELINAE, GELINI, Gelis sp. ♂.

Fig. 86. GELINAE, GELINI, Otacustes crassus ♂.

Fig. 87. GELINAE, APTESINI, Rhembobius sp. ♀.

Fig. 88. GELINAE, MESOSTENINI, Trachysphyrus sp. ♀.

Fig. 89. GELINAE, MESOSTENINI, Agrothereutes sp. ♂.

Fig. 90. GELINAE, MESOSTENINI, Messatoporus ferrum-equinum ♂.

Fig. 91. ICHNEUMONINAE, ALOMYINI, Diadromus sp. ♀.

Fig. 92. ICHNEUMONINAE, PRISTICERATINI, Platylabus sp. ♀.

Fig. 93. ICHNEUMONINAE, LISTRODROMINI, Neotypus sp. ♀.

Fig. 94. ICHNEUMONINAE, AMBLYTELINI, Cratichneumon paratus ♂.

Fig. 95. ICHNEUMONINAE, ICHNEUMONINI, Ichneumon viola ♀.

Fig. 96. ICHNEUMONINAE, TROGINI, Catadelphus buccatus ♀.

Fig. 97. PLECTISCINAE, Eusterinx sp. ♂.

Fig. 98. PLECTISCINAE, Aperileptus sp. ♀.

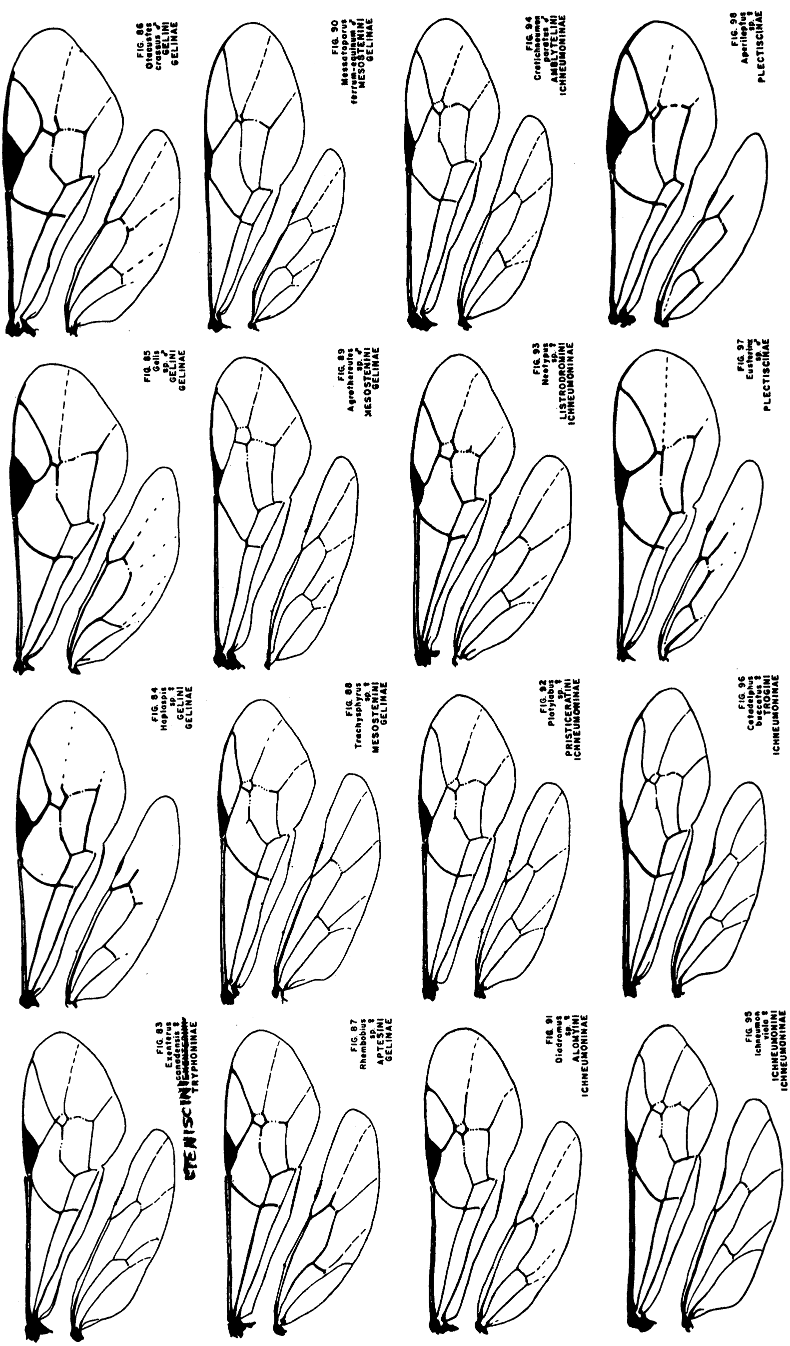


FIG. 86 Otacustes crassus ♂ GELINI GELINAE
FIG. 90 Messatoporus ferrum-equinum ♂ MESOSTENINI GELINAE
FIG. 94 Cratichneumon paratus ♂ AMBLYTELINI ICHNEUMONINAE
FIG. 98 Aperileptus sp. ♀ PLECTISCINAE
FIG. 85 Gelis sp. ♂ GELINI GELINAE
FIG. 89 Agrothereutes sp. ♂ MESOSTENINI GELINAE
FIG. 93 Neotypus sp. ♀ LISTRODROMINI ICHNEUMONINAE
FIG. 97 Eusterinx sp. ♂ PLECTISCINAE
FIG. 84 Haplaspis sp. ♀ GELINI GELINAE
FIG. 88 Trachysphyrus sp. ♀ MESOSTENINI GELINAE
FIG. 92 Platylabus sp. ♀ PRISTICERATINI ICHNEUMONINAE
FIG. 96 Catadelphus buccatus ♀ TROGINI ICHNEUMONINAE
FIG. 83 Exenterus canadensis ♀ CTENISCINI TRYPHONINAE
FIG. 87 Rhembobius sp. ♀ APTESINI GELINAE
FIG. 91 Diadromus sp. ♀ ALOMYINI ICHNEUMONINAE
FIG. 95 Ichneumon viola ♀ ICHNEUMONINI ICHNEUMONINAE

PLATE VIII

Right Wings

Fig. 99. BANCHINAE, GLYPTINI, Glypta sp. ♀ .

Fig. 100. BANCHINAE, LYCORINI, Toxophoroides sp. ♀ .

Fig. 101. BANCHINAE, LISSONOTINI, Lissonota montana ♀ .

Fig. 102. BANCHINAE, LISSONOTINI, Pimplopterus sp. ♂ .

Fig. 103. BANCHINAE, BANCHINI, Banchus sp. ♂ .

Fig. 104. SCOLOBATINAE, EUCERATINI, Euceros sp. ♂ .

Fig. 105. SCOLOBATINAE, PIONINI, Rhorus sp. ♀ .

Fig. 106. SCOLOBATINAE, PIONINI, Pion facatus ♀.

Fig. 107. SCOLOBATINAE, CTENOPELMATINI, Xenoschesis cinctiventris ♀ .

Fig. 108. SCOLOBATINAE, MESOLEIINI, Absyrtus sp. ♀ .

Fig. 109. SCOLOBATINAE, MESOLEIINI, Labrossyta indotata ♀ .

Fig. 110. SCOLOBATINAE, EURYPROCTINI, Anisotacrus spatiosus ♀ .

Fig. 111. SCOLOBATINAE, EURYPROCTINI, Hadrodactylus sp. ♀ .

Fig. 112. SCOLOBATINAE, CALLIDIOTINI, Callidiotes sp. ♀ .

Fig. 113. ORTHOPELMATINAE, Orthopelma mediator ♀ .

Fig. 114. MESOCHORINAE, Astiphromma pectorale ♂ .

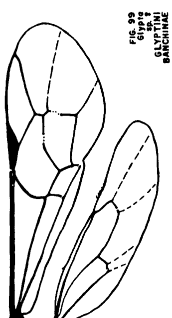


FIG. 99 Glypta sp. ♀ GLYPTINI BANCHINAE

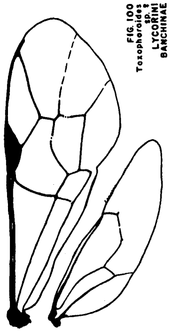


FIG. 100 Toxophoroides sp. ♀ LYCORINI BANCHINAE

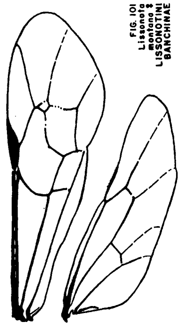


FIG. 101 Lissonota montana ♀ LISSONOTINI BANCHINAE

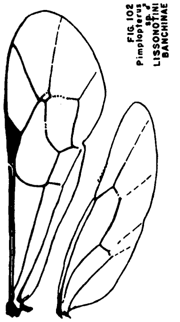


FIG. 102 Pimplopterus sp. ♂ LISSONOTINI BANCHINAE

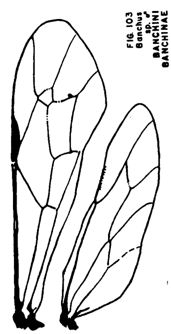


FIG. 103 Banchus sp. ♂ BANCHINI BANCHINAE

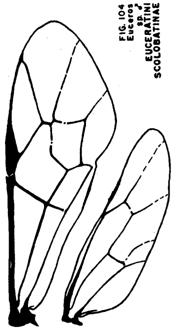


FIG. 104 Euceros sp. ♂ EUCERATINI SCOLOBATINAE

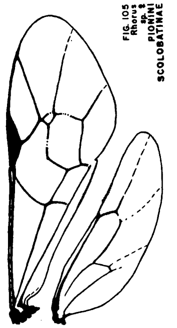


FIG. 105 Rhorus sp. ♀ PIONINI SCOLOBATINAE

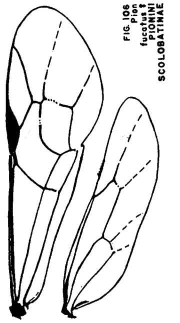


FIG. 106 Pion fucatus ♀ PIONINI SCOLOBATINAE

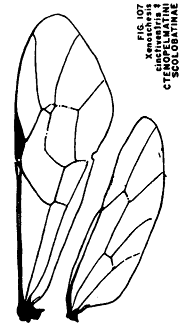


FIG. 107 Xenoschesis cinctiventris ♀ CTENOPELMATINI SCOLOBATINAE

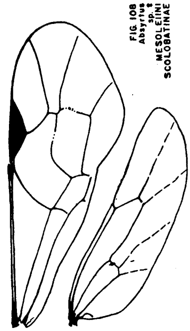


FIG. 108 Absyrtus sp. ♀ MESOLEIINI SCOLOBATINAE

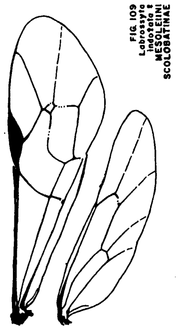


FIG. 109 Labrossyta indotata ♀ MESOLEIINI SCOLOBATINAE

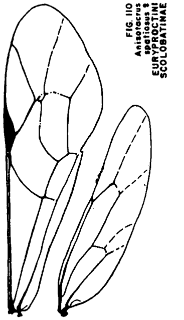


FIG. 110 Anisotacrus spatiosus ♀ EURYPROCTINI SCOLOBATINAE

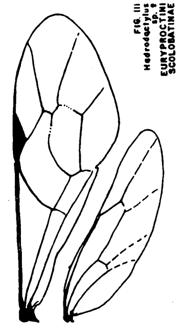


FIG. 111 Hadrodactylus sp. ♀ EURYPROCTINI SCOLOBATINAE

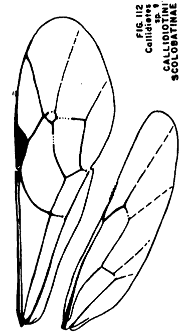


FIG. 112 Callidiotes sp. ♀ CALLIDIOTINI SCOLOBATINAE

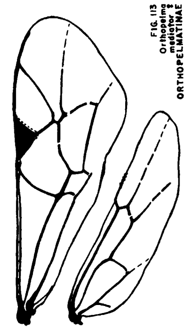


FIG. 113 Orthopelma mediator ♀ ORTHOPELMATINAE

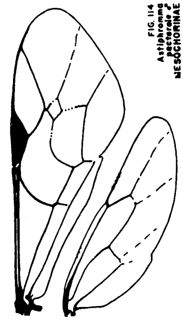


FIG. 114 Astiphromma pectorale ♂ MESOCHORINAE

PLATE IX

Right Wings

Fig. 115. ORTHOCENTRINAE, *Orthocentrus* sp. ♂.

Fig. 116. ORTHOCENTRINAE, *Stenomacrus* sp. ♀.

Fig. 117. DIPLAZONINAE, *Diplazon laetatorius* ♀.

Fig. 118. DIPIAZONINAE, *Enizemum petiolatum* ♀.

Fig. 119. METOPIINAE, *Periope aethiops* ♀.

Fig. 120. METOPIINAE, *Hypsicera femoralis* ♀.

Fig. 121. OPHIONINAE, PORIZONINI, *Idechthis canescens* ♀.

Fig. 122. OPHIONINAE, PORIZONINI, *Bathyplectes* sp. ♀.

Fig. 123. OPHIONINAE, PORIZONINI, *Horogenes* sp. ♀.

Fig. 124. OPHIONINAE, CREMASTINI, *Dimophora prima* ♂.

Fig. 125. OPHIONINAE, CREMASTINI, *Cremastus facilis* ♂.

Fig. 126. OPHIONINAE, TERSILOCHINI, *Tersilochus* sp. ♂.

Fig. 127. OPHIONINAE, ANOMALINI, *Anomalon* sp. ♀.

Fig. 128. OPHIONINAE, ANOMALINI, *Labrorychus* sp. ♀.

Fig. 129. OPHIONINAE, ANOMALINI, *Therion* sp. ♂.

Fig. 130. OPHIONINAE, OPHIONINI, *Ophion bilineatus* ♀.

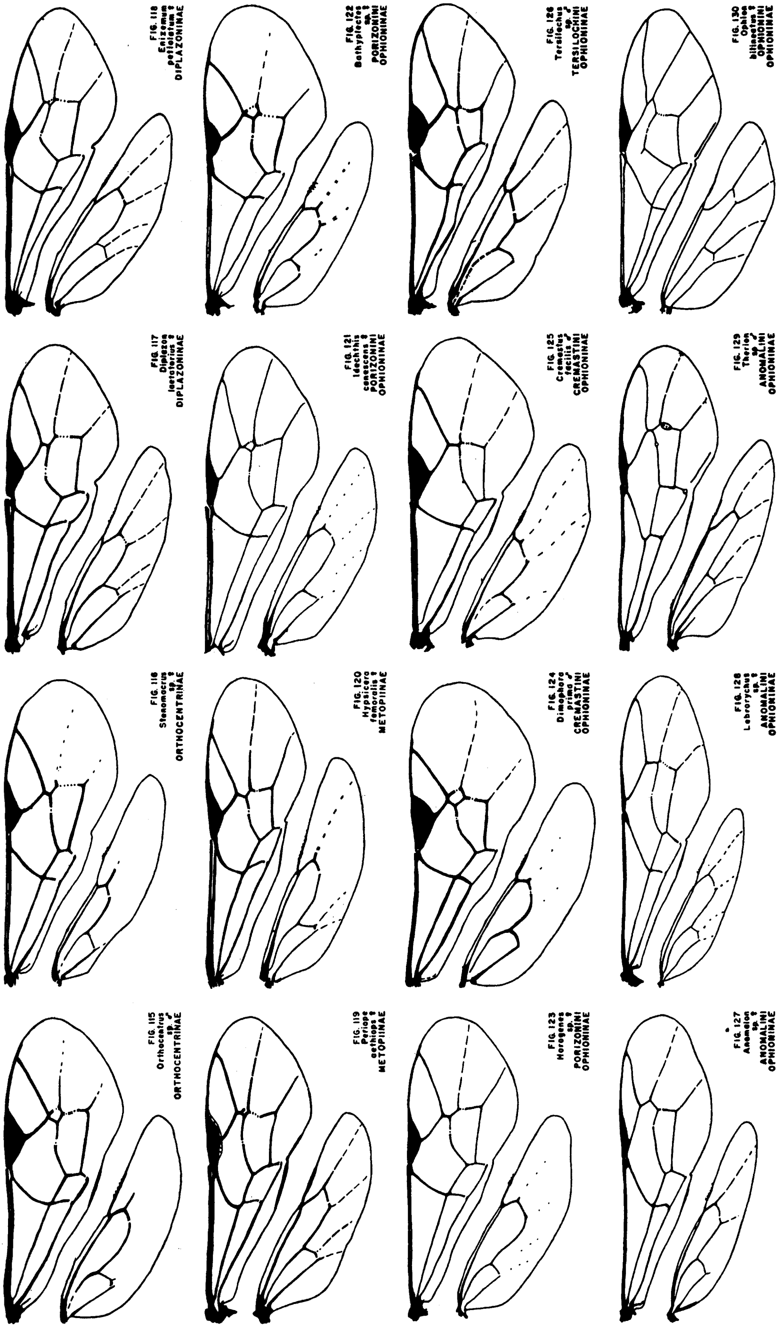


FIG. 115 Orthocentrus sp. ♂ ORTHOCENTRINAE

FIG. 116 Stenomacrus sp. ♀ ORTHOCENTRINAE

FIG. 117 Diplazon laetatorius ♀ DIPLAZONINAE

FIG. 118 Enizemum petiolatum ♀ DIPLAZONINAE

FIG. 119 Perilope aethiops ♀ METOPIINAE

FIG. 120 Hypsicera femoralis ♀ METOPIINAE

FIG. 121 Idechthis canescens ♀ PORIZONINI OPHIONINAE

FIG. 122 Bathyplectes sp. ♀ PORIZONINI OPHIONINAE

FIG. 123 Horogenes sp. ♀ PORIZONINI OPHIONINAE

FIG. 124 Dimophora prima ♂ CREMASTINI OPHIONINAE

FIG. 125 Cremastus facilis ♂ CREMASTINI OPHIONINAE

FIG. 126 Tersilochus sp. ♂ TERSILOCHINI OPHIONINAE

FIG. 127 Anomalon sp. ♀ ANOMALINI OPHIONINAE

FIG. 128 Labrorychus sp. ♀ ANOMALINI OPHIONINAE

FIG. 129 Therion sp. ♂ ANOMALINI OPHIONINAE

FIG. 130 Ophion bilineatus ♀ OPHIONINI OPHIONINAE

PLATE X

Abdomens and Abdominal Parts

Fig. 131. PIMPLINAE, LABENINI, Grotea sp. ♀.

Fig. 132. BANCHINAE, LISSONOTINI, Pimplopterus sp. ♀.

Fig. 133. MESOCHORINAE, Mesochorus sp. ♀.

Fig. 134. OPHIONINAE, ANOMALINI, Aphanistes sp. ♀.

Fig. 135. DIPLAZONINAE, Syrphoctonus pectoralis ♀.

Fig. 136. PIMPLINAE, POLYSPHINCTINI, Oxyrrhexis sp. ♀.

Fig. 137. OPHIONINAE, PORIZONINI, Campoplex sp. ♀.

Fig. 138. METOPIINAE, Hypsicera femoralis ♀.

Fig. 139. ICHNEUMONINAE, AMBLYTELINI, Pterocormus centrator ♀.

Fig. 140. ORTHOPELMATINAE, Orthopelma mediator ♀.

Fig. 141. GELINAE, GELINI, Atractodes sp. ♀.

Fig. 142. ORTHOCENTRINAE, Mnesidacus nigricoxus ♀.

Fig. 143. TRYPHONINAE, CTENISCINI, Exyston variatus ♀.

Fig. 144. SCOLOBATINAE, CALLIDIOTINI, Callidiotes sp. ♀. Petiole from side view.

Fig. 145. SCOLOBATINAE, EURYPROCTINI, Ipoctoninus uniformis ♀. Petiole from side view.

Fig. 146. PIMPLINAE, EPHIALTINI, Coccygomimus aequalis ♀.

Fig. 147. MESOCHORINAE, Mesochorus sp. ♀.

Fig. 148. PIMPLINAE, ACENITINI, Coleocentrus occidentalis ♀.

Fig. 149. SCOLBATINAE, MESOLEIINI, Opheltes glaucopterus ♀.

Fig. 150. GELINAE, GELINI, Acrolyta longicornis ♀.

Fig. 151. TRYPHONINAE, PHYTODIETINI, Netelia sp. ♀.

Fig. 152. GELINAE, GELINI, Gelis sp. ♂. Apex of abdomen from beneath and to the left.

Fig. 153. MESOCHORINAE, Astiphromma pectorale ♂. Same as Fig. 152.

Fig. 154. OPHIONINAE, CREMASTINI, Cremastus forbesi ♂. Same as Fig. 152.

Fig. 155. OPHIONINAE, PORIZONINI, Campoletis sp. ♂. Same as Fig. 152.

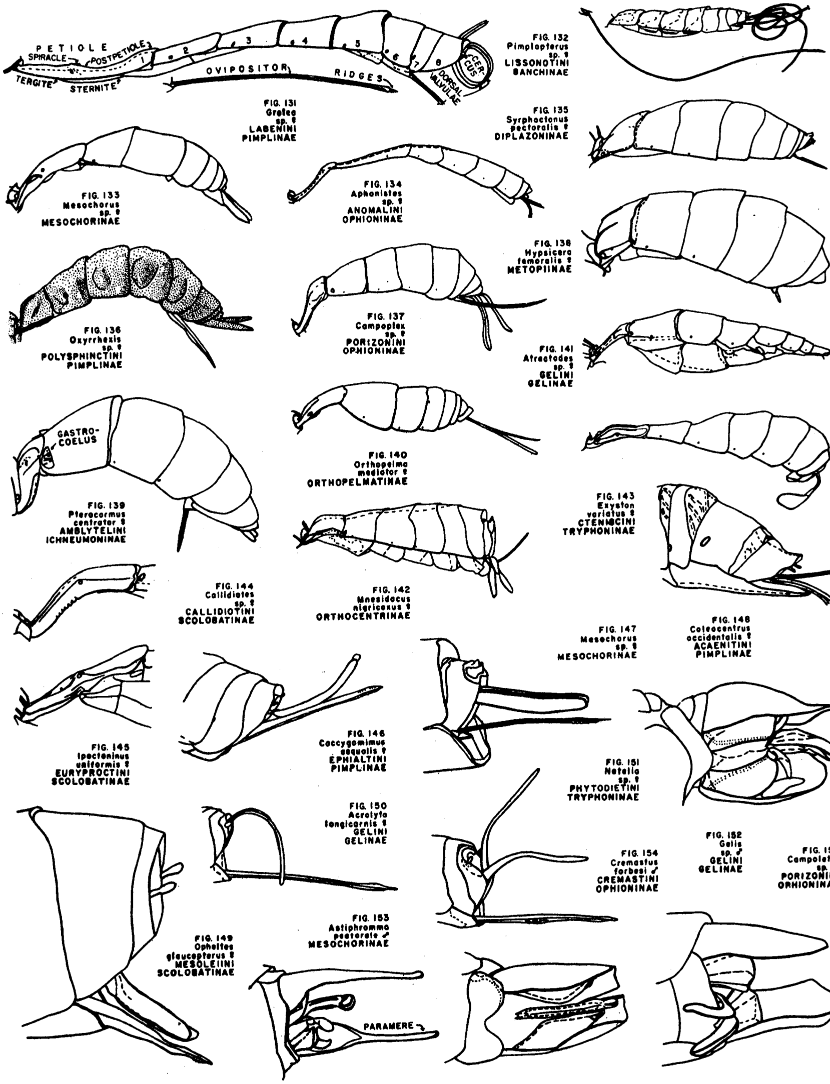


FIG. 131 Grotea sp. ♀ LABENINI PIMPLINAE

FIG. 132 Pimplopterus sp. ♀ LISSONOTINI BANCHINAE

FIG. 133 Mesochorus sp. ♀ MESOCHORINAE

FIG. 134 Aphanistes sp. ♀ ANOMALINI OPHIONINAE

FIG. 135 Syrphoctonus pectoralis ♀ DIPLAZONINAE

FIG. 136 Oxyrrhexis sp. ♀ POLYSPHINCTINI PIMPLINAE

FIG. 137 Campoplex sp. ♀ PORIZONINI OPHIONINAE

FIG. 138 Hypsicera femoralis ♀ METOPIINAE

FIG. 139 Pterocormus centrator ♀ AMBLYTELINI ICHNEUMONINAE

FIG. 140 Orthopelma mediator ♀ ORTHOPELMATINAE

FIG. 141 Atractodes sp. ♀ GELINI GELINAE

FIG. 142 Mnesidacus nigricoxus ♀ ORTHOCENTRINAE

FIG. 143 Exyston variatus ♀ CTENISCINI TRYPHONINAE

FIG. 144 Callidiotes sp. ♀ CALLIDIOTINI SCOLOBATINAE

FIG. 145 Ipoctoninus uniformis ♀ EURYPROCTINI SCOLOBATINAE

FIG. 146 Coccygomimus aequalis ♀ EPHIALTINI PIMPLINAE

FIG. 147 Mesochorus sp. ♀ MESOCHORINAE

FIG. 148 Coleocentrus occidentalis ♀ ACAENITINI PIMPLINAE

FIG. 149 Opheltes glaucopterus ♀ MESOLEIINI SCOLOBATINAE

FIG. 150 Acrolyta longicornis ♀ GELINI GELINAE

FIG. 151 Netelia sp. ♀ PHYTODIETINI TRYPHONINAE

FIG. 152 Gelis sp. ♂ GELINI GELINAE

FIG. 153 Astiphromma pectorale ♂ MESOCHORINAE

FIG. 154 Cremastus forbesi ♂ CREMASTINI OPHIONINAE

FIG. 155 Campoletis sp. ♂ PORIZONINI ORHIONINAE

GENERAL TOPOLOGY, SYMMETRY, AND CONVEXITY

PRESTON C. HAMMER

1. Introduction

INITIALLY topological concepts were a result of geometrization of analysis and an analysis of geometry. The studies soon demonstrated the need for more and more general systems and in this connection the abstract space theory and abstract general topologies have arisen. The word "abstract" may be taken to mean that the elements of the set under discussion are not specifically designated as long as certain operations are relevant. Thus the points of an abstract set may be geometrical points, circles, propositions, dishes, men, or potatoes.

"Topology" has been associated with concepts of limit points, homeomorphisms, continuity, and related concepts of closed sets, open sets, neighborhoods, convergent sequences, connectedness, continua and manifolds. The general topologies in existence have used special means to introduce the topology on the basis of axioms relating to closed sets or closure (Kuratowski), neighborhoods or open sets (Hausdorff, Sierpinski, Alexandroff), directed sets (E. H. Moore, Tukey), and filters (Weil, Bourbaki). The end in view of all such general definitions seems to be to obtain definitions of limit point and continuity of transformations and to establish under what conditions special topologies such as metric topologies may be obtained from those satisfying definitions.

In contrast to these objectives, we here give direct definitions of closedness, of closure, and of limit points requiring no initial concepts other than those associated with set algebra and the definition of function. We refuse to specialize, except in examples, to the topologies which topologists consider useful since we are here dealing with a topic which belongs in the foundations of mathematics; which has applications in algebra, geometry, and all mathematics and logic. We find that the simplest approach is to effectively define a "convergent set" which generalizes convergent sequence with the order connotation of "sequence" removed. We say simplest after viewing many other approaches and finding none in which examples are so readily generated. It is to be doubted that any will start with a more direct approach.

What are the benefits of such generality? First, the similarities of many presumably distinct phenomena become apparent. For example, the parentless persons, the extreme points of a convex set, the isolated points of a set, the point of symmetry in a symmetrical configuration, the independent proposition in a set of propositions are all shown to be examples of the same thing. Secondly, by examining the other systems in the light of our general definition we find certain undesirable definitions (limit point particularly) and we find the assumptions in many theorems concerning connectedness are much stronger than need be.

Thirdly, we propose to discuss at a later time the algebraic homeomorphisms as particular instances of homeomorphism and continuous transformations. The detail which we do not squander will permit us to do this.

Finally, the notation system used by topologists has been unfortunate for two reasons. First, it has kept them from using extensively "distributivity", "idempotency" or "fixed elements" which would carry useful words into a place where they belong; and secondly, it has been poorly adapted to consideration of interaction among closures of different sorts. We cannot claim our notation is happiest for all purposes; we do claim that it is superior for the purposes mentioned to the awkward conventions generally used by topologists.

We had hoped to write this paper so that individuals with a modest mathematical training could follow it. We have given numerous examples near the end of the paper to help with the formation of the mental images so vital to the understanding of any theory. The best example from some standpoints is the geneological one. The reader who wants an example in which most concepts of this paper are illustrated will do well to read this example early and keep referring to it throughout the paper. Unfortunately we cannot give a theory of set arithmetic, nor can we stop to discuss transfinite inductions and the well-ordering axiom. We assume the well-ordering axiom when needed but the reader will not miss much conceptually if he confines himself to finite sets. It is one advantage of this method that it has relevance for finite sets.

2. Notation and Conventions

We will use M (perhaps with subscripts) to denote a set of points in which all other sets under discussion are contained. The empty set, N, is the subset of M without elements. We will variously use C, L, K as classes of subsets of M; then the elements of C, L or K are subsets of M. If a set contains a single element, p, then we designate that set by $\{p\}$. For some purposes, the set $\{p\}$ or element p could be used interchangeably. However, for example, $\{p\}$ contains N as a subset, the element p has no subset.

The set relations and operations of relevance here are defined for subsets X, Y and Z of M. $Z_1 = X \cup Y$ is the set of all elements in X or Y (or both). This set is the union of X and Y. The set $Z_2 = X \cap Y$ is called the intersection (or cross-cut) of X and Y and is comprised of all points or elements which are in both X and Y. The difference $Z_3 = X \sim Y$ is the set of all points in X which are not in Y. The difference $M \sim X$ is called the complement of X. If all elements of Y are elements of X we say X contains Y, $X \supset Y$, or equivalently Y is contained in X, $Y \subset X$. If X does not contain Y we write $X \not\supset Y$. If p is an element of X we write $p \in X$, if q is not an element of X we write $q \in' X$. The union of a class C of sets is the set which contains all elements in all sets in the class and is denoted by $\bigcup X$, $X \in C$. The intersection of a class C of sets is the set all elements of which are elements of every set in C. This is denoted $\bigcap X$, $X \in C$. For any class C of sets the following laws of DeMorgan hold:

$$(1)\ \bigcap X = M \sim \bigcup (M \sim X) \qquad \text{and}$$

$$(2)\ \bigcup X = M \sim \bigcap (M \sim X) \text{ for } X \in C.$$

We use the Greek letters α, β, γ, μ, ν in the sense of ordinal numbers and also merely to designate an element in a class. For example, $\{X_\alpha\}$ may be, depending on context, a well-ordered class of sets or merely a class of sets of which X_α is a "typical" one. Thus $\bigcup X_\alpha$ means the union of all sets in the class $\{X_\alpha\}$ well-ordered or not.

3. Set Valued Set Functions

Let M be a set and let C be a class of subsets of M. Let f be a function defined for each set $Y \in C$ and such that fY is a subset of M. Let L be the class of all subsets fY for $Y \in C$. Then f is a set valued set function mapping C onto L. This may be designated f : C to L.

To each set valued set function f as described there corresponds an associated limit function f_1. A function $f_1 : C_1$ to L_1 is called a limit function if $Y \in C_1$ implies $f_1 Y \cap Y = N$, and $f_1 Y \neq N$. If the class C_1 of subsets of M is empty we say that f_1 is an empty limit function. Now for a given set-valued set function f : C to L the associated limit function f_1 is defined on the subclass C_1 of C obtained by deleting all sets Y from C such that $Y \supset fY$ and f_1 is determined by the condition $f_1 Y_1 = fY_1 \sim Y_1$ for $Y_1 \in C_1$.

It is clear that f_1 is a limit function. If f_1 is vacuous; i.e., if $Y \supset fY$ for all $Y \in C$ we say f is a retraction function.

With every function f : C to L there corresponds a unique associated inclusion preserving enlargement (i.p.e.) function g defined for all subsets of M such that $gX = X \cup \bigcup fY$, $Y \supset X$, $Y \in C$. A function $g : C_2$ to L_2 is an inclusion preserving enlargement (i.p.e.) function if $gX \supset X$ for $X \in C_2$ and if $X \supset Y$, X, $Y \in C_2$ implies $gX \supset gY$.

Theorem 3.1. Let f : C to L, $f_1 : C_1$ to L_1, g and g_1 be respectively a set valued set function f, its associated limit function, f_1, its associated i.p.e. function g and let g_1 be the associated i.p.e. function of f_1. Then $g_1 = g$; i.e., $g_1 X = gX$ for all $X \subset M$.

Proof: By definition $gX = X \cup \bigcup fY$, $Y \supset X$, $Y \in C$ and hence if $Y \in C_1$ we have $fY \subset Y$ but if also $Y \in C_1$ then $f(Y) \cup Y = f_1 Y \cup Y$. Hence $g_1 X = X \cup \bigcup f_1 Y$; $Y \in C_1$; $Y \subset X$ is the same set as gX.

A set $X \subset M$ is said to be f-closed if and only if $X \supset Y$, $Y \in C$ implies always $X \supset fY$. The complement of an f-closed set is f-open.

Theorem 3.2. The set M is f-closed. The null set N is f-open.

Proof: Since $M \supset Y \cup fY$ for all $Y \in C$ the theorem holds.

Theorem 3.3. The intersection set of a class of f-closed sets is f-closed.

Proof: Let Z be the intersection set of a class of f-closed sets of which, say, X is a typical member. Then if $Z \supset Y \in C$ then $X \supset Z \supset Y$ and $X \supset fY$ since X is f-closed. Hence $Z \supset fY$ and Z is f-closed.

To every set-valued set function f there corresponds a unique associated closure function h defined for each subset X of M as the intersection set of the class of all f-closed sets containing X; i.e., hX is the minimal f-closed set containing X. The set hX exists since $M \supset X$ and M is f-closed and by Theorem 3.3 the intersection set of all f-closed sets in a class is an f-closed set.

Theorem 3.4. Let f_1 and g be respectively associated limit and i.p.e. functions of f. Then the associated closure functions h_1, and h_2 of f_1 and g respectively are identical to the associated closure function, h, of f. That is, the classes of f_1-closed, g-closed, f-closed and h-closed sets are identical.

The proof is direct and will be omitted.

Any set valued set function h defined on all subsets of M is called a closure function if and only if h is an i.p.e. function and h is idempotent or projective; i.e., $h(hX) = hX$ for all X.

The composition of any i.p.e. function g defined on all subsets of M may be given for transfinite repeated compositions as follows: Let $g^0X = X$, $g^1X = gX$ and for a given ordinal $\alpha > 1$ define $Y_\alpha = \bigcup_{\beta<\alpha} g^\beta X$ and $g^\alpha X = gY_\alpha$. Thus we obtain an inductive definition of composition. Similarly, one may define a composition according to a well-ordered set of i.p.e. functions which are not necessarily all equal.

Theorem 3.5. To every i.p.e. function g defined on all subsets of M there corresponds a unique minimal ordinal λ_0 such that the composition g^{λ_0} is a closure function h. Moreover, $g(g^{\lambda_0}X) = g^{\lambda_0}X$ for all sets X. The closure function h is the unique closure function associated with g.

Proof: First, let X be a set and observe that $g^{\alpha}X \supset g^{\beta}X$ for $\alpha > \beta$. Hence, there exists a unique minimal ordinal λ (which may = 0) such that $g^{\lambda}X = g(g^{\lambda}X)$ since $M \supset g^{\alpha}X$ for all α. Moreover, then it is clear that $g^{\lambda}X$ is g-closed and hence $g^{\alpha}X = g^{\lambda}X$ is g-closed for $\alpha > \lambda$. Now let λ_o be the unique minimal ordinal not exceeded by λ for any X (since λ depends on X). Then $g^{\lambda_o}X = g(g^{\lambda_o}X)$ and $g^{\lambda_o}X$ is g-closed for all X. Hence $h = g^{\lambda_o}$ is a closure function since $h(hX) = hX$. That h is the closure function associated with g is clear, since every h-closed set is g-closed and conversely.

The unique minimal ordinal λ such that $g^{\lambda}X = g(g^{\lambda}X)$ is called the g-closing order of X or, if g is the i.p.e. function associated with a function f, then we also call λ the f-closing order of X. The ordinal λ_o is called the closing order of g (or of f).

Let f : C to L be a given limit function. Let $Z = \bigcup fY$ for all $Y \in C$; i.e., Z is the union of all sets in L. Let a be any point of Z and define C_a to be the class of all sets $Y \in C$ such that $a \in fY$. Define $f_a : C_a$ to $\{a\}$ so that if $Y \in C_a$ $f_aY = \{a\}$. We call each function f_a for all $a \in Z$ a fragment of f and the class of all such functions f_a a fragmentation of f. Corresponding to each fragment f_a of f there are the associated i.p.e. functions g_a and the closure functions h_a. The union of functions and intersections of functions is defined as expected; i.e., $f_3 = f_1 \cup f_2$ is given by $f_3X = f_1X \cup f_2X$ and so on.

Theorem 3.6. A set X is f_a-closed if and only if $a \in X$ or for every $Y \in C_a$ $X \not\supset Y$. Hence, the i.p.e. function g_a and the closure function h_a are identical. The function f is the union of all its fragments. The functions g_a are fragments of the associated i.p.e. function g of f.

Proof: If $a \in X$ and then clearly X is f_a-closed. If $a \notin X$, then X cannot contain $Y \in C_a$ if X is f_a-closed. If $X \not\supset Y \in C_a$ then X is f_a-closed whether or not $a \in X$. That f is the union of its fragments follows from the definitions, provided we assign $f_aY = N$ if $Y \notin C_a$, $Y \in C$. Since the maximum closing order of g_a is 1 it follows that $h_a = g_a$. That g_a is a fragment of g follows from the definitions of the associated i.p.e. functions and of fragment.

If f : C to L is limit-function, then we say that for a $\in Z = \bigcup fY$, $fY \in L$ that each set $Y_1 \in C_a$ is a convergent set or merely a convergent and a is an f-limit point of each such Y_1.

Theorem 3.7. Let f : C to L be a limit function. Then if f_o is the union of a subclass of the fragments f_a of f, every set which is f-closed is f_o-closed.

Proof: Since $f \supset f_o$, and since the class C_o on which f_o is defined is a subclass of C, we have that if X is f-closed then X is f_o-closed.

Theorem 3.8. Let g_1 and g_2 be two i.p.e. functions defined for all subsets of M. For the function $g_3 = g_1 \cup g_2$ the class of all g_3-closed sets contains precisely those sets which are both g_1-closed and g_2-closed. For the function $g_4 = g_1 \cap g_2$ the class of g_4-closed sets contains all sets which are g_1-closed or g_2-closed. Moreover, the class of g_4-closed sets is the smallest class of g-closed sets containing all g_1-closed sets and g_2-closed sets for any i.p.e. function g.

Proof: It is clear if X is g_3-closed then it is g_1-closed and g_2-closed. Conversely, if X is g_1-closed and g_2-closed then $g_3X = g_1X \cup g_2X = X$ and X is g_3-closed. Now if X is g_1-closed or g_2-closed then $g_4X = g_1X \cap g_2X = X$ and X is g_4-closed. However, if X is g_4-closed it is not necessarily g_1-closed or g_2-closed, since a necessary and sufficient condition for g_4-closure of X is that $(g_1X \sim X) \cap (g_2X \sim X) = N$ which does not imply always $g_1X = X$ or $g_2X = X$.

Now suppose g is an i.p.e. function such that class of all g-closed sets is the smallest class which contains all g_1-closed sets and all g_2-closed sets, and all intersections of its subclasses. Then we will show that the g-closed sets are g_4-closed. If X is a g-closed set then $X = X_1 \cap X_2$ where X_1 is g_1-closed and X_2 is g_2-closed since X is an intersection of a class of sets containing only f_1-closed and f_2-closed sets. Now $g_1X_1 = X_1$ and $g_2X_2 = X_2$.

Hence, $g_1(X_1 \cap X_2) \subset g_1X_1 = X_1$ and $g_2(X_1 \cap X_2) \subset g_2X_2 = X_2$. Hence $g_4X = g_1X \cap g_2X \subset X_1 \cap X_2 = X$. But since g_4 is an i.p.e. function $g_4X \supset X$ and hence $g_4X = X$ and X is g_4-closed. Hence g_4-closure gives the smallest class of closed sets containing all g_1-closed sets and g_2-closed sets.

It may be remarked in concluding this section that we have projected all set-valued functions into a subclass of limit functions and also into a class of inclusion preserving enlargement functions. The latter class is then projected into the closure functions by (possibly transfinite) repeated composition of each i.p.e. function. The closure functions are the idempotent or projective subclass of the i.p.e. functions. The sets fixed under an i.p.e. function g are the g-closed sets.

4. Properties of i.p.e. and Closure Functions

If g is an i.p.e. function defined on all subsets of M then there is always a limit function f such that g is the associated i.p.e. function of f. In particular, such a function may be obtained by defining $fX = gX \sim X$ for all sets X which are not g-closed; then f is a limit function, since $gX = X$ if and only if X is g-closed. In the following two theorems we summarize properties of i.p.e. and closure functions which indicate clearly the relationship with the general topologies of Sierpinski and Kuratowski.

Theorem 4.1. Let f : C to L be a set function, let g be its associated i.p.e. function; then the elementary properties of g are:

(a) Enlargement: $gX \supset X$.

(b) Inclusion preservation: If $X \supset Y$, $gX \supset gY$.

(c) A necessary and sufficient condition for a set X to be f-closed (or g-closed) is $gX = X$; i.e., X is a fixed element of g.

(d) The function g is subdistributive with respect to set union: $g(X \cup Y) \supset gX \cup gY$.

(e) The function g is superdistributive with respect to set intersection: $g(X \cap Y) \subset gX \cap gY$.

(f) The function g is a closure function if and only if g is idempotent or projective; i.e., $g^2X = gX$.

Proof: Parts a, b, c, and f are directly consequences of definitions or are merely definitions. Parts d and e are consequences of inclusion preservation, since, for example, $X \cup Y \supset X$ and $X \cup Y \supset Y$, then by (b) $g(X \cup Y) \supset gX \cup gY$.

Now, the closures we have defined include those of Sierpinski, since we do not admit that the null set N is necessarily closed, and since the following theorem holds, as is readily shown.

Theorem 4.2. Let K be any class of subsets of M containing M and such that the intersection set of every subclass of K is in K. Then, designating by hX the intersection of all sets in K which contain a set X, we have that $hX = X$ is an h-closure function in our definition. To obtain the closed sets of Sierpinski's general topology it is necessary and sufficient also to require that K contain the null set N.

The advantages of our approach, however, will be more clearly seen in the definitions of limit points, in the orders of limit points, and in the generalizations of connectedness. These are a distinct advantage, however, only if one does not concede that the interesting theory must be reduced to that involving infinite convergent sets and to the classical interests of topology. The psychological advantages of the introduction we have made are great, in that many examples of systems may be readily constructed from general set valued set functions. Another advantage of detail appears in the intermediate i.p.e. functions which are not closure functions.

Now Kuratowski assumed a closure function h which is distributive (with respect to set union); i.e., $h(X \cup Y) = hX \cup hY$. For any <u>limit</u> function f, in which the convergent sets contain two or more points each but not an infinite number, the f-closure is automatically excluded from the Kuratowski topologies, as the following two theorems show.

Theorem 4.3. Let f : C to L be a limit function with the property that each set in C contains precisely one point. Then the f-closure function h is universally distributive; i.e., $hX = h(\bigcup_{p \in X} \{p\}) = \bigcup_{p \in X} h\{p\}$. In other words, the f-closure of X is the union of the f-closures of its points considered as sets.

Proof: Suppose $q \in hX$ for any set X. Then if $q \in' X$ it follows that $q \in g^{\alpha}X \sim X$ for some unique minimal ordinal α where g is the associated i.p.e. function of f. But $gX = X \cup \bigcup f\{p\}$ where $\{p\} \in C$ and hence every point in $gX \sim X$ is in $h\{p\}$ for some $p \in X$, $\{p\} \in C$. Similarly by induction it may be shown that each point in $gX \sim X$ is in $h\{p\}$ for some p. Hence, $q \in h\{p\}$ for some $p \in X$, $\{p\} \in C$. Therefore, $hX = \bigcup_{p \in X} h\{p\}$ since $p \in h\{p\}$.

Theorem 4.4. Let f : C to L be a limit function for which its associated closure function h is finitely distributive. Then if C contains no set of cardinal less than 2, every convergent set must necessarily be infinite.

Proof: Since the cardinal of every convergent set is at least 2, the null set and every one-point set are f-closed. Now suppose C contains a finite set Y with k elements $p_1, \ldots, p_k$. Then by the finite distributivity of h we have $hY = \bigcup h\{p_i\} = \bigcup\{p_i\} = Y$. But since f is a limit function $fY \cap Y = N$ and $hY \supset Y \cup fY$ which is a contradiction. Hence every convergent set must be infinite.

It may be observed that if the null set and one-point sets are all closed then the convergent sets necessarily contain no one-point sets.

Corollary 4.5. If f : C to L is a limit function and all sets $Y \in C$ have finite cardinal no less than two then the f-closure function h cannot be distributive.

Certain applications, of which convexity is one of the best mathematical examples, Kuratowski's topology excludes. Distributivity of closures with respect to set intersection is a property which seems relatively profitless to investigate since if $h(X \cap Y) = hX \cap hY$ then with $Y = M \sim X$ we have $hN = hX \cap h(M \sim X)$ for every X. If we require $hN = N$; i.e., the null set N to be h-closed, then every set is h-closed for $hX \cap h(M \sim X) = N$ and $hX \supset X$, $h(M \sim X) \supset M \sim X$ implies $hX = X$. If N is not h-closed then $X \subset hX \subset X \cup hN$ and $M \sim X \subset h(M \sim X) \subset (M \sim X) \cup hN$, and since $hX \supset hN$ and $h(M \sim X) \supset hN$, we have again $hX \sim (hN \sim X) = X$ for all X.

The generalization of Appert and Fan in which inclusion preservation is violated; i.e., $h(X \cup Y) \subset hX \cup hY$, we do not include here. However, we can obtain such examples by requiring that the function h be inclusion reversing; i.e., if $X \supset Y$ then $hY \supset hX$, but this does not seem appropriate for examples we have in mind.

The interior function j associated with a closure function h is defined by $jX = \bigcup Z$, Z, h-open, $Z \subset X$. That is, jX is the maximal h-open set contained in X.

Theorem 4.6. The interior function, j, associated with a closure function satisfies the following properties:

(a) The interior function is a retraction function, i.e., $jX \subset X$.

(b) The interior function is inclusion preserving; i.e., if $X \supset Y$ then $jX \supset jY$.

(c) If and only if X is h-open does $jX = X$; i.e., the h-open sets are the only fixed sets under j.

(d) The interior function is idempotent or projective; i.e., $j(jX) = jX$.

(e) The interior function is subdistributive with respect to set unions; i.e., $j(X \cup Y) \supset jX \cup jY$.

(f) The interior function is superdistributive with respect to set intersection; i.e., $j(X \cap Y) \subset jX \cap jY$.

The analogy of the properties of the interior function j with those of closure function is obvious. Of course, $jX = M \sim h(M \sim X)$. In particular, $jN = N$ from (a). In view of the idempotence of j, we might ask for inclusion preserving retraction functions without the idempotence properties. However, since this development again closely parallels that of the inclusion preserving enlargement function we will not discuss it further. In this section we have given certain indications of the differences between the detailed system we are developing and the systems of Sierpinski and Kuratowski. The advantage of using functional notation instead of other symbols should now be apparent. It may be felt that we have not obtained the general topology of Sierpinski which rests on a definition of limit point. However, in the next section we give two definitions of limit points, one of which is equivalent to that of Sierpinski.

5. Limit Points

In this section we define two types of limit points as well as orders of limit points. We find here that our refined analysis requires that we deviate from the definition given by Sierpinski, and the one usually accepted, to give a more acceptable definition. However, it turns out that, from the standpoint of classical topology, the two definitions are equivalent and even in general topology many of the most significant results are unaltered for reasons which will be made clear. We assume throughout that f : C to L is a limit function and g and h its associated i.p.e. and closure functions respectively. We will usually speak here of f-<u>limit point</u> although they will also be g-<u>limit points</u> and h-<u>limit points</u>. For the generality and detail later, we <u>require</u> the i.p.e. function g but we could logically, although inconveniently, dispense with f.

A point p is a <u>strong</u> f-<u>limit point</u> of a set X if and only if $p \in h(X \sim \{p\})$. The set of all strong f-limit points of set X is called the <u>strong</u> f-<u>derived</u> set of X and we designate it by $f''X$. The strong f-limit points are the limit points of Sierpinski and of classical topology.

A point p is an f-<u>limit point</u> of a set X if and only if $p \in h(hX \sim \{p\})$. The set of all f-limit points of a set X is called the f-<u>derived set</u> of X and is designated $f'X$.

Theorem 5.1. The set functions f' and f'' have the following properties:

(a) The functions f' and f'' are inclusion preserving; i.e., if $X \supset Y$ then $f'X \supset f'Y$ and $f''X \supset f''Y$.

(b) Every strong f-limit point is an f-limit point; i.e., $f' \supset f''$.

(c) The function $f' \sim f''$ is a retraction function; i.e., for every set X $f'X \sim f''X \subset X$.

(d) For every f-closed set X, $f'X = f''X$.

(e) For every set X, $f'X \supset hX \sim X$, $f''X \supset hX \sim X$, $f'X \subset hX$, and $f''X \subset hX$.

(f) For every set X the set $f'X$ is f-closed.

Proof: Parts a and b follow directly from the definitions, since $hX \supset X$. For part e, if $p \in hX \sim X$ then $p \in f'X$ and $p \in f''X$ since $X \sim \{p\} = X$ and $h(hX \sim \{p\}) = hX$. Now since $f'X \supset f''X \supset hX \sim X$ we have $f'X \sim f''X \subset X$ which gives (c). If X is f-closed then $hX = X$ and the definitions of $f'X$ and $f''X$ coincide, which proves (d). To establish (f) let $Y \in C$, $Y \subset f'X$. Then if $p \in fY$, $p \in h(hX \sim \{p\})$ since $hX \supset f'X$ by (e) and $h^2X = hX \supset hf'X \supset fY$ so that $p \in h(f'X \sim \{p\}) = hf'X \subset h(hX \sim \{p\})$. But then $p \in f'X$ by definition. Hence, $f'X \supset fY$ and $f'X$ is f-closed.

In general, $f''X$ is not f-closed and this is one of the advantages of our definition of f-limit point. On the other hand, the sets $f'X$ and $f''X$ differ at most by a subset of X and if X is f-closed then $f'X = f''X$. Hence, many theorems proved by Sierpinski hold for $f'X$ as well as for $f''X$. It should be noted too that in our definition the set of limit points of X and of hX coincide. This is not generally true of the classical definition.

Theorem 5.2 If f is a limit function such that $h(X \sim \{p\} \cup \{p\}) = h(X \sim \{p\}) \cup \{p\}$ for every set X and every $p \in X$ then $f' = f''$.

Proof: Since $f' \supset f''$ and $f' \sim f''$ is a retraction function by Theorem 5. 1, (b, c) we merely need show that under the assumptions made that if $p \in' f''X$ and $p \in X$ then $p \in' f'X$. Consider $hX = h(X \sim \{p\} \cup \{p\}) = h(X \sim \{p\}) \cup \{p\}$. Now since $p \in' f'X$, $p \in' h(X \sim \{p\})$ and hence $hX \sim \{p\} = h(X \sim \{p\})$. But then $hX \sim \{p\}$ is f-closed since $h(X \sim \{p\})$ is f-closed and hence $h(hX \sim \{p\}) = hX \sim \{p\}$ and $p \in' h(hX \sim \{p\})$. That is, $p \in' f'X$.

The conditions of Theorem 5.2 are fulfilled, for example, if the closure function h is distributive with respect to set union and $h\{p\} = \{p\}$ for every point p. Thus for most interests associated with classical topology, the strong f-limit points and the f-limit points are identical. However, there are interesting examples in which these conditions of Theorem 5.2 are not fulfilled and in which $f' \neq f''$. The simplest example perhaps is that in which M contains only two points, p and q, and we define $f\{p\} = \{q\}$ and $f\{q\} = \{p\}$. Then $h\{p\} = M$ and $f'\{p\} = M$ but $f''\{p\} = \{q\}$ which is not f-closed. That is to say, we permit p to be an f-limit point of $\{p\}$, whereas Sierpinski's definition does not.

Theorem 5.3. A point $p \in f''X$ if and only if every f-open set containing p also contains a point of $X\sim\{p\}$. A point $q \in f'X$ if and only if every f-open set containing q also contains a point of $hX\sim\{q\}$.

Proof: Suppose $p \in f''X$ and Z an f-open set containing p. Then if $Z \cap (X\sim\{p\}) = N$ we would have $M\sim Z \supset X\sim\{p\}$ and since $M\sim Z$ is f-closed, $M\sim Z \supset h(X\sim\{p\})$. But $p \in h(X\sim\{p\})$ by definition and hence $Z \cap (X\sim\{p\}) \neq N$. Conversely, suppose every open set Z containing p intersects $X\sim\{p\}$ in a non-empty set. Then $p \in h(X\sim\{p\})$ or $M\sim h(X\sim\{p\})$ is an f-open set containing p but no element of $X\sim\{p\}$. Hence $p \in f''X$. A similar argument proves the last part of the theorem.

We now define the set X^α of (α, f)-limit points of X for ordinals α by an inductive procedure. The <u>(1, f)-limit point set</u>, X^1, of a set X, is the set $\bigcup fY$, $Y \subset X$, $Y \in C$. If the set X^β of (β, f)-limit points of X has been defined for $\beta < \alpha$ let $Z_\alpha = X \cup \bigcup_{\beta<\alpha} X^\beta$. Then the set, X^α, of <u>(α, f)-limit points</u> of X is the set of all points not in $\bigcup_{\beta<\alpha} X^\beta$ which are in $\bigcup fY$ for $Y \in C$, $Y \subset Z_\alpha$.

Theorem 5.4. For each set X there exists a unique minimal ordinal α_o such that the set X^{α_o} of (α_o, f)-limit points of X is empty. Then the f-closure hX may be written as a union of mutually exclusive sets: $hX = X^o \cup \bigcup_{\beta<\alpha_o} X^\beta$. The set X^o is a subset of X which contains all elements which are not (α, f)-limit points of X for any α. Moreover, $f'X = \bigcup_{\beta<\alpha_o} X^\beta$ and hence $\bigcup_{\beta<\alpha_o} X^\beta$ is an f-closed set.

Proof: Since $\{Z_\alpha\}$ forms a non-decreasing family of sets there exists unique minimal ordinal α_o such that $Z_{\alpha_o} = Z_{\alpha_o+1}$ and then $X^{\alpha_o} = N$ (for the lowest α_o). Since $X \subset Z_\alpha \subset hX$ for all α and Z_{α_o} is f-closed (a consequence of $Z_{\alpha_o} = Z_{\alpha_o+1}$) it follows that $Z_{\alpha_o} = hX$. Now if $p \in f'X$ then $p \in h(hX\sim\{p\})$; i.e., there exists a $Y \subset hX\sim\{p\}$, $Y \in C$ such that $p \in fY$. But then $p \in \bigcup_{\beta<\alpha_o} X^\beta$ since $Z_{\alpha_o} = hX$. Conversely, if $p \in \bigcup_{\beta<\alpha_o} X^\beta$ then $p \in h(hX\sim\{p\})$ since then $p \in fY$ for some $Y \in C$, $Y \subset hX$. Hence $f'X = \bigcup_{\beta<\alpha_o} X^\beta$ which is f-closed by Theorem 5.1 (f). Then, $hX\sim f'X = X^o$ is contained in X and no point of X^o is in X^α.

Theorem 5.4 is the principal argument in favor of our definition of f-limit point since in general $f''X \neq \bigcup_{\beta<\alpha_0} X^\beta$ and it appears reasonable to term every element of an X^β a limit element of X. It is understood, of course, that "limit" is a term used for convenience, the traditional concept of limit point being greatly extended as our examples will show. To every point p in hX we may assign a unique number 0 or an ordinal α according as $p \in X^0$ or $p \in X^\alpha$. Now we come to the use of the i.p.e. function g associated with f to obtain another decomposition of hX related to that to Theorem 5.4. For a given set X we have observed that there exists a unique minimal ordinal λ such that $g^\lambda X = hX$.

Theorem 5.5. The closure hX of X may be decomposed into mutually exclusive non-vacuous sets as follows: $hX = X \cup \bigcup_{\alpha \leqq \lambda} [g^\alpha X \sim \bigcup_{\beta<\alpha} g^\beta X]$ which is identical with the decomposition $hX = X \cup \bigcup_{\alpha \leqq \lambda} (X^\alpha \sim X)$, where λ is the f-closing order of X and X^α is the set of (α, f)-limit points of X.

Proof: We first remark that $X^\alpha \sim X = g^\alpha X \sim \bigcup_{\beta<\alpha} g^\beta X$ since $g^\alpha X \supset X^\alpha$ and each point in $X^\alpha \sim X$ is in $g^\alpha X$ but not in $g^\beta X$ for $\beta < \alpha$. Now since $g^\lambda X = hX$ we have from Theorem 5.4 that $hX = X^0 \cup \bigcup_{\alpha<\alpha_0} X^\alpha = X \cup \bigcup_{\alpha \leqq \alpha_0} (X^\alpha \sim X)$ since $X \supset X^0$. But, since $\lambda < \alpha_0$, we have $X^\alpha \sim X = N$ for $\alpha > \lambda$. Hence $hX = X \cup \bigcup_{\alpha \leqq \lambda} (X^\alpha \sim X)$.

The image associated with Theorem 5.5 is that of successive addition of layers of limit points of higher and higher order to X to achieve finally the f-closure. Examples of symmetry, convexity, and systems of propositions will illustrate this point later. In the ordinary closures this detail is missed, since the closing order is 1 at most. Certain definitions involving f-limit points are now in order.

A point $p \in X$ is an f-<u>isolated point</u> of X if and only if p is not an f-limit point of X. A set X is f-<u>dense-in-itself</u> if and only if $f'X \supset X$. A set X is f-<u>dense in</u> Y if and only if $f'X \supset Y$. A set X is f-<u>thick in</u> Y if and only if $hX \supset Y$. A set comprised of f-isolated points is f-<u>isolated</u>. An f-closed set which is f-dense in itself is f-<u>perfect</u>. The f-<u>nucleus</u> of a set X is the maximal subset of X which is f-dense-in-itself. If the f-nucleus of X is empty, then X is said to be f-scattered. The f-frontier of a set X is the set $[f'(M \sim X) \cap X] \cup [(M \sim X) \cap f'X]$.

Theorem 5.6. The set, E, of all f-isolated points of an f-closed set, X, is the maximal subset of X such that $X \sim E_1$ is f-closed for every subset E_1 of E and conversely.

Successive removals of f-isolated points of an f-closed set, X, gives a decomposition of X into an f-perfect set and f-isolated sets of certain subsets of X. Specifically, let E_1 be the set of f-isolated points of X. Then if E_β has been defined for $\beta < \alpha$, define $Z_\alpha = X \sim \bigcup_{\beta < \alpha} E_\beta$ and E_α is the set of f-isolated points of Z_α. The unique minimal ordinal μ such that $Z_\mu = Z_{\mu+1}$ is called the f-perfecting order of X. Then $X = Z_\mu \cup \bigcup_{\alpha < \mu} E_\alpha$ is the decomposition since Z_μ is f-perfect.

In some cases it is convenient to define a relative f-closure. For example, a set $Z \subset X$ is f-closed relative to X if $Z \supset Y \in C$ implies $Z \supset X \cap f(Y)$. Since we may use X as the space, then all the theorems concerning f-closure apply to relative f-closure.

6. Connectedness

In popular language two events or phenomena are connected if there is virtually any sort of relationship between them. In topological usage one restricts connectedness often to be the negation of separability. We will generalize the concept of connectedness greatly, but we basically proceed by a negation of separability. The surprising feature of our general definitions is that so many of the standard theorems concerning connected sets are unaltered in form, indicating that the assumptions for the theorems as usually stated are too strong.

A pair of sets X_1, X_2 is a dichotomy of X if and only if $X_1 \neq N$, $X_2 \neq N$, $X_1 \cap X_2 = N$ and $X = X_1 \cup X_2$. Let S be a class of pairs of sets (U_α, V_α) where the subscripts are used for convenience, and where $U_\alpha \cap V_\alpha = N$ for all pairs in S. Then two sets X and Y neither of which is empty are said to be S-separated if there exists a pair $(U_\alpha, V_\alpha) \in S$ such that $U_\alpha \supset X$ and $V_\alpha \supset Y$ or $U_\alpha \supset Y$ and $V_\alpha \supset X$. It is necessary for X and Y to be S-separated that $X \cap Y = N$ since

$U_\alpha \cap V_\alpha = N$. If we assume, as we shall hereafter, that $(U_\alpha, V_\alpha) \in S$ implies that $(V_\alpha, U_\alpha) \in S$ then we may state that X and Y are S-separated if there exists a pair of sets $(U_\alpha, V_\alpha) \in S$ such that $U_\alpha \supset X$ and $V_\alpha \supset Y$.

A set X is said to be S-connected if no dichotomy of X is S-separated; i.e., if for every dichotomy X_1, X_2 of X and $(U_\alpha, V_\alpha) \in S$ it follows that $U \not\supset X_1$ or $V \not\supset X_2$.

Corollary 6.1. The null set is S-connected and every set containing precisely one point is S-connected.

Theorem 6.2. If X_1 and X_2 are S-separated sets and if Y_1 and Y_2 are a pair of non-empty sets such that $X_1 \supset Y_1$ and $X_2 \supset Y_2$ then Y_1 and Y_2 are S-separated.

Proof: Let $U_\alpha \supset Y_1$ and $V_\alpha \supset X_2$. Then $U_\alpha \supset Y_1$ and $V_\alpha \supset Y_2$ which states that Y_1 and Y_2 are S-separated.

Theorem 6.3. If an S-connected set X is contained in the union, $Y_1 \cup Y_2$, of two S-separated sets then either $X \subset Y_1$ or $X \subset Y_2$.

Proof: Let $X_1 = Y_1 \cap X$ and $X_2 = Y_2 \cap X$. Then $X = X_1 \cup X_2$. But since there is a pair of sets $(U, V) \in S$ such that $U \supset Y_1$ and $V \supset Y_2$ then $U \supset X_1$ and $V \supset X_2$. But then $X_1 = N$ or $X_2 = N$ or X_1, X_2 is an S-separated dichotomy of X. If $X_1 = N$ then $X \subset Y_2$ and if $X_2 = N$ then $X \subset Y_1$.

Theorem 6.4. If X is an S-connected set and Y is any set containing X and contained in $\bigcap U_\alpha$ where $U_\alpha \supset X$ and $(U_\alpha, V_\alpha) \in S$ then Y is S-connected.

Proof: Let Y_1, Y_2 be a dichotomy of Y and suppose contrary to conclusion that there is a pair of sets $(U, V) \in S$ such that $U \supset Y_1$ and $V \supset Y_2$. Define $X_1 = Y_1 \cap X$, $X_2 = Y_1 \cap X$, $X_2 = Y_2 \cap X$. Then $X_1 \cup X_2 = X$ since $Y \supset X$ and $U \supset X_1$, $V \supset X_2$ which gives X_1, X_2 as an S-separation of X unless $X_1 = N$ or $X_2 = N$. Suppose, say, $X_2 = N$. Then $X_1 = X$ and $U \supset X$. But then $U \supset \bigcap U_\alpha \supset Y$ for $U_\alpha \supset X$, and $(U_\alpha, V_\alpha) \in S$ since U is one of these sets U_α and hence $Y_2 = N$ which contradicts the assumption that Y_1, Y_2 is a dichotomy of Y. Hence Y is S-connected.

Theorem 6.5. If every pair of points in a set X are in an S-connected subset of X then X is S-connected.

Proof: Let X_1, X_2 be a dichotomy of X. Let $p_1 \in X_1$ and $p_2 \in X_2$. Then there is a set $Y \subset X$ such that $p_1 \in Y$, $p_2 \in Y$ and Y is S-connected. Hence there is no pair of sets $(U, V) \in S$ such that $U \supset X_1$ and $V \supset X_2$ or $U \supset Y \cap X_1$ and $V \supset Y \cap X_2$ and $Y \cap X_1$, $Y \cap X_2$ is a dichotomy of Y. Hence no dichotomy of X is S-separated and X is S-connected.

Theorem 6.6. If X and Y are S-connected sets and $X \cup Y$ is not S-connected, then X and Y are S-separated.

Proof: If $X \cup Y$ is not S-connected, then there is a dichotomy Z_1, Z_2 of $X \cup Y$ and a pair of sets $(U, V) \in S$ such that $U \supset Z_1$ and $V \supset Z_2$. But by Theorem 6.3, $X \subset Z_1$, or $X \subset Z_2$ and then $Y \subset Z_2$ or $Y \subset Z_1$ respectively and X and Y are S-separated.

Theorem 6.7. Let $\{X_\beta\}$ be a well-ordered class of non-empty S-connected sets. Let $Y_\alpha = \bigcup_{\beta < \alpha} X_\beta$ and let $Z = \bigcup X_\beta$. Then if for every ordinal α in the range of β it follows that X_α and Y_α are not S-separated sets, Z is S-connected.

Proof: Let Z_1, Z_2 be a dichotomy of Z and suppose, contrary to conclusion, that there exists a pair of sets $(U, V) \in S$ such that $U \supset Z_1$, and $V \supset Z_2$. Since each set X_β is S-connected it follows from Theorem 6.3 that $X_\beta \subset Z_1$ or $X_\beta \subset Z_2$. Suppose, say, $X_1 \subset Z_1$. Let ν be the first ordinal such that $X_\nu \subset Z_2$. Then $Y_\nu = \bigcup_{\beta < \nu} X_\beta \subset Z_1 \subset U$ and $X_\nu \subset V$. But then X_ν and Y_ν are S-separated contrary to hypothesis and hence Z is S-connected.

The above Theorem is the most general statement concerning the connectedness of a union of connected sets of which we are aware. However, since it depends on well-ordering, we state another which does not depend on well-ordering.

Theorem 6.8. Let $K = \{X_\beta\}$ be a class of non-empty S-connected sets. Let Y be the union set of any proper subclass K_1 of K. Then if there exists a set $X_\alpha \in K \sim K_1$ for each such Y such that X_α and Y are not S-separated it follows that $Z = \bigcup X_\beta$ is an S-connected set.

Proof: Contrary to conclusion suppose Z_1, Z_2 is an S-separated dichotomy of Z so that there is a pair of sets (U, V) $\in$ S such $U \supset Z_1$ and $V \supset Z_2$. Then by Theorem 6.3 for every appropriate β, $X_\beta \subset Z_1$ or $X_\beta \subset Z_2$. Let $Y = \bigcup X_\beta$ where $X_\beta \subset Z_1$. Then $Y \subset Z_1 \subset U$ and let X_α be the set required by the Theorem. Then $X_\alpha \subset Z_2 \subset V$ and then Y and X_α are S-separated contrary to assumption. Hence Z is S-connected.

Corollary 6.9. If K is a class of S-connected sets such that every pair of sets in K have a common point then the union of all sets in K is S-connected.

Corollary 6.10. If $K = \{X_\beta\}$ is a class of well-ordered S-connected sets such that for each ordinal α X_α has a point in common with $\bigcup_{\beta < \alpha} X_\beta$ then the union of all sets in K is S-connected.

Corollary 6.11. If $K = \{X_\beta\}$ is a class of S-connected sets such that if Y is the union of any proper subclass K_1 of K there exists a set $X_\alpha \in K \sim K_1$ such that $Y \cap X_\alpha \neq N$ then the union of all sets in K is S-connected.

The general definitions of S-separation and S-connectedness we have given have not been related to the limit functions or more appropriately to their associated i.p.e. functions and closure functions. Let f be a limit function and h its associated closure function. Then with S comprised of the pairs containing hX and $M \sim hX$ for all subsets X we obtain the h-connectedness as a special form of S-connectedness. This is the usual form of connectedness. However, for connectedness of a more rigid character or of a different degree of generality, we are constrained to introduce another mode of generalization of connectedness.

Let g_1, g_2 be a pair of i.p.e. functions defined for all subsets of M. Then we say that a pair of non-empty sets X_1, X_2 are $g_1 g_2$ -separated if $g_1X_1 \cap g_2X_2 = N = g_2X_1 \cap$

g_1X_2. A set X is called g_1g_2-connected if no dichotomy of X is g_1g_2-separated. Note that with g_2 the identity i.p.e. function and g_1 = h we have h-connectedness as a particular case of g_1g_2-connectedness. If g_2 is the identity and $g_1 = g$ we speak of g-separated sets and g-connected sets as special cases of g_1g_2-separation and g_1g_2-connectedness. It is not possible, in general, to reduce g_1g_2-separation and g-separation to S-separation, since we require specific sets to be associated with set pairs for separation in the former case.

Theorem 6.12. Let S : $\{(U_\alpha, V_\alpha)\}$ be a class of pairs of sets which gives an S-separation. Then S-separation implies gg-separation with g defined by $gX = \bigcap U_\alpha$ for $U_\alpha \supset X$, $(U_\alpha, V_\alpha) \in S$.

Proof: Suppose X and Y are two S-separated sets. Then there exists $(U, V) \in S$ such that $U \supset X$ and $V \supset Y$. But, by definition, $U \supset gX$ and $V \supset gY$ and hence, since $U \cap V = N$ we have $gX \cap gY = N$, which is gg-separation.

Since in general the converse of Theorem 6.12 does not hold, we now are faced with establishing theorems concerning the g_1g_2-connected sets and g-connected sets. However, rather than restate theorems, the basic forms of which do not change, we will merely state that all the foregoing Theorems and Corollaries, 6.1 - 6.11 hold for g_1g_2-separation and g_1g_2-connectedness, and hence for g-connectedness. We will merely prove results hereafter specifically appropriate to g_1g_2-connectedness. When we refer to a Theorem or Corollary numbered from 6.1 to 6.11 it will be understood that we mean the appropriate re-wording of that proposition.

Lemma 6.13. If X is $g_1^{\alpha_1} g_2^{\alpha_2}$-connected, then $g_1^{\beta_1} X$ and $g_2^{\beta_2} X$ are each $g_1^{\alpha_1} g_2^{\alpha_2}$-connected where $1 \leq \beta_1 \leq \alpha_1$ and $1 \leq \beta_2 \leq \alpha_2$.

Proof: Let $Z = g_1^{\beta_1} X$ and suppose Z_1, Z_2 to be a $g_1^{\alpha_1} g_2^{\alpha_2}$-separation of Z. Then $X = X_1 \cup X_2$ where $X_1 = Z_1 \cap X$ and $X_2 = Z_2 \cap X$ since $Z \supset X$. Now either $X_1 = N$ or X_2

$= N$ or one of $g_1^{\alpha 1} X_1 \cap g_2^{\alpha 2} X_2 \neq N$ and $g_2^{\alpha 2} X_1 \cap g_1^{\alpha 1} X_1 \neq N$ hold. But, since $Z_1 \supset X_1$, $g_1^{\alpha 1} X_1 \subset g_1^{\alpha 1} Z_1$ etc., so that since Z_1, Z_2 is the indicated separation of Z we must have $g_1^{\alpha 1} X_1 \cap g_2^{\alpha 2} X_2 = N = g_2^{\alpha 2} X_1 \cap g_1^{\alpha 1} X_2$. Hence, say, $X_2 = N$ since X is $g_1^{\alpha 1} g_2^{\alpha 2}$-connected. However, then $X_1 = X$ and $Z = g_1^{\beta 1} X = g_1^{\beta 1} X_1 \subset g_1^{\beta 1} Z_1 \subset g_1^{\alpha 1} Z_1$ since $\beta 1 \leqq \alpha 1$ and then $g_1^{\alpha 1} Z_1 \cap g_2^{\alpha 2} Z_2 \supset Z_2 \neq N$ which is contradictory. Hence the theorem holds for $g_1^{\beta 1} X$ and similarly for $g_2^{\beta 2} X$.

Corollary 6.14. The f-closure of an h-connected set is h-connected.

Proof: Let $g_1 = h$, the associated closure function of f, let g_2 be the identity i.p.e. function and let $\alpha_1 = \beta_1 = 1$ in Lemma 6.13.

Lemma 6.15. If X is $g_1^{\alpha 1} g_2^{\alpha 2}$-connected then X is $g_1^{\gamma 1} g_2^{\gamma 2}$-connected for $\gamma_1 \geqq \alpha_1$ and $\gamma_2 \geqq \alpha_2$.

Proof: We need merely show that if X is $g_1^{\alpha} g_2$-connected then X is $g_1^{\gamma} g_2$-connected for $\gamma > \alpha$ since g_1 and g_2 play commutative roles and since $g_2^{\alpha 2}$ is an i.p.e. function. Since $g_1^{\gamma} \supset g_1^{\alpha}$ for $\gamma \geqq \alpha$ it follows that if $g_1^{\alpha} X_1 \cap g_2 X_2 \neq N$, for example, then $g_1^{\gamma} X_1 \cap g_2 X_2 \neq N$ and hence X is $g_1^{\gamma} g_2$-connected.

Corollary 6.16. The class of $g_1^{\alpha_1} g_2^{\alpha_2}$-connected sets is contained in the class of $g_1^{\gamma_1} g_2^{\gamma_2}$-connected sets for $\gamma_1 \geqq \alpha_1$ and $\gamma_2 \geqq \alpha_2$. In particular every g^{α}-connected set is h-connected where g and h are associated i.p.e. and closure functions of a limit function f.

Theorem 6.17. If X is a $g_1^{\alpha_1} g_2^{\alpha_2}$-connected set, then $g_1^{\beta_1}X$ and $g_2^{\beta_2}X$ are $g_1^{\gamma_1} g_2^{\gamma_2}$-connected sets for all $\gamma_1 \geqq \alpha_1$, $\gamma_2 \geqq \alpha_2$ and $\beta_1 \geqq 1$, $\beta_2 \geqq 1$.

Proof: By Lemma 6.15, X is $g_1^{\gamma_1} g_2^{\gamma_2}$-connected for all $\gamma_1 \geqq \alpha_1$ and $\gamma_2 \geqq \alpha_2$. By Lemma 6.13, then $g_1^{\beta_1}X$, for example, is $g_1^{\gamma_1} g_2^{\gamma_2}$-connected for $1 \leqq \beta_1 \leqq \gamma_1$, but, since γ_1 has no upper bound, we may take $1 \leqq \beta_1$

Theorem 6.17 generalizes extensively the usual theorem that the closure of a connected set is connected. It should be noted that if g_1 or g_2 is not the identity that we may have weaker connectedness conditions than usual. For example, if $g_1 = g_2$ is a closure function h then $g_1 g_2$-connectedness is weaker than h-connectedness; i.e., every h-connected set is hh-connected, moreover, every h-connected set is gh-connected where g is any i.p.e. function.

Theorem 6.18. Let X be a g-connected set and Y a set such that $X_1 = X \cap Y$; $X_2 = X \sim Y$ is a dichotomy of X. Then if X_1^1 and X_2^1 are the (1, g)-limit points of X_1 and X_2 respectively, $(X_1 \cap X_2^1) \cup (X_2 \cap X_1^1) \neq N$.

Proof: If $(X_1 \cap X_2^1) \cup (X_2 \cap X_1^1) = N$ then $X_1 \cap X_2^1 = N$ and

$X_2 \cap X_1^1 = N$. Note that $gX_2 = X_2 \cup X_2^1$, and $gX_1 = X_1 \cup X_1^1$ and $X_1 \cap X_2 = N$. But then $gX_1 \cap X_2 = N$ and $X_1 \cap gX_2 = N$ which contradicts the g-connectedness of X. Hence the theorem holds.

Let g be an i.p.e. function. The set $[X \cap (M \sim X)^1] \cup [(M \sim X) \cap X^1]$ is the (1, g)-frontier of X where the superscript 1 denotes the (1, g)-limit points of a set. Note that the (1, g)-frontiers of X and $M \sim X$ coincide.

Corollary 6.19. A g-connected set which intersects two complementary sets contains an element of their (1, g) -frontier.

The introduction of the S-separability and S-connectedness was made partially to include separation of sets such as the slab-wise separations which will be mentioned in the examples. The disadvantage of S-connectedness from a topological point of view lies in its lack of relationship with the closure functions. However, since forms of S-separability are popular in other usages, we have included it. On the other hand, the g_1g_2 -separability concept does fit into our generalized limit point concepts and provides the possibility of more detailed analyses of transformations.

Lest it be felt that we have carried out extremes of generalization, we may point out that there are conceivably useful systems in which our particular definitions are embedded properly. For example, let $s_1, \ldots, s_n, t_1, \ldots, t_m$ be a finite set of separations and let X and Y be termed separated if X and Y are separated according to all definitions $s_1, \ldots, s_n$, and to one of $t_1, \ldots, t_m$. One may of course carry this further. Another enticing mode for which we have no particular brief here is to consider trichotomies instead of dichotomies and consider triplets of sets to be separated, etc.

The theorems in this section are frequently direct generalizations of those of Hausdorff and others in Sierpinski. However, the definitions we have given we have not seen elsewhere, except for the special case of h-connectedness. In particular Theorems 6.7 and 6.8 we have not seen stated in similar form, and of course those dealing with properties of g_1g_2 -connectedness specifically we have not seen elsewhere.

7. Continuity and Homeomorphisms

Before defining continuous transformations we observe that it is simplest to consider the domain set and range of a transformation to be the entire spaces. Since we have defined relativization of closures earlier and since all theorems proved hold by considering a subset to be the space, we will not here consider any transformations which map a proper subset of a space into a proper subset of another.

Let M_1 and M_2 be two spaces and let t be a transformation associating with each point of M_1 a point in M_2 so that every point in M_2 is an image of a point in M_1. We assume that f_1, g_1, h_1, and f_2, g_2, h_2 are limit functions, associated i.p.e. and closure functions in M_1 and M_2 respectively.

Then $t : M_1$ to M_2 is said to be <u>continuous</u> if and only if $t(f_1' X) \subset h_2 (tX) = tX \cup f_2' (tX)$ for every $X \subset M_1$. That is to say, t is continuous if and only if the image of the derived set of X is contained in the union of the image of X and the derived set of the image.

The transformation t, M_1 to M_2, is <u>strongly continuous</u> if and only if $t(g_1 X) \subset g_2 (tX)$; i.e., if the (α, f_1)-limit points of X are transformed so that orders of limit points are not increased.

The transformation t, M_1 to M_2 is <u>strictly continuous</u> if and only if $tg_{1a}X \subset g_{2b} (tX)$ where $a \in M_1$, $X \subset M_1$, $b = ta$ and g_{1a} and g_{2b} are the i.p.e. functions corresponding to the fragmented forms of f_1 and f_2 respectively (cf. section 3).

Theorem 7.1. The transformation $t : M_1$ to M_2 is continuous if and only if $X_2 \subset M_2$, X_2 being f-closed implies that the set $X_1 = t^{-1} X_2$ is f-closed.

Proof: First suppose t is continuous. Then suppose X_2 is an f_2-closed subset of M_2 and define $X_1 = t^{-1} X_2$. Now if $h_1 X_1 \neq X_1$ then there is an f_1-limit point p_1 of X_1 such that $p_1 \in {}'X_1$. Hence, $tp_1 \in {}'X_2 \cdot h_2 X_2$ which contradicts our definition of continuity, since $p_1 \in f_1' X_1$. Conversely suppose $t : M_1$ to M_2 is such that $t^{-1} X_2$ is an f_1-closed set if X_2 is an f_2-closed set. Let $X \subset M_1$. Then $X \cup f_1' X = h_1 X$ and $t(X \cup f_1' X) = tX \cup tf_1' X$. Now the set $X_2 = tX \cup f_2' (tX)$ is f_2-closed, whence $t^{-1} X_2 = X_1$ is f-closed. But $X_1 = t^{-1} X_2 \supset X$ and hence $X_1 \supset h_1X$, and therefore $X_2 \supset t(h_1X)$ which is equivalent to our definition of continuity of t. Hence, t is continuous.

Theorem 7.2. Every strictly continuous transformation is strongly continuous, every strongly continuous transformation is continuous.

Proof: Since $g_1 = \bigcup_{a\in M_1} g_{1a}$ and $g_2 = \bigcup_{b\in M_2} g_{2b}$ we have that strict continuity implies strong continuity. Since $h_1 = g_1^{\lambda_1}$ and $h_2 = g_2^{\lambda_2}$ we have that strong continuity implies continuity. Here λ_1 and λ_2 are respective closing orders of g_1 and g_2.

Theorem 7.3. Let t_1: M to M_1 and t_2: M_1 to M_2 be two transformations which are continuous (strictly, strongly), then the composition $t = t_2t_1$ is a transformation from M to M_2 which is continuous (strictly, strongly).

Proof: We will prove the theorem only for strongly continuous transformations (letting f, g, h be respectively the limit function, associated i.p.e. and closure functions for M). We have for $X \subset M$, $t_1(gX) \subset g_1(t_1X)$ and $t_2(g_1(t_1X)) \subset g_2(t_2t_1X)$. But $t_2g_1(t_1X) \subset t_2(t_1gX) = t_2t_1(gX)$ whence $t_2t_1 = t$ is a strongly continuous transformation from M to M_2.

Theorem 7.4. Under a continuous transformation t: M_1 to M_2, h_1-connected sets are transformed into h_2-connected sets. Under a strongly continuous transformation g_1-connected sets are taken into g_2-connected sets.

Proof: Let X_1 be an h_1-connected subset of M_1 and let $X_2 = tX_1$. Then if Y_1, Y_2 is a dichotomy of X_2 which is h_2-separated we have $h_2Y_1 \cap Y_2 = N_2 = Y_1 \cap h_2Y_2$. But then $t^{-1}(h_2Y_1) \cap t^{-1}Y_2 = N_1 = t^{-1}Y_1 \cap t^{-1}h_2Y_2$. Now

$t^{-1}h_2Y_1$ and $t^{-1}h_2Y_2$ are f_1-closed sets by Theorem 7.2 and since $t^{-1}Y_1$, $t^{-1}Y_2$ clearly form a dichotomy of X_1 we would have X_1 is not h_1-connected. Hence X_2 must be h_2-connected.

Suppose X is a g_1-connected subset of M_1 and Y = tX. Then if Y_1, Y_2 is a dichotomy of Y which is g_2-separated we would have $g_2Y_1 \cap Y_2 = N_2 = Y_1 \cap g_2Y_2$. Now $t^{-1}g_2Y_1 \supset g_1(t^{-1}Y_1)$ and $t^{-1}(g_2Y_2) \supset g_1(t^{-1}Y_2)$. Now since $t^{-1}Y_1$, $t^{-1}Y_2$ form a dichotomy of X and since $g_1(t^{-1}Y_1) \cap t^{-1}Y_2 = N_1$ and $t^{-1}Y_1 \cap g_1(t^{-1}Y_2) = N_1$ we have that X is not g_1-connected if tX is not g_2-connected. Hence tX is g_2-connected.

It may be observed that since there are fewer g_1-connected sets in general than h_1-connected sets it is necessary generally to require stronger continuity to preserve the type.

Theorem 7.5. A necessary and sufficient condition that a biunique transformation $t: M_1$ to M_2 be continuous is that $tf_1' X \subset f_2' tX$ for all $X \subset M_1$.

Proof: The sufficiency is obvious since the condition is stronger than the requirements of our definition. To prove necessity let $p \in f_1' X$ and suppose that $tp \notin f_2' tX$ contrary to conclusion. Then, however, $tp \in tX \cup f_2' tX$ since t is continuous, and hence tp is an f_2-isolated point of tX and hence $Y = tX \cup f_2'(tX) \sim \{tp\}$ is an f_2-closed set and therefore $t^{-1}Y$ is f_1-closed by Theorem 7.1. But since t is biunique $t^{-1}Y = X \sim \{p\}$ and hence p is not an f_1-limit point of X contrary to supposition. Hence $tp \in f_2' tX$ and $t f_1' X \subset f_2' tX$.

Theorem 7.6. A necessary and sufficient condition that a biunique transformation $t: M_1$ to M_2 be a homeomorphism is that $t f_1' X = f_2' tX$ for all $X \subset M_1$.

Proof: The sufficiency follows directly since if $Y \subset M_2$ and $X = t^{-1}Y$ then $t f_1' X = f_2' tX$ or $t f_1' t^{-1}Y = f_2' Y$, i.e., $t^{-1}f_2' Y = f_1' t^{-1}Y$ which gives t^{-1} is continuous also. To prove necessity since t and t^{-1} are both continuous we have that $t f_1' X = f_2' tX$ from Theorem 7.4.

Theorem 7.7. Necessary and sufficient conditions that a biunique transformation t, M_1 to M_2, be a homeomorphism are that tX is f_2-closed if X if f_1-closed and $t^{-1}Y$ is f_1-closed if Y is f_2-closed.

Proof: By Theorem 7.1, the conditions of this Theorem are necessary and sufficient that t and t^{-1} by continuous.

It will be observed that our definition of continuity is based on our definition of limit point, which then does not include certain transformations as homeomorphisms which Sierpinski includes. Theorem 7.7 does not hold in Sierpinski's general topology, nor does the sufficiency part of Theorem 7.1.

Theorem 7.8. A necessary and sufficient condition that a biunique transformation t, M_1 to M_2, be strongly continuous is that $t(g_1X \sim X) \subset g_2(tX) \sim tX$ for every $X \subset M_1$.

Proof: The sufficiency is a direct consequence of the definition of strong continuity. To prove necessity let $p \in g_1X \sim X$. Now since t is strongly continuous $tg_1X \subset g_2tX$ and hence $tp \in g_2tX$. But if $tp \in' g_2tX \sim tX$ then $tp \in tX$ and hence since t is biunique $p \in X$ contrary to assumption. Hence $tp \in g_2tX \sim tX$ and $t(g_1X \sim X) \subset g_2tX \sim tX$.

Theorem 7.9. A necessary and sufficient condition that a biunique transformation t, M_1 to M_2, be a strong homeomorphism is that $tg_1X = g_2tX$ for every $X \subset M_1$.

Proof: The condition is clearly sufficient that t be strongly continuous. Also t^{-1} is strongly continuous, for if

$Y \subset M_2$ let $X = t^{-1}Y$ and then $tg_1(t^{-1}Y) = g_2tt^{-1}Y = g_2Y$ or $t^{-1}g_2Y = g_1t^{-1}Y$. The condition is necessary since by Theorem 7.8 if t is a strong homeomorphism then $t(g_1X \sim X) = g_2tX \sim tX$ or $tg_1X = g_2tX$ since $g_1X \supset X$ and $g_2tX \supset tX$.

We could continue here with a study of other properties invariant under homeomorphisms and to theorems similar to the above for strict homeomorphisms. However, since we expect to extend these homeomorphisms to include algebraic homomorphisms elsewhere, we will not go further with the discussion now. It is to be observed that the use of the words is based on the rich vocabulary of topology, but that continuity is not a suggestive term for the generalization.

8. Examples

A. Geneological Closures:

Let M be a specified set of people. Let C be the class of all one-person sets where such a person is a parent of a person in M. Let f associate with each set in C the immediate offspring of that parent. Then a set X of people is f-closed if and only if all the direct descendants of each person in the set (in M) are in the set. The function f is a limit function.

The set of f-limit points of a set X are all descendants (in M) of people in X including people in X who are descendants of others. The set of (1, f)-limit points of X is comprised of all persons in M who are immediate descendants of persons in X. The maximum f-closing order of any set is one less than the maximum number of generations represented in M.

A set X is h-connected if and only if it is impossible to separate X into two parts such that neither has a descendant of the other in it. For example, two lineages with a common descendant are h-connected. Two disjoint sets X and Y are g-separated if and only if there are no immediate descendants of persons in X which are in Y and vice versa. Two disjoint sets X and Y are hh-separated if and only if there are no common descendants; i.e., $hX \cap hY = N$. Thus, two persons who are not related comprise an hh-connected set if they have a common descendant. For example, husband and wife form an hh-connected set if and only if they have a child (in M).

There are no f-perfect sets in this general topology except for the empty set, since the first of a lineage in M is f-isolated. The f-isolated set of M is composed of all the persons first in a lineage.

The fragment function f_a corresponding to a person a is defined only for the parents of a. Continuity and homeomorphisms imply various types of geneological similarity between two classes, M_1 and M_2. The reader may make applications of the various definitions given.

B. Symmetry:

Let M be the euclidean plane. Let C contain all one point sets except O where O is the origin of M. Let f associate with each $Y \in C$ its reflection through O. Then a set is f-closed if and only if it is symmetrical with respect to the origin. The origin O is f-isolated in M. The function g = h and the maximum f-closing order of a set is at most 1. The only h-connected sets are the null set, one-point sets and sets comprised of a symmetrical pair of points. Every f-closed set is f-open since the complement of a symmetrical set is symmetrical.

The only possible f-isolated point of an f-closed set is O. If a set is symmetrical and does not contain O then the set is f-perfect. Since the convergents contain one point, the f-closure is universally distributive. (This is also true of the geneological closure.)

The class of f-limit points of any set not containing O is the f-closure of the set. The class of strong f-limit points in a set containing no symmetrical pair of points is empty.

The two disjoint sets X and Y are h-separated if the reflection of X through O does not intersect Y.

It may be remarked that all forms of symmetry are particular instances of f-closures since f-closures contains the basis of symmetry; i.e., the presence of a certain part of a configuration requires another for symmetry.

C. Convexity:

Let M be the euclidean plane with origin O. Let C be the class of all two-point sets and let f associate with each point pair in C the open line segment between. Then a set X is f-closed if and only if it is convex. The i.p.e. function gX contains X and all points on line segments with both end-points in X. The maximum f-closing order of a set is 2 which is achieved for three non-collinear points.

The f-isolated points of a set X are its extreme points: i.e., points not lying interior to any line segment in hX. The closure h is not distributive since convergent sets contain two points. The only sets which are f-closed and which have f-interior points are "essentially" half-spaces or the entire space.

The half-spaces are both f-open and f-closed. The only h-connected sets are trivial since every set containing a pair of points constitutes an h-separable set. The f-perfecting order of an f-closed set is at most 1 since, on removal of extreme points, the residual set is f-perfect. The set of points (O, $\pm$ n), ($\pm$ n, O) is f-dense in M; i.e., the space M is separable.

The fragment f_a is defined for all point pairs in M such that the open segment between them contains a.

D. Jensen Convexity:

Let M be the plane and let C be the class of all pairs of distinct points, let f associate with each the midpoint of the pair. Then a set X is f-closed if and only if it contains the midpoint of every pair it contains. The f-closing orders range from O to ω, the first infinite ordinal.

For example, if X is comprised of a pair of points, then there are 2^{n-1} (n, f)-limit points of X and the closing order of X is ω. The plane is not separable under Jensen convexity.

E. Implicative Systems:

Let M be a class of propositions, let C be a class of subsets of M and let fY, Y $\in$ C be a class of propositions implied by Y but not overlapping with Y. Then X is f-closed if and only if X contains all f-implications of its subsets.

Here, as in the preceding example, the (α, f)-limit points make sense since α is now an indication of <u>remoteness</u> of implication; i.e., if a proposition p is an (α, f)-limit point of X then it requires at least α successive implications to reach p. An f-isolated point p of X is now a proposition independent of all implications of points in $hX \sim \{p\}$. An f-perfect set is one which is f-closed and in which every proposition is implied by others in the set.

Two disjoint sets X and Y are h-separated if neither contains an implication of the other. Two disjoint sets X and Y are hh-separated if the implications of both do not intersect. Two disjoint sets X and Y are g-separated if neither contains an <u>immediate</u> implication of the other. The disjoint sets X and Y are gg-separated if their immediate implications do not overlap.

The fragment f_a is defined for the class of all subsets Y in C such that $a \in fY$. If the sets in C are finite but contain more than one proposition it follows that h is not distributive. Homeomorphisms correspond to implicative parallelism between systems.

F. <u>Usual Closure</u>:

Let M be the euclidean plane. Let C consist of all convergent sequences in M which do not contain their limit points. Let f associate with convergent sequences their limit points. Then we have the ordinary closure in the plane. The h-closure is distributive, g = h, the maximum f-perfecting order may be any denumerable or finite order.

Most of the terms used in this paper come from the topology of the real number system and the plane. In this case continuity and strong continuity coincide. However, the hh-connectedness is a weaker form of connectedness than usual. Any set in the plane which is dense in a connected set is hh-connected and all the theorems concerning g_1g_2-connected sets apply. Now, if we let $g_1 = h$ and $g_2 = h_2$, the closure function associated with the convex limit function of example C, then two disjoint sets X and Y are hh_2-separated if and only if the convex hull of neither intersects the closure of the other.

Here, also, we may mention a special form of S-connectedness. Let the set pairs (U, V) contained in S be all pairs of closed non-intersecting half-spaces. Then for each (U, V) there is an open strip (or slab) which is between U and V. A pair of sets X and Y are S-separated if and only if they are separated by an open strip between two parallel lines. In general, we have designated this form of separation slabwise separation. This concept is useful in connection with additive set functions in some applications we have made.

Other forms of S-connectedness may be obtained by specifying, for example, that U and V be "complementary" open half-spaces or, say, that U and V range over all pairs containing a closed circular disk and the exterior of a concentric open circular disk containing the first. In all cases the theorems concerning S-connectedness apply.

On the other hand, the separation of interiors of closed convex bodies by a line is not a proper form of separation since it leads to no corresponding connectedness, inasmuch as every closed convex body in the plane is separable.

G. Groups and Closure:

Let M be the elements of a group. Let C consist of all sets containing each one-point set except the identity and of all two-point sets where neither point is the identity. Let f associate with each one-point set in C its inverse and its square and with each two-point set the two products of the two elements. Then a subset X of M is f-closed if and only if it is empty or is a subgroup of M. Then the i.p.e. function g adds to a set X the inverse of each element in X and the products of every pair of elements in X. It is clear that a biunique homeomorphism from M to another group is a strict homeomorphism in the sense we have defined. Interpretations of various modes of connectedness are left to the reader. This closure is not distributive.

If X is a subgroup of M then one may associate with each element the left coset with respect to X. Then the only closed sets are the left cosets.

H. Subclosures:

If M is the euclidean plane then one may specify as convergent sets certain a subclass of the class of all convergent sequences. For example, one may require that the convergent sequences lie on lines thus obtain the so-called linear limits. This form of closure has achieved some popularity in the study of linear spaces. Since this f-closure in the plane has more closed sets than the regular closure, the requirement of h-connectedness is more severe; i.e., every h-connected set is connected in the planar topology but not conversely. In this case, a bounded infinite sequence in the plane may have no limit points. This linear closure is distributive. The f-closing order of a set may be greater than 1 even in the planar case—i.e., the i.p.e. function $g \neq h$.

I. Sub-Convexity:

Let M be the euclidean plane and let C contain all distinct point pairs lying on either vertical or horizontal lines. Let f associate with each such pair the open line segment between. Sets which satisfy conditions of this sort are met in integrating around contours. These sets contain the convex sets as a subclass. We expect to develop a theory of this form of convexity in detail elsewhere.

9. Interactions Among Closures

Certain combinations of closures are quite standard in analysis and geometry. Thus one speaks of the closed convex hull of a set, of symmetrical convex sets, of closed symmetrical convex sets, of circled convex sets and so on. We here give some preliminary results on the interactions among closures. We confine ourselves to closure functions h_1, h_2, all defined for all subsets of M.

If $h_1 h_2 X$ is h_2-closed then we say that h_2 penetrates h_1 at X. If $h_1 h_2 X = h_2 h_1 X$ we say that h_1 and h_2 commute at X. We say h_2 penetrates h_1 if h_2 penetrates h_1 at every subset X of M and h_1 and h_2 are commutative if h_1 and h_2 commute at every X.

Theorem 9.1. (a) If h_1 penetrates h_2 at X and h_1 penetrates h_3 at $h_2 h_1 X$ then h_1 penetrates h_2 and h_3 at X; i.e., $h_3 h_2 h_1 X$ is h_1-closed. (b) If h_1 penetrates h_2 at X then $h_2 h_1 X \supset h_1 h_2 X$.

Proof: (a) By assumption $h_1(h_2 h_1 X) = h_2 h_1 X$ and $h_1(h_3 h_1 h_2 h_1 X) = h_3 h_1 h_2 h_1 X$. But since $h_1 h_2 h_1 X = h_2 h_1 X$ we have $h_1h_3h_2h_1X = h_3h_1h_2h_1X = h_3h_2h_1X$ which proves (a). (b) We have always $h_1X \supset X$ and hence $h_2h_1X \supset h_2X$. Now if h_2h_1X is h_1-closed then $h_1h_2h_1X = h_2h_1X \supset h_1h_2X$.

Theorem 9.2. Necessary and sufficient conditions that h_1 and h_2 commute at X are that h_1 penetrate h_2 at X and h_2 penetrate h_1 at X.

Proof: For the necessity we have $h_1h_2X = h_2h_1X$ which shows that h_1h_2X is h_2-closed and h_2h_1X is h_1-closed which gives the penetrations required. The sufficiency follows from Theorem 9.1b.

For example, in the plane the convex closure penetrates the ordinary closure but not conversely, since a point and an infinite line not through the point is a closed set but its convex hull is not closed, whereas the closure of the convex hull of this set is convex. In a bounded subregion of the plane convex closure and closure commute. The symmetric closure of X penetrates the convex but not conversely in general since the symmetric closure of a convex set is not always convex. Thus, again, symmetric closure penetrates ordinary closure and convex closure.

Conclusion

In drawing this paper to a close we may mention that limitations of space and time have kept us from making more extensive applications and from extending the theory more completely. For example, the closures in partially ordered sets discussed by Everett are amenable to the kind of treatment we have given here. We hope to take up this extension elsewhere. We intend to make a more thoroughgoing analysis of connectedness and to consider homeomorphisms in relation to algebraic concepts. However, we have given here an adequate development to indicate the range of applications possible.

We have drawn most heavily upon Sierpinski [8] for guidance in certain theorems. We have seen no need, for our purposes, to include the order concept in the definition of convergent set and hence our treatment is set-theoretic.

It may be noted that our examples failed to include any in which the null set is not closed. The usefulness of this generality, however, may be indicated by the following: In the example on symmetry we might require that the origin be in every f-closed set by defining fN = {0}. In the example concerning subgroups we could require fN = {e} where e is the identity to avoid obtaining the empty set as a "subgroup". Generally one may require that all f-closed sets contain a specified set and this is done by the device indicated. Since requiring the null set to be closed would serve no useful purpose in this paper, economy dictates that we should not arbitrarily make a useless specialization.

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