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HYBRIDIZATION IN PLANT AND ANIMAL IMPROVEMENT

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THE function of hybridization is the rearrangement of already existing characters, the bringing together of qualities scattered about in different forms into one or a few individuals which represent the beginning of a new variety, or a new breed. How the common fruits, flowers and vegetables of our gardens and domestic animals in the fields and about the house have been multiplied into endless kinds by a recombination of a relatively few types becomes apparent when the history of any particular group of plants or animals is reviewed.

The dahlia is one of the most popular garden flowers due largely to its easy culture, simple vegetative propagation and the wealth of colors and forms. The fact that the plants can also be easily grown from seed, giving an astonishing array of markedly different flowers, has made this a fascinating subject for experimentation by the amateur gardener and has greatly increased the number of well recognized varieties. The dahlia was first generally cultivated in Europe in 1789 having been introduced from Mexico. At that time the flowers were single and not greatly different from *Cosmos* and *Coreopsis* which are its nearest relatives. The first double flowered form was recorded in 1814 at which time there were listed some 12 well marked color types. Twelve years later the number of varieties had increased to 60 due to recombinations of the existing color varieties with the double flowered condition and also new shades of color were brought out by crossing and doubtless by mutation as well.

The first Cactus dahlia came to light in 1879. This form was a radical departure from the common type. The margins of the petals were bent back instead of forward giving the flowers a very distinct appearance and a welcome change from the extreme forms which look too artificial. A small flowered and profusely blooming type known as Pompon was also discovered. There now existed four main types based on flower form: Single, Double, Cactus and Pompon. The double dahlias are classified in two groups by the florists as Show and

Fancy according to color pattern. Crossing between the Cactus and Show types produced a new dahlia intermediate in form with the tips of the petals curved backward somewhat like the hooded sweet peas but with the body of the petals broad and bent forward and double as in the Show types. This new creation called the Decorative type is one of the most highly prized and beautiful of all the dahlias. The flowers are not so compact and artificial looking as the Show and Fancy groups, and their fluffiness has much of the beauty of the Chrysanthemum and Aster together with an astonishing array of soft yet brilliant colors. The broad petaled, semi-double peony-flowered dahlia and the collarette type with a row of small and odd shaped petals of different color surrounding the central bud are the latest additions to the ever growing list of varieties of this most popular flower.

The first Cactus dahlia also introduced a new color resembling that of the cactus, *Cereus speciosissimus*, from which fact it originally got its name. Other variations which were brought out from time to time were dwarf plants, plants with long stemmed and short stemmed flowers, flowers with petals divided, others quilled and still others rolled into tight tubes like some China asters. Colors are as profuse in dahlias as in almost any cultivated flower. They occur in self-colored patterns and in variegations which are classified into five different types as shaded, edged, margined, striped and mottled. How the individual variations first arose is, in most cases, wholly unknown but having once been found it is not difficult to see how by recombination all these different flower forms, colors and patterns together with differences in the growth of plants, the more than 3,000 named varieties could be developed in 150 years.

Many horticultural achievements have not been developed by intentional hybridization. Natural crossing between different varieties growing together has undoubtedly been responsible for most of the new forms. Because flowers are so conspicuous new deviations are usually easily detected and so seed saved. Cultivation gives a plant a far greater opportunity for further improvement as compared to wild forms because of the immense numbers grown and the fact that these are more under observation. Careful culture also allows many new forms to live which would be exterminated in the open. Those plants whose valuable part is comprised in conspicuous flowers or definitely marked seeds are more extensively multiplied into different varieties than those plants which are not so easily catalogued. Roses, tulips, irises are a few notable examples of flowers which are widely diversified in form and color. Among the vegetables beans are listed in almost endless variety because the well marked seeds in color and pattern and characteristic pods make the different varieties easily recognized and therefore generally kept true to type.

The way in which many varieties of garden and field crops origi-

THE PROGENY OF A FEW NATURALLY CROSSED BEANS FOUND IN A COMMONLY GROWN VARIETY. THE OUT-CROSSED SEED TYPE AND THE ORIGINAL VARIETAL PATTERN ARE SHOWN ABOVE

nate is well illustrated by a natural cross of a commonly cultivated variety of garden beans. From a plot of Dwarf Horticultural beans the seeds of which are characterized by splashes and stripes of irregular red bands on a light background, a few off-type seeds were found when the crop was shelled. These seeds were densely marked with a thick mottling of dark brown. There were only a few of the seeds among many hundreds of thousands of the Horticultural type but they were very conspicuous on account of their darker color and altered pattern. They were probably due to natural crossing which had taken place the year before as the plants were grown adjoining plants of other varieties. This was proven to be the case when the odd looking seeds were planted and the resulting seeds harvested. Almost every plant was different in color and markings of the seeds. A representative seed from a number of these plants is shown in the figure.

The seeds shown in the illustration having the same markings differ strikingly in color. The differences are abrupt. Although there are eleven distinct kinds of seeds in this lot it can be seen that they are made up of different combinations of color and pattern. In arrangement of color there are three types: self-colored, splashed and mottled. The colors are cream, tan, brown and red. Only a few of the many possible combinations of these characters are expressed in this small number of plants. Each seed is a possible beginning of a new variety. Some of the combinations are undoubtedly hybrid and will break up in later generations. One of the seeds is an exact reduplication of the parental hybrid seeds. Another goes back to the one known grandparent. What the other grandparental variety was can only be conjectured.

In addition to these striking differences of color and markings the seeds differ somewhat in size and shape. Whether these are genotypical differences or merely modifications due to the growth of the plant can only be told by further testing. The plants which produced these seeds differed in no less degree. They were yellow or green podded and the pods were flat or round. They were diverse in time of blooming and ripening. They were also unequal in productiveness, hardiness, disease resistance, stringiness and toughness of the pods. These are the more important qualities but they are not so surely recognized as the noticeable seed characters.

Natural crossing in this manner has been the most important agency in the multiplication of varieties. Striking variations such as occurred in the beans just described attract the fancy of the gardener. The seeds are saved and sown. The unusual features may or may not persist. Some of them may be an improvement over existing sorts. The seed from the most promising plants is again saved and since beans are largely self fertilized the hybrid combination of characters are quickly reduced in numbers and uniform and constant strains are established in the course of several years, that is, they soon come true to type. The best of these strains are selected and a new variety has been created or rather re-formed. Further testing shows whether the new variety has sufficient merit to be worthy of general cultivation and if it has it soon finds its way into the seed catalogues. Such in brief is an outline of the history of nearly all the commonly cultivated vegetables and flowers.

It is generally thought that selection has brought out these new forms. Such is indeed the case but the variability induced by crossing has made the opportunity for selection to be effective. Those characters which really determine the value of a variety, such as hardiness, productiveness, quality, and which are dependent upon all parts of the plant, are so complex in mode of inheritance that it is not at once apparent that recombination of definitely hereditary factors takes place just as surely as in color and pattern. The changes are usually small in degree and the characters are more easily influenced by the external conditions. For that reason selection is the means of sorting out the best hereditary material and with many plants selection must always be continued to maintain improved varieties at their high level.

The application of selection to plant and animal improvement has not been greatly changed by the recent advances in the knowledge of inheritance. It was used effectively long before Mendel's principles of heredity were known. But in the past much time and effort have been wasted in selecting variations which were not inherited and which led to no change. Mendelism has shown clearly the distinction between the two kinds of deviations. Only germinal variations can be transmitted permanently. These are brought about either by original changes in the structure of the hereditary units about whose cause almost nothing is known and which are comparatively rare in occurrence, or by the much more usual and frequent recombination arising from crossing. The only sure means of identifying these germinal variations is the progeny performance test.

In one sense hybridization produces nothing new. It merely takes materials which are already in existence and by putting them into different associations makes forms which have never been seen before. This is a common if not universal method of diversification. The Aryan alphabet has only some 30 symbols yet the English language alone has over 450,000 words. All chemical compounds are different groupings of about 80 elements. That hybridization can produce nothing new is equivalent to saying that architects can create no new buildings because they have to use the same bricks and boards, cement and sand they have always used or the musician can write no new songs because he has at his disposal only the same set of notes and modulations. The possibilities for creation by combination are practically unlimited. Particularly is this true in organic substances where each new compound forms a new unit which can associate with other units to form new compounds. The hereditary factors as far as known are compounds so complex that their formulas can not as yet be written.

The history of the more recently created breeds of animals shows that hybridization has furnished the beginnings; controlled matings and careful selection have followed this up. Poultry furnishes many excellent examples of the part played by hybridization in animal breeding. The history of their development is the best known for the general purpose breeds of American origin although all are not agreed as to the foundation stocks. For the Barred Plymouth Rocks, the most popular all around fowl among the farmers of this country, the Dominique furnished the pattern and the Black Java or Black Cochin the size. The Minorca and Brahma were also used it is believed. The first specimens were exhibited in 1869 from Connecticut. The type of body has been fairly well fixed and Plymouth Rocks are now obtainable in several different colors and patterns.

The Wyandotte has a distinct type of its own and is another product of the American breeders. Its short blocky build and compact frame set it off from the other larger and more rangy general purpose fowls but this type is not well fixed probably because more attention has been paid to feathers and color than to body characters. According to some authorities a Sebright Bantam and a Cochin hen were first mated to produce a Cochin Bantam. The offspring were again crossed with

Cochin and also with Silver Spangled Hamburgs. Wyandottes first made their appearance in about 1870.

The Rhode Island Red remained for a long time as a farm fowl and was not considered as a distinct breed and was not taken up by the "Standard" breeders until after it had established its reputation as a utility fowl. It is one of the most variable breeds in color due to its extremely mixed origin. Although the material used is somewhat in doubt both Asiatic and Mediterranean stocks were crossed in native breeds. According to one writer Red Malay, Shanghai, Chittagong, Brahma and Leghorn were crossed in every conceivable way. The red color being distinct from all other common fowls it was easy to establish a new breed. It illustrates well the point that breeds are based on a few outstanding easily seen characters and the more valuable features are built up around them. Such has been the origin of the more recent breeds. With various modifications it is probably typical of the beginning of all breeds of poultry whose past history is now unknown.

Sheep are among the oldest of domesticated animals and nowhere have they been more highly developed than in England. Most of the modern mutton breeds with which we are now familiar had their origin there. Some were so excellently formed since very early times that their beginnings are not known, such as the Southdowns and Dorsets. The former has very fine qualities as indicated by its widespread popularity and from the fact that it has been used in crossing with other local strains to produce many of the now prominent breeds. For example it is generally believed that the Shropshires are the result of crossing Southdowns with the native horned, black faced sheep of Shropshire. Also the Leicester and Cotswold breeds are thought to have contributed something to the prominence of this famous race. Similarly the Oxford sheep grew out of intermixing the Cotswolds and Hampshires, while the Hampshires in turn got their start in crosses of the native Wiltshire and Berkshire sheep followed by judicious use of Southdown rams. Later the Sussex sheep which had a somewhat similar origin were united to make the material out of which have come the modern Hampshires. And to-day in the western states the Department of Agriculture is endeavoring to unite as many of the good qualities of the Lincoln and Rambouillet breeds as possible to form a new one for which the name of Columbia is proposed.

Should one examine the history of the creation of the present day breeds of swine he would find that much the same line of development has taken place. Crossing to bring together desired characters from different types brought out in different places and to serve different purposes, followed by intermating and back-crossing of the progeny and close selection towards a more or less fixed objective—such has been the almost unvarying recent history of the smaller and faster breeding animals. The larger and more slowly reproducing farm animals, the cow and the horse, are not so easily handled in this way. The creation of new varieties which means the culling out of enormous numbers of inferior individuals is too expensive a procedure to be undertaken without good reason. But is it not a logical assumption from the known history of the smaller animals that crossing has played an equally important part in their early development which had already reached a high plane before the written history of the breeds began?

It has long been stated that the chief contribution of France to agriculture, the Percheron horse, reached its highest development following the infusion of the heredity of the Arabian horse into the native heavy horses after the defeat of the Saracens in 732. Sanders and Dinsmore, recent writers on the Percherons, are, however, strongly of the opinion that the influence of the Arabian horse has been greatly exaggerated and even question whether or not mixing ever occurred in any important amount and persisted. They base their chief argument on the fact that the color pattern of the Percheron is distinct from the markings of the Arabian. Unless this objection is supported by more convincing evidence it can hardly be conclusive as it would not be expected that a complex parental pattern would be recovered completely from such a mixture unless it was specifically selected for. It is a fact that the Arabian war horses were present in France in large numbers and magnificent animals they undoubtedly were. It can hardly be doubted that they were frequently crossed with native stock. How many of their desirable qualities have persisted is largely to be conjectured. But the Percheron differs from the other heavy draft breeds most noticeably in neatness of body and lightness of foot, qualities which could very easily have come from part Arabian ancestry.

Wheat being the most important bread making cereal in Europe and America, naturally a great deal of attention has been given to the upbuilding of this plant. Most of the varieties now widely grown have come from individual plant selections from older varieties. A beardless head in a field of bearded wheat or a blue-stemmed plant in colorless sorts attracts attention. Seed may be saved from such plants and if the progeny prove to be sufficiently distinct and better a new variety is in process of formation.

The Scotch Fife wheat has been popular in the Northern States and Canada. Its origin is typical of many other varieties. David Fife living in Ontario received a quantity of wheat which had come originally from Russia. He planted it in the spring but it proved to be a winter variety and consequently only three heads ripened, these belonging to a single plant. Sown again the following year the wheat proved remarkably resistant to rust and from these few plants the seed was rapidly increased and widely grown. In time a number of somewhat different types of Fife developed and by crossing among these types the Marquis wheat which has played a considerable part in Ca-

THE DIFFERENT TYPES OR AGRICULTURAL SUB-SPECIES OF MAIZE. DENT CORN IS THE STANDARD PRODUCER IN THE MAIN CORN GROWING REGION AND COMBINES FEATURES OF THE NORTHERN GROWN FLINT AND SOUTHERN FLOUR TYPES

nadian wheat growing was produced by William Saunders of the Canadian Experiment Station at Ottawa.

Fultz is one of the best known of the older varieties of American wheats. It originated from three heads of beardless wheat in a field of Lancaster. Later S. M. Schindel of Hagerstown, Maryland, crossed Fultz and Lancaster and out of this came Fulcaster, which is a bearded, semi-hard, red grained wheat considerably resistant to rust and drought. It has been grown generally over the country but particularly in the region from Pennsylvania to Oklahoma.

One of the best illustrations of a successful plant breeding enterprise from the standpoint of practical results obtained was the potato varieties produced by E. S. Carman, late editor of the Rural New Yorker. Rural Blush, Rural New Yorker No. 2, Carman No. 1, Carman No. 3 and Sir Walter Raleigh are varieties which came from a collection of 62 varieties which were gotten together for the purpose of crossing. Artificial pollination proved to be impossible on account of failure to find good pollen but from seed bolls naturally formed (undoubtedly many of the seeds resulted from crossing between different varieties) a large number of seedlings were raised and from these the five best were distributed after careful testing. It is stated that at one time 80 per cent. of the potatoes grown in this country were either Carman's productions or seedlings from them. He accomplished what he set out to do in producing a better potato than the old Early Rose and Peach Blow.

That natural crossing has played a large part in the production of corn varieties of all kinds is apparent to every one. The ease by which pollen is carried by the wind and the practice of growing many different sorts near together or even in the same field maintain a constant state of out-crossing and a resultant variability out of which selection can start new departures.

The history of Reid's Yellow Dent, now one of the most popular varieties throughout the corn belt, is typical. Robert Reid brought with him to Tazewell County, Illinois, from Ohio seed of a local variety know as Gordon Hopkin's corn. This was planted in the spring of 1846 and did not thoroughly mature, consequently the seed did not germinate well the following year. The missing hills were replanted with an early variety known as Little Yellow corn. The corn has not been purposely mixed since then and by selection the type of this well known corn has been developed.

The improvement of the famous variety of corn known as Leaming was first begun in 1826 with the use of Indian varieties commonly grown at that time and is probably the first variety of corn to be systematically selected. It is also probably the first dent variety of modern type to be developed. According to a grandson of the original Leaming[1] some of the material used at the start consisted of the purple or black seeded varieties. Evidences of this aleurone color are still seen

THIS CORN PLANT WITH PERFECT FLOWERS IN A SINGLE TERMINAL INFLORESCENCE IS BOTANICALLY QUITE SIMILAR TO A DISTINCT TRIBE OF GRASSES, THE SORGHUMS, WHICH GIVES CONSIDERABLE PROBABILITY TO THE THEORY OF A HYBRID ORIGIN OF MAIZE

[1] Wallace's Farmer, Dec., 1919.

THE GREAT VARIABILITY OF MAIZE ADAPTING THE PLANT TO A RANGE OF CONDITIONS FROM THE EDGE OF THE ARCTICS TO THE TROPICS THROUGHOUT THE WORLD IS DIFFICULT TO ACCOUNT FOR UNLESS A MIXED ANCESTRY IS ASSUMED

at rare intervals in this variety. That the large-eared, compact-rowed, many-seeded variety now so familiar should be got out of the few-rowed, round-seeded, floury and flinty varieties grown by the Indians for many centuries is a really remarkable instance of plant improvement through hybridization followed by thorough-going selection.

The dent type of corn was not produced for the first time in Leaming as this kind of corn has been known since very early times having been reported to be in the possession of the Powhattan Indians as early as 1608. The characteristic indentation of this most productive kind of corn is due to a corneous outer layer surrounding a center of soft starch. The greater shrinkage of this soft starch than the hard starch outside on drying bring about the depressed and folded tip from which the type gets its name. The two kinds of corn grown by the natives of America were floury varieties in Mexico and adjacent regions and flint varieties in the north. That the combination of flint and floury types has made possible the dent corn now so widely grown is somewhat more than a surmise. The absence of leaves on the modified leaf sheaths forming the husks on the ears, a characteristic of dent corn, is common for floury corn but not flint corn. On the other hand the corneous nature of the endosperm and early maturity are largely flint features.

A familiar example of the rapidity with which varieties can be produced by crossing is furnished by the yellow varieties of sweet corn which have been introduced during the past few years. Practically all of them owe their start to a small eared, yellow seeded variety known as Golden Bantam. This variety for some time was little known and not appreciated because its yellow color differentiated it from all other varieties of sweet corn commonly grown and made it appear like field corn. It was finally realized that Golden Bantam was somewhat more tender in texture and better flavored than any other variety. Its small ears and low yield induced many to cross this corn with the larger growing corns and then to regain the yellow color combined with larger stalks and ears and as much of the quality of Bantam as possible. The yellow color is easily regained because in the second generation following the cross of yellow and white one seed in every four will be pure yellow but retaining the sweetness and tenderness of Golden Bantam in a larger and more productive corn is more difficult. Some success has been achieved judging from the popularity of the new yellow sorts such as Golden-rod, Golden Giant, Buttercup, Bantam Evergreen and a host of others which represent a recombination of the characters of Golden Bantam and such standard varieties as Evergreen, Howling Mob and Country Gentlemen. Yellow color has now become the badge of honor among sweet corns.

The number of new roses continually being offered are so great that only an exceptional variety or novelty creates much interest. Within recent years the climbing American Beauty has attracted considerable attention. This variety was developed from a crossing of American Beauty and Rambler and possesses the large flowered, long

NO OTHER PLANT THAN MAIZE EXHIBITS A GREATER RANGE IN SIZE, SHAPE, TEXTURE AND COLOR OF SEEDS

SIZE OF PLANT IS ALSO ASSOCIATED WITH THE ADAPTIBILITY OF MAIZE TO VARIED CONDITIONS

stemmed features of one parent combined with the profuse bloom and rampant growth of the other.

Practically there are limits to what can be done by hybridization and selection although no one can say exactly what these limits are. Certain characters are antagonistic. Fruit growers dream of an apple with the productiveness and hardiness of a Ben Davis or Baldwin combined with the delicacy, sweetness and flavor of a McIntosh or Northern Spy. Yet the tough skin, thick cell walls and low sugar content of the Ben Davis are probably the very things which make it resistant to disease and able to produce abundantly under adverse climatic conditions.

The plant breeder who sets out to produce a wheat with the best milling and baking qualities together with maximum yielding capacity, resistance to disease and severe climatic conditions has a task which is extremely difficult if not impossible. Likewise the animal breeder can not expect a rapid maturity and tenderness of flesh together with ability to withstand adverse conditions.

Those qualities which have been developed in domesticated forms are the ones which make them less able to cope with their surroundings. Wild species on the other hand are constantly selected on their ability to endure climatic extremes, pests and diseases. Their chief aim in life is apparently to provide for reproduction. Anything beyond this is a handicap. Moreover there are physiological limits beyond which it is impossible to go. Obviously a cow cannot be expected to give milk which is all cream, neither can a sugar beet be all sugar. What the limit is can not be closely approximated. Certainly if one were familiar with only the wild gourds he would be inclined to think a pumpkin or water melon weighing over 100 pounds a fantastic dream not to be actually realized. The lime tree gives no indication that a near relative could produce a fruit as large as the tropical grape fruit which often weighs over ten pounds. Between the wild cattle in the parks of England and the prize winning Shorthorns and Herefords at the live-stock expositions there are almost incredible changes.

Selection even in the long expanses of time in which plants and animals have been domesticated could not bring these vast differences were it not for the variability made possible by frequent crossings between widely diverse stocks. When the origin of the familiar cultivated plants and domesticated animals is looked into it is significant that nearly all of the more important ones have been derived from more than one wild species and these are usually from separate regions.

As an example of a valuable animal which has been cared for in nearly every part of the world the domestic fowl can be taken. It has long been thought that all the diverse breeds and types of chickens came originally from the Jungle Fowl of India, Southern China and the East Indies but it is now believed that the unknown ancestor of the Aseel or Malay Fowl, which has been bred in captivity for over 3,000 years, is also in part responsible for present divergent development exhibited by the many different breeds and races.

According to Davenport "The Aseel has many points of difference from the Jungle Fowl and brings in a whole set of characters that our domestic races have and the Jungle Fowl lack. Thus the Jungle Fowl is a slender, agile bird with long wings, erect tail and a good flyer; while the Aseel is a very broad, heavy bird with short wings, drooping tail and unable to fly. The Jungle Fowl has a long slender beak, that of the Aseel is short and thick. The comb of the former is single, high, that of the latter triple (or "pea") and low. The former has slender olive colored shanks; the latter thick and yellow shanks. The Jungle Fowl has a red eye; that of the Aseel is pearl colored. The

Jungle Fowl has the well known English Black-breasted Red Game pattern; the Aseel is mottled. The Jungle Fowl is the foundation stock of our nervous, flighty, egg laying races—the Leghorn, Minorca, Spanish, Andalusian, etc.—the races that first spread over Europe, probably from the stock that was brought back from Persia by the expeditions of Alexander the Great. All of these races ordinarily carry the determiners of the Jungle type of coloration. Representatives of the Aseel type (which had long been established in Eastern Indian and China) were brought to America, becoming the ancestors of the Asiatic breeds and the fine general purpose breeds—the Plymouth Rocks, Wyandottes, Orpingtons, etc. Such do not regularly carry the Jungle type of color pattern. In one case on the contrary,—namely the Buff Cochins—they introduced a new kind of color which (arisen in China 1,500 years ago) has never been produced independently since. The fowl of the Aseel type are poor egg layers, but their stocky build and great size make them unrivalled as 'table birds.'"

Of all domesticated animals the dog is probably the most varied in size, in form, in color and in covering. Ranging from the Poodle and Dachshund to the Bulldog, Greyhound and Great Dane, the dog has been the companion of man in nearly every part of the world. The near relatives to the dogs are numerous and although they are truly wild many are capable of being tamed and most of them will cross with some breeds of dogs. The timber wolf of Russia, the Jackal of Europe, Asia and Africa, the coyote of North America and the dingo of Australia have all probably contributed something to present day forms. Even the fox is quite like the dog in certain respects and may be remotely connected with some of our dogs.

Catlike animals are numerous in all parts of the world and more than one species have been brought together in the making of this pet. The common wild-cat of England (*Felis catus*) and the Egyptian cat (*Felis caffra*) are probably the immediately sources of the familiar kinds of cats but the golden cat (*Felis temmineki*) of northern India, Tibet and the Malay Peninsula, the fishing cat (*Felis viverrina*) of India, the spotted leopard cat (*Felis bengalensis*) are near relatives which might have added something to the variety of form and color so characteristic of this animal.

The pig is a widely domesticated animal which reached its greatest development when the breeds of Europe and Asia were brought together and their qualities intermingled. Early in the 17th and 18th centuries Chinese hogs were introduced into Europe and from these sources there grew up the great breeds of Yorkshire, Berkshire, Poland-China and Duroc-Jersey. Many of these breeds have been perfected and named in this country but their foundation stock came originally from England, the Continent, and from Asia. The wild ancestors of the pig are considered to be the wild boar of Europe and Africa (*Sus* *scrofa*) and the Indian wild boar (*Sus Cristata*) but almost every region of the earth has its native species more or less closely allied to domesticated swine.

One could extend this recital of the origin of tame animals to show that in the case of sheep there are at least six wild species which could have been drawn upon and a host of more distantly related forms and with cattle domesticated forms are classified in two species, European and East Indian, and any number of closely allied wild species. The horse is rather unique in being the only animal with no closely related wild congeners from which it could be re-established in case the horse became extinct. Either the horse has had a comparatively simple origin or else it has been cared for so long that its prototypes have been lost.

Although much of the history of domesticated races is largely surmised there can be no doubt but that the intercrossing of different species from separated regions has played a very important part in their great alterations to suit the needs of man. Desirable qualities existed in several forms of allied animals in different regions. Tribal migrations and commercial intercourse furnished the means for bringing them together and as far as they were sexually compatible crossing undoubtedly was utilized to combine good features; and also the crossing and resulting variability brought out new possibilities not before realized. How else can one account for the great flexibility of domesticated races as contrasted to wild species?

The same occurrence of species-hybridization is largely at the bottom of the development of cultivated plants. Some forty-two distinct species and sub-species of cotton have been described from both the Eastern and Western Hemispheres. Many of these are cultivated in various parts of the world. In this country 99 per cent. of the cotton grown is the short staple upland type and the remainder is the long fibered Egyptian or Sea Island cotton, so called as it was grown successfully only on the islands off the South Atlantic coast, and parts of the mainland. It is now grown in Egypt and in the irrigated valleys of the southwest.

Authorities differ as to the origin of the cultivated cottons. Cross-pollination of the plant is easily effected by insects and hybridization between species introduced into new regions has certainly taken place. Watt considers upland cotton to be various hybrids between *Gossypium herbaceum*, *G. mexicanum* and *G. hirsutum*. The former is the old world form which probably originated in north Arabia and Asia Minor. The other two species are natives of the southern United States, the West Indies and Mexico. Sea Island cotton is generally considered as *G. barbadense* originating in Barbados or other West India islands but Watt is convinced that it too has had a mixed beginning. He considers it as having been developed somewhere in South America and having the Peruvian or Andes cotton, *G. peruvianum* as one parental stock.

Indian corn is perhaps the best example of a widely cultivated plant having apparently a single origin. Belonging to a small subdivision of the grass family its nearest wild relative is teosinte with which it hybridizes readily. Teosinte, *Euchlaena mexicana,* is a large semi-tropical grass which is sparingly cultivated and differs in many ways from maize. The seeds are born in one-rowed spikes. If corn has been derived solely from teosinte there has been a remarkable sequence of changes in that the original condition of two or more spikelets in a place which is typical of most cereals has been replaced by the one-rowed spike in the pistillate inflorescences of teosinte and then regained in the paired-row condition in the ears of maize. Collins has pointed out that there exists in pod corn, *Zea mays* var. *tunicata* a form with perfect flowered terminal inflorescences, which strongly suggests another species as one of the original stocks. These perfect flowered plants can not be distinguished by present botanical standards from a distinct tribe of grasses, the sorghums. In those characters in which maize differs most from teosinte it approaches the characters of this perfect flowered pod corn. Certain other considerations also make it highly probable, although not proved, that maize likewise must be assigned a hybrid origin. The great variability and extreme plasticity by means of which corn is grown in many regions from the edge of the arctics to the tropics throughout the world would be difficult to comprehend on any other assumption.

Of all cultivated plants the rosaceous fruits give the most unmistakable evidence of having been developed by means of species hybridization. Some thirteen wild species of apples exist in the temperate regions of the Northern Hemisphere. Many of these have characters which entered into the make-up of this widely cultivated fruit. The cherry-plum-apricot-peach-almond group intergrades from one to the other so that it is impossible for the taxonomist to fix any exact limits to any division. Bailey lists 75 species and over 150 horticultural types of plums alone. From six native species 300 named varieties have been produced since the settlement of the New World.

The rose itself is both the despair of the systematic botanist and the delight of the gardener bent on originating new forms. The rose grows wilds in nearly all parts of Europe, Asia, Northern Africa and North America. The taxonomists have great difficulty in defining a rose species. Bentham and Hooker list 30 while a French botanist, Gandager, describes 4,266 species from Europe and Western Asia alone. Most botanists recognize over 100 species. The more common horticultural types and the specific names under which they go are as follows:

Horticultural Types and Species of Rose

Ayrshire	*R. arvensis*	Memorial	*R. Wichuraiana*
Banks	*R. Banksiae*	Moss	*R. gallica var. muscosa*
Bengal	*R. chinensis*		
Bourbon	*R. Borbonica*	Musk	*R. moschata*
Champney	*R. Noisettiana*	Noisette	*R. Noisettiana*
Cherokee	*R. laevigata*	Praire	*R. setigera*
Cinamon	*R. cinamonea*	Provence	*R. gallica*
Damask	*R. Damascena*	Scotch	*R. spinossima*
Dog	*R. canina*	Sweetbrier	*R. rubiginosa*
Eglantine	*R. rubiginosa*	Tea	*R. chinensis*

The names of the two principal groups of the large flowered roses, such as the Hybrid Perpetuals and Hybrid Teas, denote their mixed origin. The latter group, of which the variety La France is a popular representative, is the result of back-crossing a hybrid combination of the Provence, Chinese and Cabbage roses on to the tea-scented China rose.

The development of the native varieties of grapes, after the inability of the European varieties to thrive in the Eastern part of this country, furnishes one of the most interesting chapters in horticultural history. Many species of grapes grow wild in North America and individual seedlings of some of these wild forms came very early into cultivation and are still grown. The principal native species and the most important varieties derived chiefly from them are:

Vitis	*labrusca*	Catawba	Concord
"	*rotundifolia*	Scuppernong	
"	*aestivalis*	Norton	
"	*riparia*	Clinton	

From these varieties as basic stock have come nearly all of the many excellent grapes now grown. Concord is the leading variety. In New York 75 per cent. of all the grapes grown are Concords alone. This variety and its derivatives produce three-fourths of the grapes grown in the eastern region. The history of the Concord is obscure but the evidence indicates that it is the product of a large fruited plant of the wild fox grape pollinated by a plant of the Catawba variety which was growing near by. The botanical characters of the Concord are almost wholly *labrusca* but some of the self-fertilized seedlings of Concord show strong indications of influence by *Vitis vinifera,* the European grape. Catawba, one of the assumed parents of Concord, is also a seedling of *labrusca* brought in from the wild but it shows even more indications of *vinifera* characters than Concord in the vinous flavor of the fruit, susceptibility to mildew, appearance of occasional seeds and especially in the seedlings of the Catawba, many of which resemble *vinifera* more than the parent. The Catawba was one of the first native grapes to be cultivated. It originated in 1819 in Montgomery County, Maryland, and is still widely grown. While it is not positively known, there seems to be little doubt that crossing took place between European varieties and the wild plants growing near by. Large numbers of the *vinifera* grapes were grown at that time in an attempt to find some that would withstand the ravages of unaccustomed insects and diseases in the new world. These chance crosses gave size and sweetness together with resistance and made possible for the first time satisfactory grape culture. Hedrick in the "Grapes of New York" gives the derivation of all the leading varieties. In many cases the parentage is doubtful as many varieties have originated as chance seedlings which were noted as being superior in some respect and propagated for that reason. Out of 205 varieties 74 are the result of a combination of *V. labrusca* and *V. vinifera.* Eighty-eight varieties are more complex hybrids but most of them have either *vinifera* or *labrusca* heredity in addition to other native species. The remaining 43 varieties listed as coming from single species are mainly seedlings of Concord and this, as has been stated, is strongly suspected of a hybrid American-European origin.

The systematic production of new grape varieties is illustrated by the work of Roger, one of the early hybridizers. The American variety Carter was pollinated by Black Hamburg and Chasselas, two European varieties. A large number of seedlings were raised and from this lot 45 were chosen as sufficiently promising to be sent out for trial. From these a number of named varieties were placed on the market and some are still grown of which Agawam is the most popular. The Concord, although the most widely cultivated grape at the present time, is somewhat lacking in quality. It is exceeded in this respect by many varieties such as Diamond, Dutchess and Brighton which have been derived from Concord by bringing in more of the qualities of the sweet European grape.

The opportunities for hybridization of species are not so evident for animals as with plants at the present time. Most of the types and breeds are well established and experimentation with animals is so costly that it is doubtful if radically new forms will ever supplant them. Plants can be raised by the millions for the purpose of producing only a few of merit without prohibitive expense but with animals the situation is different. One instance serves to indicate what the procedure has probably been in the past in the creation of new kinds of animals. The American buffalo crossed by domestic cattle has given a type with the hybrid name Cattalo which is promising as a range animal for the exposed prairies. The first generation progeny of such a cross are sterile in the males but the females crossed back with tame bulls give animals which are still highly variable but combine in various degrees the conformation of the beef breeds with the ruggedness of the buffalo and the flesh also partakes somewhat of that animal which was so highly prized by the native Indian and early plainsman.

This outline of the origin of domesticated animals and plants includes only those forms which show clear evidence of having had a mixed beginning. Not all plants and animals have such a complicated ancestry. The pea and soy bean among plants and horses among animals, as a few examples, have had a comparatively simple line of descent yet they are represented by great variations in nearly every feature and are important additions to the list of cultivated and domesticated plants and animals.

The evidence is sufficient, however, to show that the one word which gives the key to the creation of useful forms of life is *hybridization*. The bringing together of qualities scattered about among different species, their rearrangement and from these still higher developments along strictly new lines this is what hybridization makes possible; and while it is not the primary method of evolution it is the most rapid means of changing animals and plants under the controlling hand of man. When it is noted that the forms which have come into domestication within recent times and especially where rapid progress is made are unmistakably the result of hybridization it can not be doubted that germinal mixing in the past has been a most potent agency in the creation of valuable forms of life.

It is not without significance that the plants and animals in both the eastern and western hemispheres which best serve the needs of man originated at or near the places where the great continents join. Southern Europe, Asia Minor and Northern Africa in the old world have been the birth place of staple cereals such as wheat and barley. Cotton and alfalfa are other plants of great value indigenous in this region. The grape vine, date palm, fig and olive are also native here. Sheep, swine, cattle, and horses were early used in these regions, as far as the evidence shows, for the production of food and clothing and carrying burdens. In the new world maize, beans, long staple cotton, potato, sweet potato, tomato, squashes and tobacco are the outstanding plant contributions and all of them come from Central American or adjoining regions.

In each of the two Hemispheres in which early civilizations developed through long periods of time uninfluenced by each other— the Egyptian, Assyrian in the East and the Inca, Mayan, Aztec in the west— we find the greatest progress in man's achievements made where the paths leading from one continent to another cross each other. During this period of upbuilding use was undoubtedly made of the plants and animals nearest to hand. The fact that diverse forms of life made so by intermingling of different races from widely separated regions were here most abundantly available furnished the best opportunity for the origin of domesticated animals and plants and points the way for future progress.

ADVENTURES IN STUPIDITY: A PARTIAL ANALYSIS OF THE INTELLECTUAL INFERIORITY OF A COLLEGE STUDENT

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A youth whom we will designate as "K" entered Stanford University with credentials showing graduation from a small but accredited California high school. On matriculation he presented 15 units of high school work, all of which were of "recommended" grade. The only suspicious circumstance was the fact that he had spent five years in high school and was almost 20 years old. He registered in mechanical engineering (woodwork), psychology (mental hygiene), drawing (still life, perspective). Three weeks later the instructor in drawing asked me to give the boy a mental examination, because of suspected mental deficiency. This instructor stated that he had never had a student who seemed so completely unable to grasp the principles of perspective or who made such foolish and absurd mistakes in trying to draw simple objects.

A Stanford-Binet test gave K a mental age of 12½ years. Some of the results of this test were so incredible that in the next few weeks I devoted about twenty hours to a further study of the case, applying a large assortment of standardized educational and mental tests. As we shall see later, his scores on the various intelligence scales ranged from 12 to 13½ years, and on the educational tests from the median for grade 5 to the median for grade 9 or 10. Average achievement in the educational tests was not far from grade 7.

K was of course not told the results of the tests. Effort was made, however, to impress him with the fact that he would have to work very hard in order to pass his courses. From time to time I gave him advice on use of references, methods of study, note taking, etc., partly to see whether it would be possible for an individual so lacking in intelligence to pass a college course. K responded with willing, even dogged, industry. He refrained from participation in the usual freshman frivolities and studied every night until 10 or 11 o'clock. It is not surprising, however, that at the end of the term he failed in all his courses and was dismissed from the university. His examination in psychology had included such questions as "Explain how anything is (a) retained, and

(b) brought back to consciousness. Distinguish between (a) philosophy and psychology; (b) sensation and perception; (c) mind and soul"! [1]

In physical and personal appearance K was rather prepossessing than otherwise. He carried himself well and had a pleasant smile and expressive eyes. As he also had good clothes, excellent manners and a high-powered automobile, he was promptly initiated into one of the Greek letter fraternities.

For purposes of observation I invited K to my home for dinner. His behavior and manners gave unmistakable evidence of a home environment above the ordinary. However, in spite of a certain superficial polish, a discerning observer would readily note the extreme commonplaceness of his remarks, and occasional almost infantile crudities of language. He talked little, answering often with only a knowing smile or a softly spoken yes or no. There was something in both smile and voice that tended to disarm suspicion and to incline one to give him the benefit of the doubt, if doubt should arise. His attitude toward me was always one of child-like trustfulness. At no time during the tests did he raise any question regarding the propriety of taking so much of my time, as college students almost invariably do under such circumstances, and at no time did he appear self conscious or apologetic because of his poor showing.

Investigation disclosed the fact that K belonged to one of the most prominent families in the small city where he lived. His father was a banker, proprietor of the leading general store, and had formerly been a member of the local school board. K's mother is said to be a superior woman. K is an only son. His one sister, several years his senior, is a graduate of the University of California.

When K left the university he came to my office to bid me goodbye and told me he was glad it was all over. He said he had not wanted to come to college or even to graduate from high school. He "never could learn books anyway," and now that he had done his best in college and failed he was glad to go back home to work in his father's store.

We will first recount K's test performances in some detail, and later examine them in order to discover, if possible, the psychological nature of their inadequacy.

Stanford-Binet Test

Year VIII, Credit, 12 months.

Although all the tests in this year were passed, K's responses to three of them gave clear evidence of intellectual inferiority. For example, *Finding Similarities* brought the following responses, each given only after 15 to 30 seconds of thinking:

[1] Only one of K's teachers knew anything about the results of the mental tests, or even that such tests had been given.

(a) Wood and coal—"Both used for *firewood.*" (b) Apple and peach—"Skin about the only thing." (c) Iron and silver—"Don't know that one. Oh yes, they are heavy." (d) Ship and automobile—"Propeller."

In the *Ball and Field* test K studied for two minutes and said he could not do it. Persuasion finally brought a response which showed barely enough plan to satisfy the requirements for year VIII. Inferiority of practical judgment was evidenced by the crossing of lines and by the lack of parallelism.

Vocabulary. Score 45, or about median for 13½ years. Typical responses: Lecture—"To be taught. Sort of lecture course. One who relates about his experiences." Skill—"Knowledge." Ramble—"Go fast." Civil—"Don't know." Nerve—"Pertaining to mind. Get more nerves. Sort of brain." Regard—"Meaning good." Brunette—"White, I guess." Hysterics—"Pertaining to the nervous system." Mosaic—"Pertaining to architecture from a foreign country." Bewail—"Can't think of that at all." Priceless—"No value." Disproportionate—"Can't think of it at present." Tolerate—"Try to get away from." Frustrate—"Sort of nervous." Harpy—"Happy, I guess." Majesty—"Don't know how to use it. Would it pertain to a queen?" Treasury—"Pertaining to money." Crunch—"Don't know." Sportive—"Pertaining to sport; not sure about it." Shrewd—"Conservative." Repose—"Don't know that one." Peculiarity—"Very peculiar." Conscientious—"Good in his work, I guess." Promontory, Avarice, Gelatinous, Drabble, all met the answer, "I don't know." Philanthropy—"Would it be wealthy?" Irony—"Strong."

Year IX. Credit, 10 months. Failed on Rhymes.

No error in *Date, Weights, Change* or *Four Digits* reversed.

Three Words. (a) "The boy *hit* the ball into the river." (b) "Men must work to have money." (c) "The lakes flows into the river and the river comes to a desert where it dries up."

Rhymes. (a) No rhyme found for *day* even in two minutes. "I can't seem to get any." (b) Mill—"Pill, bill, hill, rill." (50 seconds). (c) Spring—"Spring, sprung." Told to give *rhymes,* "I can't seem to think of any."

Year X. Credit 10 months. Failed on *Report.*

Absurdities. No error; answers given quickly.

Designs. One correct, the other half correct.

Reading and report. Read passage in 18 seconds without error. "A fire burnt three blocks near the center of the city. There was a girl asleep in bed. While at the fire a fireman burnt his hands."

Comprehension. (a) What ought you to say, etc.—"Nothing." (b) Before undertaking, etc.—"Think about it." (c) Why judge, etc.—"Actions count more. You can see him so much on his actions. Actions usually tell a great deal about a man. He might not have much talking ability."

Sixty words. In successive half minutes gave 19, 15, 10, 11, 7, and 7 words; total 69. Hardly any of the words given were what Binet would call "aristocratic" words. Class series all very brief.

Year XII. Credit, 21 months. Failed on *Ball and Field.*

Abstract words. Hazily explained but all scored plus.

Dissected sentences. (a) and (c) correct. (b) "I asked my teacher for paper to correct."

Fables. (a) Hercules and Wagoner—"Don't sit in the same rut and call for help but get out and do it yourself." (Half credit.) (b) Milkmaid—"Not to be thinking so far ahead." (Full credit.) (c) Fox and Crow—"Let's see. I know, but can't think. The crow was too vain of herself." (Half credit if liberally scored.) (d) Farmer and Stork—"That the innocent sometimes may be caught and the guilty get away. You must not judge all by the ones being caught." (No credit.) (e) Miller, son and donkey—"Mustn't do everything what other people tell us." (Full credit.)

Five digits reversed. One of three correct.

Picture interpretation. First picture brought description only, the others were fairly plausibly interpreted.

Similarities. (a) Snake, cow, sparrow—"Don't know unless it would be the tail." (b) Book, teacher, newspaper—"Learn knowledge from all of them." (c) Wool, cotton, leather—"Clothing." (d) Knife-blade, penny, piece of wire—"Steel." (e) Rose, potato, tree—"Skin, or the heart." (The first three were scored plus, the last two minus.)

YEAR XIV. Credit, 12 months. Failed on *Vocabulary, President and king, and Clock problems.*

Induction. Answers were 2, 2, 4, 8, 12, 32. That is, the principle was grasped only at the last folding.

President and King. (1) "President has more power. He has a cabinet and rules over the cabinet. A king is mostly a figurehead and is ruled over by parliament." (2) "President is commander-in-chief of the army." (3) "President has the veto power and a king has not." (Scored plus on power, minus on accession and tenure.)

Problems of Fact. (a) and (b) both plus. (c) Indian coming to town—"Carriage; wagon."

Arithmetical Reasoning. All correct in 20, 30 and 7 seconds, respectively.

Clock Problems. (a) 6:22—"It would still be 22 after 6." (Task explained again.) "Will it go like this—25 after 6?" (Failure in 2 minutes.) (b) 8:10—After 2 minutes, "I can't do it." (c) 2:46—After 1½ minutes, "I see now, it would be 15 after 10."

AVERAGE ADULT. No credit.

Responses on Vocabulary and Fables have already been described.

Abstract Words. (a) Laziness and idleness—"One is not willing to work, and other because he won't work." (Scored plus, but is hazy.) (b) Evolution and revolution—"Revolution means revolves. Don't know the other word." (c) Poverty and misery—"Poverty is without means, misery might be with means but not wanting to use them. One suffering." (Plus on liberal scoring.) (d) Character and reputation—"Reputation is what you *have* had, character is what you have got at present."

Six Digits Reversed. No success. Not over two successive digits given correctly in any series.

Enclosed Boxes. (a) and (b) correct. (c) "10." (d) "17."

Code. Time, 5 minutes and 40 seconds. Only two letters correct.

SUPERIOR ADULT. No credit.

Paper cutting test. Made one hole in center of paper.

Eight Digits Forward. Not over three successive digits given correctly in any series.

Thought of Passages. (a) "Tests that you are giving at present is very good for the scientific—let's see—the scientific way. This test may help a person in something what they take up. I forget the rest." (b) "Let's see—many people—happiness—we do not have all happiness in life—and many people wish upon us that—let's see—I can't get it."

Seven Digits Reversed. Would not attempt.

Ingenuity test. Showed no comprehension of the task whatever, although I twice explained it and even solved the first problem for him.

The mental age score is 12 years, 5 months. The distribution of successes and failures does not differ especially from what one might expect of an average child of 12 or 13 years. Qualitatively, however, many of the responses are characteristically different from those of an average child of the same mental age. They show more of what Binet called "maturity" of intelligence, and less of "rectitude."

K's 14 years of schooling have brought his vocabulary about a half year or year above the average of his mental age and have made him a fairly fluent reader (pronouncer of words). He makes change quickly and solves simple arithmetical problems, but in practical judgment, in finding likenesses and differences, and in a certain inaccuracy and slowness of thought suggesting faint awareness, his stupidity is more apparent.

Yerkes-Bridges Point Scale

Total score, 79 points, or about median for 13 years.
The following failures were typical:

Repeating 21 syllables. Three errors.

Absurdities. (a) I have three brothers, etc.—"Let's see. It should be Paul, Ernest and *I.*" (b) Swinging cane with hands in pocket, etc.—"That one's all right." (c) Guidepost directions (if you can't read this sign inquire of the blacksmith, etc.)—"He never would be able to find the blacksmith.

Analogies. (b) Arm is to elbow as leg is to—"abdomen." (c) Head is to hat as hand is to—"arm." (d) Truth is to falsehood as straight line is to—"I have to pass that one." (e) Storm is to calm as war is to—"Have to pass that too." (f) Known is to unknown as present is to—"Known. No, I don't know."

Yerkes-Rossy Adolescent Point Scale

Total score, 48 points. Satisfactory age standards are not available for this scale, but 48 points is probably not far from average for 13 years. Typical responses include the following:

Digits Forward. Memory span, 5 digits.

Repeating Sentences. Failed on all sentences of more than 14 syllables.

Comprehension Questions. (b) Actions versus words—"What they usually do is what they usually say." Asked to explain, "What a person usually does, he has his mind made up and if he should say anything that way his mind would run in the same order." (c) Why honesty is the best policy—"Because you're never caught in a lie; if you are, always there's nothing to hinder you from getting a position."

Definitions. (d) Conceit—"One who only thinks about himself. One who thinks nobody is as good as he is—the branches of work what he's in—pretty, or anything that way."

Analogies. Whole is to part as six is to—"half." (f) Sunday is to Saturday as January is to—"February."

Opposites. Wise—"not wise." (20 sec.) Silent—"still" (18 sec.). Similar—"things" (20 sec.). Cheap—"goods" (7 sec.). Never—"will" (12 sec.). (Here task was explained again, as it was evident K had lost the goal) Joy—"gloom" (4 sec.). Prompt—"late" (6 sec.). Vacant—"don't know." Busy—"dull" (12 sec.). Distant—"close" (3 sec.). Lazy—"don't know" (35 sec.). Easy—"hard" (2 sec.). Generous—"close" (3 sec.). Horrid—"mild" (12 sec.). Rude—"good" (5 sec.). Top—"tail" (13 sec.). Many—"few" (2 sec.). Rough—"calm" (4 sec.). Upper—"lower" (3 sec.). After—"before" (2 sec.).

Letter Line Test. Only one point credit.

Code Learning. No credit.

Army (1917) Individual Examination

Of tests A to V of the original individual examination methods prepared for use in the army (1917), the following were given:

Clock Test. Could tell time promptly and, when clock was visible, could tell what time it would be if hands were reversed. Failed on latter when clock was not visible. (About a 12 or 13-year performance.)

Knox imitation. Six successes in ten trials. No success beyond five moves.

Porteus maze. One error in 10-year maze, two in 11-year maze and none in mazes for 12 or 13 years. (About a 13 year performance.)

Orientational information. No failure.

Vocabulary. Average for two series of 50 words each was 21 correct definitions. Easy words failed included voluntary, perpetual ("motion in a line"), embers, tragic, optimist, repent, capitulate, contemplate, bestow, cooper ("builds coops"), hypocrite ("sort of non-believer"), etc. (About a 13½ year performance.)

Disarranged sentences. Two of three correct. (12 years).

Absurdities. Series 1 and 2, twenty absurdities in all, were given. Only the following were failed: Series 1 (i)—A mistake is much worse than a lie, for all people make mistakes and all liars tell lies; Series 2 (g)—Just before sunset we sat in the shade of a tall tree and amused ourselves by watching the shadows as they gradually grew shorter and shorter. (At least a 12 year performance).

Rhymes. For *stone* three rhymes were found in one minute, for *permit* one, and for *resist* four.

Likenesses and Differences. Series 1 and 2 were given, on 20 items in all. There were six failures, besides several passes of low value. (12 or 13-year performance.) Typical inferior responses were as follows:

How hat and coat are alike—"Both gold rimmed."
Rose, potato, and tree—"Can't get that."
Animal and plant—"Both have hearts."
Lamb, calf, and child—"All have feet."
Grass, cotton, tree, and thistle—"All green."

Memory for Designs. Of the five designs, two were reproduced correctly and two half correctly (liberal scoring). This is probably about a ten-year performance.

Logical memory. Passages 1 and 2 were given. These are perhaps slightly more difficult than the Binet passage (Fire in New York), and have 20 "memories" each. Both were read fluently and without error. Seven memories were given for the first and 11 for the second. (11 or 12-year performance).

Comprehension. All five series were given, or 25 in all. There were eight failures. (About a 10 or 11-year performance). The following errors are typical:

Why are people who are born deaf usually dumb also?—"Don't know."

You are hauling a load of lumber; the horses get stuck in the mud, and there is no help to be had. What would you do?—"Go for help."

Why has New York become the largest city in America?—"Because of its size and wealth. It covers such a large area."

Why should women and children be rescued first in a shipwreck?—"There ain't any reason."

Why should people have to get a license to get married?—"There would be too many marriages."

Sentence Construction (3 words). All five series given, 15 items. All the responses were correct. (This test belongs at 9 or 10 years).

The scoring of this series of individual tests has not been standardized and age norms are lacking, but I estimate that the value of K's performance is about equal to that of an average child of 12 or 13 years.

Miscellaneous Tests

Trabue Completion Tests. Series B. (3) "The stars and the *stripes* will shine tonight." (6) "She *could* if she will." (7) "Brothers and sisters *should* always *try* to help *the* other and should *not* quarrel. (9) "It is very annoying to *have a* tooth-ache, *which* often comes at the most *bad* time imaginable." (10) "To *make* friends is always———the———it takes." (Score is 12, or approximately seventh grade ability).

Series C. (6) "The boy who *studied* hard *will* do well." (7) "Men are more *capable* to do heavy work *than* women." (8) "The sun is so *hot* that one can not *sit in it* directly *without* causing great discomfort to the eyes." (9) "The knowledge of *man to* use fire is———of———important things known by——but unknown——animals." (10) "One ought to *take* great care to *do* the right———of———, for one who———bad habits———it———to get away from them." (Score again is 12, seventh grade ability).

Easy opposites. The easy opposites of List 3, Whipple's Manual, brought the following responses: (1) Best—"poor" (3.2 sec.); (2) weary—"tired" (2.4 sec.); (3) cloudy—"clear" (.6 sec.); (4) patient—"impatient" (2 sec.); (5) careful—"not careful" (5 sec.); (6) stale—"old" (.8 sec.); (7) tender—"tough" (1 sec.); (8) ignorant—"bright" (.6 sec.); (9) doubtful—"don't know" (6 sec.); (10) serious—"number" (3 sec.); (11) reckless—"not reckless" (.8 sec.); (12) join—"not joined" (1.2 sec.); (13) advance—"not advanced" (3.6 sec.); (14) honest—"dishonest" (.6 sec.); (15) gay—"don't know" (9 sec.); (16) forget—"remember" (.8 sec.); (17) calm—"rough" (.8 sec.); (18) rare—"tender" (.6 sec.); (19) dim—"bright" (.8 sec.); (20) difficult—"easy" (.6 sec.).

By the usual method of scoring only 8 of the 20 responses are correct. Although reliable age norms for this list are not available, this is probably no better than children of 9 or 10 years ordinarily do. The haziness of K's mental processes and his difficulty in holding to a goal are especially striking. The average time is 3.3 seconds, as compared with the Woodworth-Wells norm of 1.11 seconds for adults. This large difference is in line with K's time record in the Kent-Rosanoff test and suggests marked intellectual inhibition.

Whipple's information test. After checking up the words as marked, it was found that K was able to define only 5 of the 100 words and to give a rough, inexact explanation of only 5 others. This is probably not far from an average eighth grade ability.

Matching proverbs test (Otis). K was given the three Otis provisional lists. These resembled the form of the test included in later published editions of the Otis Group Scale, but were not identical with the latter. K's scores on the three lists were 4, 9 and 6. The average of 6.3 represents about eighth grade ability.

Absurd pictures. The Terman series of 44 absurd pictures was next given.[2] As these do not measure above 12 years, it is not surprising that K succeeded with all but two. His intellectual deficiency is clearly not found chiefly on the perceptual level.

Group Examination A (Original 10-Test Alpha)

Test 1. Oral Directions. Only 2 correct. Weighted score 6. (About 8½ years).

Test 2. Memory for digits. Four correct. Weighted score, 8. (About 9 years). Extreme memory span, 5 digits. (8 or 9 years).

Test 3. Disarranged sentences. Nine correct, 3 wrong. Raw score, 6; weighted score, 12. (About 12 years.) People are many candy of fond—marked false. Property floods life and destroy—marked false.

Test 4. Arithmetical reasoning. Raw score, 6; weighted score, 18. (12½ years.) How many hours will it take a truck to go 66 miles at the rate of 6 miles an hour?—Ans. "10." If you buy 2 packages of tobacco at 7 cents each and a pipe for 65 cents, how much change should you get from a two-dollar bill?—Ans. "1.28."

Test 5. Information. Raw score, 28; weighted score, 56. (About 16 years.)

Test 6. Synonym—Antonym. Score, 21. (About 16 years.) Score of this test is not weighted. Omitted definite—vague, concave—convex, adapt—conform, debase—exalt, repress—restrain.

Test 7. Best Answer. Five attempted, 4 correct. Weighted score, 12. (About 11½ years.) Why judge a man by what he does rather than by what he says?—"It is wrong to judge anybody."

Test 8. Number Series Completion. Raw score, 7; weighted score, 14. (About 15 years.)

Test 9. Analogies. Six correct. (About 10½ years.) This test is not weighted. Omitted or failed on items like the following:

(5) Dress—woman: feathers—(bird, neck, feet, bill);
(6) Water—drink: bread—(cake, eat, coffee, pie);
(7) Shoe—foot: hat—(coat, nose, head, collar).

Test 10. Number Cancellation. Score, 19. (About 15 years.)

Total weighted score, 175. This is about median for the high seventh grade, or age 13½ to 14, and is approximately equivalent to score 70 on Alpha. The lowest score earned by any Stanford University student in a group of 300 tested was 205. However, K evidently does consider-

[2] Described in *J. of Applied Psychology,* 1918, vol. 2, p. 348. The pictures themselves have not been published.

ably better on this kind of test than on tests of the Binet type, perhaps because it is more subject to the influence of schooling.

Kent-Rosanoff Association Test

K presented no symptoms whatever of psychopathological tendencies, but the Kent-Rosanoff test was given in order to compare his responses with those found by the authors for typical dull subjects. The results showed 14 per cent. of "individual" and 4 per cent. of "doubtful" reactions. Kent and Rosanoff found 6.8 per cent. of individual responses for normal adults, 14.3 per cent. for normal ten-year olds, and 26.8 per cent. for insane adults. Eastman and Rosanoff found 13.2 per cent. for delinquents (presumably averaging much below normal in intelligence). Accordingly, as far as individual responses are concerned, K's performance resembles that of a dull youth or normal child.

The median frequency of the responses was 22, which is considerably lower than for normal adults. In this case, the low score indicates dullness rather than mental eccentricity. There were no predicate reactions.

There was only one instance of failure to respond, and seven instances of perseverance. These figures are not greatly different from those found for normal adults.

Average reaction time was 3.1 seconds, ± 1.54. The average for college students is usually between 1.5 and 2.25; for children or mentally inferior adults, about 3. Four responses required more than 10 seconds. K's slow reaction time, as well as the quality of his responses, indicates mental inferiority.

Educational Tests

Handwriting. Smooth and legible, entirely lacking in infantile qualities. Grades 14 on Thorndike scale.

Kansas silent reading. Slightly better than eighth grade ability.

Buckingham spelling test. Lists 1 and 2. Better than ninth grade ability.

Courtis arithmetic. The results are shown in the following table:

Process	Attempts	Right	Notes
Addition	16	11	Far above eighth grade.
Subtraction	14	11	About eighth grade.
Multiplication	11	7	Slightly below eighth grade.
Division	7	4	Between fifth and sixth grade.
Speed of Reasoning	5	2	About fifth grade.

The striking thing in the above table is the rapid deterioration in quality of performance in the successive parts of the test from addition to reasoning. That is, the higher the mental processes involved in a test, the more clearly it brings out K's subnormality. In speed and accuracy of adding he compares favorably with the average high school pupil, while in arithmetical reasoning he is little above fifth-grade ability. Three errors, all as absurd as the following, were made in indicating operations necessary to solve problems:

1. The children of a school gave a sleigh-ride party. There were 9 sleighs used, and each sleigh held 30 children. How many children were there in the party? Ans.—"Subtract."

History. History was K's favorite school subject. He had studied it for four years in high school, covering ancient, medieval and modern, English, and American History. Van Wagenen's American History Scale (Information B) was first given. From K's responses, we learn that New York was settled by the English, that the Missisippi Valley was first explored by the United States and England, that Lafayette and Hancock were American generals in the Revolutionary War, that Jamestown was not settled until after the fall of Quebec and the capture of New Amsterdam by the English, that Louisiana was not purchased until after the Missouri Compromise and the Dred Scott Decision, and that Alexander Hamilton was president of the United States. This list of interesting facts could have been greatly extended. The performance indicated about seventh or eighth grade ability.

Sackett's Ancient History test was also given. This is also chiefly an information test. The test is in six parts.

I. What the following were noted for: Hannibal, Cheops, Solon, Attila, Mithridates—"Don't know"; Demosthenes—"Great writer"; Charlemagne—"He was a ruler over Egypt"; Constantine—"Ruled over Egypt."

II. Name one of each of the following, from ancient history: a sculptor, a historian, a philosopher, a builder, a poet—"Don't know." A painter—"Raphael"; law-giver—"Demosthenes."

III. Historical significance of important events. K could tell nothing whatever about the historical significance of the Battle of Tours, the Age of Augustus, the Check of the Saracens, the Reign of Alexander the Great, the Age of Pericles, the Burning of Carthage, the Peloponnesian War, etc.

IV. Important battles. Could not tell who fought or won any of the important battles listed.

V. Important dates. The closest he came to any of the ten dates was about 100 years. The Roman Empire was established about 100 A. D. and fell to the Barbarians about 261 A. D. The Saracens were also defeated around 100 A. D. Most of the events in this list he had "never heard of."

VI. The most important contribution of each of the following to civilization: Greeks—"No idea unless ships. Sort of a fleet is what they had mostly." Teutons—"Came from Northern Europe. Don't know what they gave to the people." Phoenicians—"Don't know who they were." Saracens and Arabians—"Don't know." Romans—"Don't know, unless it was the great art what they had." Hebrews—"Hebrew language only thing I know." (Who were the Hebrews?) "Don't know who they were." (Are they related to the Jews?) "Sort of same thing; are not Jews, though." Persians—"Don't know." Egyptians—"Don't know." Babylonians—"Don't know." Prehistoric Man—"Don't know.'

K's stock of historical information may be inferred from the fact that of the 55 questions in the above six series, 2 were answered correctly. He did know that Cicero was an orator and that Alexander was a warrior ("general").

Notes on Reading and Hobbies

Reading. K stated that from the time he entered high school he had read from one to two hours a day, chiefly newspapers and magazines. The latter included *American Boy, The Youth's Companion, Popular Mechanics, The Literary Digest* and *World's Work.* Asked what books he had read through, he could name only the following: *Little Women,* Alger's books, *Robinson Crusoe,* and several volumes of Draper's *Self Culture.* Said he had also read a book about the Civil War, but could not name it. Could not remember that he had ever read a book of travel, any novel, or any books on mythology. He had read no poems except those in his school texts—"I don't like poetry."

Hobbies. Seems never to have had any persisting hobbies. Four years earlier had put up a telegraph line, which worked, and learned some of the Morse code. This interest lasted only one winter. Had never tried wireless telegraphy. Once he "helped" another boy construct a biplane model. It seems that this was a simple affair and that K played only a minor rôle in it. Can ride a motorcycle, but "does not take care of it himself or try to fix it when it is out of order." Likes an auto better; says he can grease it, fix the fan belt, repair punctures or adjust the carburetor. However, could not explain the principle of the gas engine or tell what the carburetor and commutator are for. Has never had a set of tools and admits that he was "never much good" with them.

The Psychology of Stupidity

The details of K's test performances have not been set forth merely as amusing illustrations of intellectual gaucherie. Let us see what light they throw on the psychology of stupidity, for the essential nature of intelligence or stupidity is best grasped by thoughtful observation of the bright or dull mind in action.

First, however, it will be well to note that the degree of stupidity with which we are here concerned is really not extreme. K is in fact only moderately less dull than the average of the genus homo, judging from the intelligence scores made by nearly two million soldiers. His intelligence is probably not equalled or exceeded by more than 70 per cent. of our white voters, by more than 50 to 60 per cent. of semi-skilled laborers, by more than 40 to 50 per cent. of barbers or teamsters, or by more than 20 to 30 per cent. of unskilled laborers. It is probably not equaled or exceeded by more than 30 to 40 per cent. of our South Italian or by more than 20 to 30 per cent. of our Mexican immigrants. Compared to the average American Negro, K is intellectually gifted, being equalled by probably not more than 10 to 15 per cent. of that race. Among the Jukes, Kallikaks, Pineys or Hill Folk, he would represent the aristocracy of intellect. Just as we are prone to forget how the other half lives, so we are equally likely to forget how the other half thinks. It is now fairly well established that the strictly median individual of our population meets with little success in dealing with abstractions more difficult than those represented in a typical course of study for eighth grade pupils, that the large majority of high-school graduates are drawn from the best 25 per cent. of the population, and that the typical university graduate ranks in intellectual endowment well within the top 10 per cent. K is stupid only by contrast. Only occasionally does an individual of his moderate ability manage to graduate from high school or enter college. Only an exceptional combination of dogged persistence and parental encouragement or other favoring circumstances can accomplish it. But the introduction of intelligence tests is showing that the majority of colleges and universities do unknowingly enroll a few students of K's intellectual caliber. How this happens and how it may be prevented are questions with which we are not here concerned.

In what, psychologically, does K's stupidity consist? Certainly not in the ordinary sensorial, perceptual or sensorimotor processes. In visual acuity he probably equals or exceeds the average savant. In the cancellation of given letters or figures in a mass of printed matter he would rank little if at all below the average of college students. He is probably in less danger of being run over by an automobile than the average college professor. He can probably drive an automobile as skillfully as the average lawyer, doctor or minister could do with the same amount of experience. There is nothing in his intelligence that would prevent him from reaping world renown as a champion athlete. His handwriting would be a credit to a statesman. His spelling is unquestionably more accurate than the spelling we find in the letters and official reports of Colonel Washington, afterward the savior and the father of his country.

Going from these relatively simple functions to the slightly higher processes of memory, we at once find unmistakable evidence of K's mental inferiority. His memory span is only five digits, direct order, and four digits, reversed order. But we have to do not merely or chiefly with a weakness of memory for discrete impressions. He is able to recognize and pronounce almost any printed word in his spoken vocabulary, but his memory span for words making sentences resembles that of a child of eight or ten years. His "report" of glibly read passages of the newspaper type is childish in its scantiness and inaccuracy, while his report of abstract passages rises little above zero efficiency. He is sometimes able to carry out directions given orally in 15-word sentences, but he responds with only a blank stare to similar directions in 30 to 40 word sentences. So many sounds will not coalesce in his mind into a meaningful whole. Nor is this weakness confined to memory for words, for he does little better with simple geometrical designs. He is unable to reproduce correctly simple geometrical designs because he apperceives the figures merely as composed of many lines in apparently complex relationship to one another.

How can we reconcile this apparent weakness of memory with the fact that K's fund of general information, as measured by the army test, is equal to that of the average high-school sophomore? Does not the acquisition of information depend upon memory? The answer is that it depends largely on the kind of information. The kind called for in the original form of the army test relates largely to every-day perceptual experiences (common animals, plants, advertisements, sports, etc.). In information involving memory for abstract terms or appreciation of logical relationships, K makes a ludicrous showing. Information about base-ball champions or movie stars is within his reach; historical information is not.

K's success is no more brilliant when it comes to feats of constructive imagination. He was able to draw a clock face so as to show the position of the hands at any specified time, but he could not in imagination reverse the hands. He could not construct in imagination the situation represented by the problem of enclosed boxes. In the Binet paper cutting test, he could not imagine how the notched sheet of paper would look when unfolded. He could not retain or manipulate visual imagery well enough to reproduce the letter code. To think out new combinations of machinery or forces, as in the field of mechanical inventions, appears to be as far beyond him as the ability to manipulate abstract language symbols.

The weakness of K's constructive imagination is also shown in his lack of resourcefulness in meeting practical difficulties like those involved in the Ball and Field problem, the ingenuity test or the Knox Imitation test. The latter is not, strictly speaking, an imitation test, for success in its more difficult parts depends chiefly on adopting the scheme of numbering the positions, as 1, 2, 3, 4, etc., and remembering the numbers. This required resourcefulness is of a kind K can not bring to bear on a new problem. If he were a factory laborer, he could doubtless be taught to perform satisfactorily fairly complicated kinds of routine work, but he would not be likely to devise any new procedure to make work easier or lighter.

In the appreciation of absurdities of a kind which are chiefly on the perceptual level or which involve only the simplest of ideas (absurd pictures), K makes a fairly good showing. He shows somewhat less ability to detect absurdities expressed in language, particularly if expressed in fairly long or complicated sentences. To absurdities on the level of the abstract he is of course blind. He would doubtless read without the slightest suspicion of fraud a poem or sermon or legal document constructed so as to contain nothing but absurdity, provided only the language was sufficiently smooth-flowing. The absurdity about the road which was down hill in both directions involves little more than the re-presentation of sensed experience, hence was well within K's ability. That about the three brothers demands an appreciation of language relationships which proved to be beyond him.

In "Combinative ability" of the kind which Ebbinghaus rightly regarded as such an important aspect of intelligence, K reveals, notwithstanding fourteen years of schooling, the capacities of an average child of twelve years. His desert-rivers-lakes sentence is correct in form, but absurdly foolish. In the Trabue test we find habitual associations dominant over sense, as in "The stars and *stripes* will shine to-night"; also a weak appreciation of sequential relationships and language form, as in "She *could* if she will," "The boy who *studied* hard will succeed," etc. The meaning of a simple mixed sentence like "people are many candy of fond" is not grasped by K because he is unable to profit from logical cues. He sometimes reacts to pictures by descriptions rather than interpretations because he sees merely parts without grasping the whole they compose. Subtle meanings, whether of language or pictorial representation, are lost on him. The gulf that separates him from Millet is as enormous as that which separates him from Shakespeare. In no intellectual activity that involves the "elaboration of parts into their worth and meaning" (Ebbinghaus) could he possibly excel. "Two and two" as numbers he can put together by the simple laws of habit; "two and two" as parts of a more complex situation will not combine.

In comprehension K fails equally with simple cause and effect relationships in nature, human relationships, and the rationalization of custom. Why the deaf should also be dumb is as much a mystery to him as why the rainbow is many-colored. New York is the largest city "because it covers such a large area." Why honesty is the best policy, why women and children should be saved first in a shipwreck, why marriage licenses are necessary, involve issues too subtle for him to grasp. Although his inferior powers of comprehension render him incapable of real morality, his moral life, measured by the ordinary standards, appears to be quite normal. He is honest, and considerate and not likely to commit bigamy or marry without license. He follows custom but can not see beneath it or behind it. He is about as likely to be a moral reformer as to be a philosopher or poet or inventor or scientist.

Closely associated with this weakness of comprehension is his inability to interpret fables, which usually bring either a comment in terms of the concrete situation or else a generalization which is beside the point. He grasps crudely the general trend of the story, but is insensible to the thought fringes which give it meaning. He is able to imagine the objects and activities described, but taken in the rough such imagery gets him nowhere. It is no wonder, therefore, that he should match as equivalents proverbs of the most diverse meaning, for proverbs are generalized experience expressed in highly figurative language. K's moral life will never be integrated by principles of action derived from experience. It is more likely to consist of rule-of-thumb behavior. And if he can not generalize his own experiences he is not likely to read much meaning into the behavior of others. He is not likely to develop that intuitive appreciation of the motives and attitudes of others which are necessary for the exercise of leadership. He will make as little headway in understanding the universe of personalities around him as in understanding the laws of gravity, the properties of the atom, the theory of evolution, or the canons of poetry.

Striking examples of the poverty of K's intellectual resources are seen in the various tests of association. Of the dozens of words in his vocabularly which rhyme with *spring* he could not think of one. During the last minute of the sixty-word test he was able to name words only at the rate of 7 in a half minute. Analogies involving concrete objects he can sometimes complete correctly, more often not; but his response is not often wholly irrelevant. *Arm is to elbow as leg is to*—he completes with "abdomen"; a part of the human body, but not the part called for by the logical relationships given. In naming opposites he sometimes loses sight of the goal and responds with a synonym, as in weary—"tired"; stale—"old." In other cases he responds with a word which is frequently associated with the stimulus word in everyday phraseology, as cheap—"goods"; never—"will." Still other responses are either slightly inexact, at best—"poor," or else almost but not quite irrelevant, as top—"tail"; horrid—"mild." Both the low "frequency" of the Kent-Rosanoff response words, and the slowness with which they are given, indicate a lack of variety in concept interconnections, with consequent poverty of verbal associations. As Binet might put it, K's ideas lack direction, are not fruitful, and do not multiply. They are inert and lack valence. The result is intellectual sluggishness and haziness. Our subject will never draw hair-splitting distinctions; he is even incapable of quibbling or making puns.

An essential aspect of the higher thought processes is the ability to associate ideas on the basis of similarities or differences. This ability is involved in such diverse mental acts as the understanding of simple figures of speech, the appreciation of poetry, the scientific classification of natural phenomena, and the origination of hypotheses of science or philosophy. Intellectual superiority is especially evidenced in the ability to note *essential* likenesses and differences, as contrasted with those which are superficial, trivial or accidental. It is here that K displays one of his most characteristic weaknesses. An apple and a peach are alike because they have a skin; iron and silver, because they are heavy; an animal and a plant, because they have hearts; a snake, a cow and a sparrow, because they have a tail; grass, cotton, tree and thistle, because they are green. Other similarities given are far-fetched or inaccurate. A hat and a coat are alike because they are gold rimmed; a rose, a potato and a tree, because they have a skin or heart. There is little logical connection among K's concepts; they do not light up one another; they have not been subsumed under classes; they lack definiteness of content.

All of this is again brought out in the vocabulary test, which in a remarkable degree is a test of one's ability to distil concepts—from experience. Mere schooling affects it a little, but very little. Although K has attended school fourteen years, his vocabulary is less than a year beyond the standard for average children of his own *mental* age. Both the school and the cultural influences of a superior home have failed to give him an understanding of such common words as civil, brunette, bewail, priceless, disproportionate, tolerate, shrewd, repose, character or reputation. His definitions are occasionally infantile in form (given in terms of use, etc.), but are more often vague, or grossly inaccurate without being wholly irrelevant. For example, lecture means "to be taught"; ramble, "to go fast"; conscientious, "very good in his work"; brunette, "white"; tolerate, "to get away from." All of these words he has probably seen or heard scores of times, but he has failed to grasp their meanings because of inability to analyze the situations in which they have appeared.

Summing it all up we may say that K responds normally to simple situations directly sensed, and that his inferiority is chiefly evident in responses involving intellectual initiative, planning, range and flexibility of association, analysis of a situation into its elements, alertness, and the direction of attention toward the significant aspects of experience. Most of all, K is stupid because he is not adept in the formation and manipulation of concepts; because he is unable to master the intellectual shorthand of general ideas.

What is the practical bearing of the above facts on K's vocational outlook? While an exact answer to this question is at present not possible, a few tentative predictions may be ventured. K is at present performing the duties of a regular clerk in his father's store, apparently with success, but it is unlikely that he will ever be able to manage a business of any considerable importance. That he will ever succeed his father in the local bank is hardly in the bounds of possibility. Perhaps he will know how to get credit and how to grant it with fair discretion, but he will never understand the principles of credit by which banking is carried on. He may learn how to purchase bonds, to clip coupons, and how to save his income; but he will never know what a bond is. That he could become a minister, lawyer or doctor is unthinkable. He will never engage in theological disputes or concern himself about principles of artificial immunization. On the other hand, a hundred kinds of skilled or at least semi-skilled work are open to him. As far as intelligence is concerned there is no reason to suppose that he could not be a reasonably good baker, barber, bricklayer, butcher, carpenter, drill sharpener, freight checker, game warden, glass blower, harness-maker, horse-clipper, jail-keeper, joiner, lathe-hand, policeman, professional baseball player, plumber, prize fighter, peddler, railroad brakeman, riveter, roofer, section boss, soldier, street car conductor, timer, truckman, valet, weaver or yardman. There are doubtless also innumerable kinds of routine clerical work in which he could do well. For all we know he may become a successful business man, but this is unlikely unless through the shrewd choice of assistants or marriage to a capable woman.

Whatever he does for a living, K may be expected to become a citizen of average respectability, though he is not likely to be elected to important office or to play a leading rôle in the affairs of his community. As a voter, he will never glimpse the fundamental problems relating to taxation, tariff, government ownership, systems of credit, education, labor or capital. If he ever concerns himself at all with political matters, it will probably be as a loyal adherent to his party and a devout repeater of its catchwords.

CERTAIN UNITIES IN SCIENCE

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THAT the several sciences taken as a whole form one science is a proposition which has often been urged, sometimes apparently as an article of faith and sometimes as a reasoned conclusion. To an individual who holds, with nearly religious fervor, the doctrine that the universe is one and that the truth of science asymptotically approaches the absolute truth about the universe, there can be no doubt of the oneness of all science; there is no room or opportunity, except through error, for that diversity which destroys the oneness of the whole. To an individual of such an outlook it may be almost or quite an article of faith that all science is one. But to him whose universe is not so tidy, in whose thought there is the ever-present possibility that after all we may be building on insecure foundations, the assertion of the unity of science can be made only on a reasoned analysis of its characteristics and on the established fact of the presence in it of such dominant qualities as bind the whole indissolubly into one. To exhibit such elements and to show that they have such qualities is a task of large proportions, far beyond the possible achievements of a single paper. Our purpose is the more modest one of exhibiting certain common elements, certain unities, in science as a whole and of partially analyzing the way in which their presence affects the character of scientific truth.

The unities in science, however far-reaching, can never be absolute. Whatever is common to two domains of knowledge appears in each of them colored by the dominant light of the particular discipline. Perhaps the most obvious unity of all is that of experimentation and observation; its presence in natural science is almost universal. But in mathematics it is partially obscured from view by a universal insistence upon logical connection in exposition, so that the processes of experimentation and observation which were employed in discovery are not in evidence in the finished product. In the case of empirical theorems stated as conjectures (such as have occurred frequently in the history of the theory of numbers) we have the most notable partial exception to what is the general rule. The results conjectured are genuine empirical theorems. Mathematics differs from the natural sciences in refusing to accept these conjectured theorems without a logical demonstration. In thousands of cases it has been observed, for instance, that an even number is a sum of two primes and no even number is known which does not have this remarkable property. It is conjectured to be true that every even number is a sum of two primes. But, as long as a logical demonstration is wanting, no mathematical memoir or treatise will assert its truth. Such an ideal of carefulness is possible as a practical ideal for the control of actual mathematical exposition; and, since it is possible, we insist upon it absolutely. But, from the greater complexity of its problems and the nature of the truth with which it deals, natural science can not insist upon such perfection of logical form but must rely upon incomplete induction from particular observations to general laws and their subsequent experimental verification either directly or through the intervention of their consequences. The nearly universal unity of experimentation and observation is seen in varying colors in the different sciences.

Probably a more important, if less obvious, unity is that of invention or creation. This is most clearly in evidence in pure mathematics; but an examination of it as it appears there leads to the judgment that it is perhaps dominant throughout all science. There are those who wish to have the universe so tidy that nothing actually novel could happen in it, that happening would be impossible, that every event should be a mere consequence of the events which have preceded it. But there are others who would not object to the surprises and thrills of true novelty, who would not be disconcerted by the conclusion that a law reached inductively by the mind is essentially a creation of the mind, made (to be sure) for the purpose of relating in thought a class of observed phenomena, but none the less a veritable creation or invention. The whole matter turns on this question: Are the laws obtained by induction found in nature and dictated entirely by nature, or does the mind in some manner impose its own bias upon them? It appears that we are forced to the latter conclusion, particularly when we see the dominance of a general theory like the atomic theory or the rapid inroads of such a one as the theory of relativity and reflect how these were conceived in the mind before there existed any empirical evidence for them. In such cases as these the mind has either imposed its own bias upon the laws of nature or it has had an uncanny foresight of them before they appeared in experimental science. The former seems to be the more natural and justifiable hypothesis.

There is much to be said in favor of the thesis that natural science should be considered a construct of mind rather than a paraphrase of nature wrought out by the mind. The processes of invention are most in evidence in the formulation of hypotheses, and most clearly when these are based on only a few observations. There is no experimental proof, and perhaps in the nature of things there can be none, for the hypothesis of the conservation of energy on which all modern physical science is based. This seems to be a law imposed by the mind for its convenience but without direct experimental support; at best it is contradicted by no experimental fact.

But invention seems also to be present in the process of experimentation. The experimenter is not a merely passive recipient. He is active in directing the course of events. He invents phenomena which would be non-existent without his guiding influence. He gives attention to what he wills and ignores other things. He will not see all that happens, nor will he record all that he sees. He selects before he places on record for the examination of others.

The principle of direct causality is almost universally held to underlie all natural science; the principle of inverse causality is also generally asserted as true, but with less confidence in the assertion. If the principle of causality exists at all in mathematics it must be in some greatly attenuated form. It can hardly be said that the triangularity of a Euclidean triangle is a cause having as an effect the proposition that the sum of the angles of the triangle is equal to a straight angle—unless one thinks of the cause-and-effect relation as having here a quality peculiar to mathematics. But in the natural sciences the principle seems to rule supreme. In some of them it is employed mostly in the direct sense, as in physics where one generally utilizes it for proceeding from the cause to the effect; in others the principle of inverse causality is more often in evidence, as in geology where we infer the past state of the earth from its present state. If the principle of causality affords a unity in science it can do so only on the assumption of at least the three well-distinguished forms which we have just mentioned. Moreover, however one approaches it, it involves him in speculative difficulties from which it is hard to extricate himself. It is a severe, if not an impossible, task to adjust his conception of the principle and his practice in its use so as to avoid just criticism and his own dissatisfaction with it.

The difficulties which we have seen here in these cases are probably to be found, singly or in combination, in the case of most of the more obvious unities in science. The element of unity may fail to be as well marked as we like throughout the whole range of the sciences, as in the case of the unity of experimentation and observation; or it may be of such character that people can not be brought to general agreement about it as in the unity of method involved in the hypothesis of invention or creation; or it may lack somewhat in oneness, as in the case of the three forms in which the principle of causality appears. The main object of this paper is to discuss certain actual or possible unities not having these defective qualities.

The complexity of nature is great beyond our ability to understand or perceive. The material universe is too rich in form and the fullness of phenomena for us to reach the whole extended complex in a single grasp of the mind. The extreme variety of kinds of objects, the multitudes of individuals of a kind, their almost innumerable relations in time and space, the ramifying causal connections among them and their mutual dependencies, their diverse relations to our own life and thought, and the hidden things in them which our organs of sense are unable to perceive even when supported by the powerful instruments of science—all these tend to produce a complexity in the presence of which we are helpless so far as logical organization of all impressions is concerned.

Even in the realm of those objects of thought which are constructed by the mind itself there is too much diversity for us to contemplate the whole at once if we are to do anything other than make glib general statements unsupported by anything more than a certain appeal to the imagination. It is evident that the mind is able to contemplate successively the elements of a range of objects of thought far too vast to be embraced in a single encircling mental act. This is true not only in general but also in the case of such extended ranges as pertain to a single domain, as for instance that of mathematics or that of philosophy.

Two quite distinct worlds about which we should have exact information may be conceived separately; the world of matter and the world of logical thought. Let us examine the two things presented to our consideration by the physical phenomena of matter on the one hand and on the other hand that special domain of logical thought which is embodied in mathematics. There is a very wide range of mathematical knowledge apparently unconnected with the properties of matter. There are physical properties of matter, so complicated that mathematical methods are still powerless in their presence. Each of these domains is vast in its extent. There is a relatively narrow strip on which the two overlap, the properties of matter yielding themselves to mathematical formulation and the mathematical truth seeming to have its concrete embodiment in the properties and phenomena of matter. The existence of this common region of the two things apparently so widely separated has arrested our attention and has directed it so forcibly to the striking parallelism that we have sometimes felt that we have in it a fair measure of evidence for believing the whole universe to be rational. So far this conclusion has too much the appearance of a pious wish and two little the character of a demonstrated result to justify our confidence in it. The relative narrowness of the common region of the two is rather disconcerting if we examine it closely. Even if all physical relations should be reduced to mathematical formulation we would still have far to go to reduce all phenomena to rational order and to find logical connections among all their parts.

This diverse character of the most widely separated elements of physical and of mathematical science is one evidence of the necessity for breaking up into parts the total body of material concerning which we seek to attain exact and permanent knowledge so as to bring it within the range of such methods as we are able to conceive and employ in one connected investigation or analysis. But if we break this material up into parts it is only by ignoring certain connections of importance, only by making abstraction of elements which may be omitted for the intended partial view but are essential to a complete understanding of the whole.

The general situations actually presented by nature or by thought are too complex for us if we are to gain permanence or invariance in the conclusions which we reach. We have to create ideal situations where we are more at home and over which a restricted range of method will carry us with safety and with conclusions of sufficient penetration to have abiding value. We have to adapt our procedure to the strength of tool afforded by our minds when brought to their state of highest effectiveness. With a more penetrating insight less abstraction would be necessary; but only omniscience would enable us to conceive and handle at once the total flux of nature and thought. We have to work subject to the restrictions of our essential limitations.

This process of abstraction has been carried further in mathematics than in any other science, having attained a place of importance there long before its primary character was recognized in other disciplines. Every organism possessed of locomotion has to deal with the problem of space relations, and particularly an architectural animal like a beaver or a man. Long experience in construction and measurement will give rise to a certain body of empirical knowledge and rule-of-thumb methods for making standard constructions. To such a state of advancement the knowledge of space had already attained among the ancient nations of the Orient and particularly among the ancient Egyptians. But their progress was intercepted by their inability to make needful abstraction of the essentially irrelevant and to concentrate on those properties which afford the essential elements of geometrical form as such. They could only imperfectly conceive a triangle as anything more ideal than a piece of land of a certain outline or a flat stone of a certain shape.

As long as the problems are conceived as those of the space relations of material objects there is present to thought a large disturbing element which successfully turns the attention away from what is essential. In order to construct a theory of the space relations of objects it seems to be practically necessary to do a more ideal thing first. Before one can make serious progress in the way of definite conquest, one must abstract from the general complexity of the situation and attain to a new one relatively much simpler. In fact, not only in the study of properties of geometrical space but also in many domains of science it is necessary to create a new situation having certain analogies with the actual one of nature but being so much simpler that we are able to grasp the interrelations of all its parts.

This idealizing of the problem of space relations was first effectively achieved in the geometry of the ancient Greeks. They were able to get away quite completely from the material triangle and to conceive the ideal triangle defined by certain essential ideal properties. Likewise they were able to make abstraction of what was not necessary to the purposes of a pure geometry in the various lines and circles and other figures which they wished to consider. This new attitude toward the subject matter of the theory of geometrical space allowed an altogether unforeseen extension of knowledge; geometry came into being in one of those forms which stand as part of the modern theory. By abstraction of unessential elements the mind came to behold a much simplified object of thought and analysis a knowledge of whose properties gave the needful insight into the space relations involved in normal everyday experience.

For a long time this body of geometrical truth stood apart from all other knowledge, separated by qualities of generality and ideal conception from all other doctrines whether of mathematics or of some other discipline; but, after a time, algebra began to assume a like position of separate completeness and it existed so until algebra and geometry were brought together by the invention of analytical geometry.

The abstraction of the unessential in the study of space relations, difficult as it was and effected only in relatively recent times, seems to have been the easiest large abstraction for the human race to achieve. This was probably due to our intimate racial acquaintance with the space of experience during the whole period of our evolutionary history and to some peculiar adaptation of ourselves to the understanding of spatial relations. That our long drawn out experience with it is not in itself sufficient to enable us to fix attention upon the essential elements and to understand their relations is shown by the fact that we have been quite as long acquainted with the weather as with space relations and that we have not yet been able to reduce to the form of an exact science our knowledge of its daily changes—unless indeed we have been hindered in such progress by essential changes in the character of the weather during geological ages while the relations of space have been an invariant element throughout our experience.

The fact that mathematics first succeeded in making these large abstractions from the complexity of the environment in building up its body of doctrine and that is today relative the furthest advanced of the sciences raises the question as to whether there is a general correlation between the state of advancement of a science and its success in forming appropriate abstractions. The just conclusion seems to be that no science is far advanced until it has first succeeded in isolating by abstraction a large body of material, conceived ideally apart from the matrix of its environment and possessed of such essential properties as make it possible to pass from the conclusions of this ideal science into the actual complexity of phenomena with a better understanding of important phases of the latter than is otherwise possible.

In meteorology, where successful abstraction is exceedingly difficult, we find a relatively small body of securely achieved truth. The same is true in our study of industrial organization and of the complex phenomena of the social relation. But if we turn to the work of the astronomer in celestial mechanics, where nature herself almost made the abstractions for him, we find a science relatively far advanced and one which achieved its position of preeminence early in the modern era.

Under the inspiration afforded by the laws of Kepler Newton meditated on the question as to the ultimate law of nature upon which the properties of the planetary orbits depend; and he was led to conceive, and establish by geometrical reasoning, the principle of universal gravitation and the law that the force of attraction between two material particles is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. These discoveries of Newton condensed an almost immeasurable volume of thought into a compact and simple formula, bringing the theory and observation of past ages to a focus from which new lines might diverge in many directions. Laplace undertook to draw out the consequences of the laws of Newton, his purpose being to "offer a complete solution of the great mechanical problem presented by the solar system, and to bring theory to coincide so closely with observation that empirical equations should no longer find a place in astronomical tables." His success in both respects brought him very close to his lofty ideal.

The "Mécanique Céleste" of Laplace holds a unique place in the history of science. It was the first instance in which an extensive unified and logical theory had been developed for a large class of observed phenomena. A very few fundamental principles lay at the basis of the entire work, owing to abstraction of unessential details; and it was developed from these principles in its entirety solely by mathematical processes, this logical procedure being rendered possible by the essential simplicity of the ideal situation. In such a body of truth there is something esthetically satisfying in a high degree. It could not fail to have a profound effect on the development of thought.

The cosmical and subsequently many terrestrial phenomena having been explained, it was natural that Newton, and still more Laplace and his school, should attempt the explanation of molecular phenomena by similar methods, importing into molar and molecular physics the astronomical view which had arisen in mechanics. This celestial mechanics became the model for the exact sciences. Men sought to give to other theories an equally beautiful and logically consistent form. The start from a few principles, easily enunciated and readily comprehended; the forward march of the theory into new fields, comprising in the range of its explanation an ever-increasing portion of observed phenomena; and its ultimate comprehensiveness in this respect—these things gave it a hold on the imagination. It thus became a profound factor in the development of the whole of physical science in its mathematical form. The cold touch of exact thinking and the calculating mind, both products of the method of abstraction in the development of scientific truth, have proved to be the spell by which knowledge has been found, new sciences have been created and a novel trend has been given to the development of thought.

Perhaps I may digress widely enough to indicate how the precarious character of scientific advancement is indicated by some of the matters now in consideration. Suppose that our earth, instead of being one of a few planets moving around a single sun, had been one of several satellites of a large planet moving about the center of gravity of a double star; then it is clear that the facts of astronomical observation which would first have pressed themselves upon our attention would have been much more complex than those of our actual system. When we consider the long period of time which it required the race to unravel the intricacies of the much simpler system of which the earth is a part and the uncertain and haphazard way by which it took the necessary steps, we see that there is room for grave doubt as to whether we would ever have conceived a suitable explanation and whether (having missed such a guide as this) we would be in a position successfully to attack or even to conceive the problems of natural science. Our progress has been made under the inspiration of the ideal afforded by astronomy on account of a success due to abstractions to which the nature of the observations pointed the way. Could we have ever conceived such an ideal if we had been confronted with a much more complicated astronomical system? And could we have already built up, or would we have ever been able to build up, a body of science comparable to that which we possess today? Certainly the answer can not be a confident affirmative.

Natural science and mathematics are not the only domains of thought in which the principle of abstraction is prominent; it appears also in speculative philosophy. But its relation to the latter is quite different from that to the former domain. In science we are quite willing to admit abstraction frankly as a universal characteristic which is necessary on account of the limited character of the intellect. But the philosopher desires to get away from it as far as possible. He wishes to embrace in his system an ever-widening range of material; and he would be most pleased if it might be ultimately comprehensive. He knows that he has not attained to such an ideal and probably never expects to; but he still feels a certain sense of uneasiness when he finds a body of truth quite unrelated to the system by which he has brought things to order in his own mind.

But in art and literature the matter is quite different. Here the intention is to contemplate at once the whole stream of life and existence, at least so far as to have no purposed exclusions. Here one deals with the actual complexity of events and even with the character and emotions of individuals. One does not state theorems; one does not announce universal laws; one does not reach rules-of-thumb for doing mechanical things; one does not even find general principles upon which there is universal and permanent agreement nor those by which one may have precise guidance for conduct in any given situation; but one does reach permanent conquest in the creation of things of enduring beauty; one produces lasting values for the emotional life even if one does not increase the body of exact knowledge.

From the foregoing considerations it appears that the method of abstraction, as an active means for clearing off the ground and an active support to the consequent investigations, is common to all science and is characteristic of science. It is therefore one of the important characteristic unities in scientific method. We find it necessary to isolate one subject from another by abstraction in order to avoid being smatterers. We reduce our serious problems to ideal abstractions because no deep-lying problem can be solved without reducing it to abstractions. If we do away with them we do away with mathematics and logic and natural science. They have thoroughly justified themselves through the marvelous conquests of modern science which they have so effectively supported.

But these abstractions are not without their dangers. It has been said that the supreme fallacy of the academic mind is carefully to make abstractions and then straightway forget that they are abstractions. "The expert in the conceptions belonging to one field of knowledge legitimately solves the problems of that field in their terms. But sometimes he forgets that these are very special and limited notions of truth, applicable only to that one field. He ignores that his science is only one abstracted aspect of concrete life, separated from other aspects of life only for the sake of specialization of labor. Ignoring this, he attempts to solve the problems of other fields with his own field's special concepts. Thus, a biologist sometimes endeavors to reduce all psychology to biological concepts; or an economist to reduce all moral values to the special values of the economic world."

Perhaps, for the sake of unity in point of view, one may be allowed to treat, as resulting from a certain form of the method of abstraction, a quality of the mathematical formulation of the laws of nature which first appears explicitly in the general Einstein theory of relativity. This is not the place to give any of the technical developments [1] belonging to the latter theory. But it is a matter of general scientific interest to indicate the character of a new ideal for the form of scientific laws which was first insisted upon in the investigations of Einstein, particularly as it can be successfully described without any of the heavy mathematical machinery which is essential to a detailed development of the theory. This ideal emerges in connection with the analysis of the now celebrated principle of equivalence, which we may enunciate as follows: A gravitational field of force is exactly equivalent to a field of force introduced by a transformation of the coordinates of reference so that we can not by any possible experiment distinguish between them.

The notion of transformation of coordinates of reference, which appears here, is quite essential to an understanding of the quality of mathematical formulation of laws which we wish to explain. Perhaps we may best approach the matter by conceiving a geometrical curve fixed in the space interior to a given room of four walls meeting at right angles. If we take the floor and two adjacent walls to be a system of reference by means of which to locate the positions of a point in the room, then we can uniquely define the positions of a point on our curve by giving its distance from the floor and from each of the two walls selected. If the point moves along the given curve then the numbers expressing these distances will be related according to a law determined by the shape and position of the curve; these three variable numbers will satisfy certain equations of condition. If we used the ceiling and the other walls as a system of reference we should in general obtain different equations of condition for the same curve. Those would be further modified if we chose for reference system some other set of three planes mutually perpendicular to each other, and especially so if these planes should be oriented in some new directions.

[1] The reader interested in these developments will find them in the second edition of my "Theory of Relativity," Wiley & Sons, 1920.

It is clear that these changes in the system of reference have in no wise affected the properties of the curve itself, though they have constantly modified the mathemaitcal expressions by means of which we may most compactly and most completely describe the curve and its position. Let us for a moment forget these systems of reference and study the curve itself by passing along it from point to point. Two characteristics will force themselves upon our attention; the amount of bending of the curve as we pass along it, its curvature; the amount of twisting of the curve, its torsion. These are intrinsic properties of the curve itself capable of representation at each point by definite numerical values. These numerical values can be expressed in terms of the three distances pertaining to any given one of the systems of reference mentioned above; it turns out that definite rather simple formulae exist for expressing the curvature and torsion in terms of the named measurements. Since these describe intrinsic properties of the curve their values must be unaltered by the transformations of variables due to the changes of the system of reference; that is, they must be invariants of the transformations.

It is seen therefore that the analytic expressions for the curvature and torsion are unchanged in form and in value as we pass from one system of reference to another. It can be shown that they completely determine the intrinsic properties of the curve. Then we have in them a complete mathematical description of the intrinsic properties of the curve in a form from which we have abstracted those pecularities which belong to the special system of reference by means of which we described the curve and its position in the first place. This sort of abstraction is of frequent and important use in mathematical investigations. It affords one of our methods of excluding from consideration those things which are irrelevant to the central purpose of the investigation and of fixing attention upon those things alone which are unaltered by, or are invariant under, the transformations permissible among the elements in consideration. A similar but extended use of invariants is a central feature of the Einstein theory of relativity.

Two rather considerable extensions of the method are necessary in order to realize the situation in the Einstein theory. The first has to do with a generalization of the system of reference. In what we said above we contemplated the location of a point always through the measurement of its distances from three planes. Now we wish to replace the three planes by three warped surfaces, perhaps twisted and corrugated and bent into a great variety of shapes and restricted only enough to allow us to utilize them successfully for the location of points in space. By means of these we are to describe the space-configurations with which we have to deal.

The other step which we wish to take is that in connection with the introduction of time into our system. We can not well develop the mechanics of three dimensions by means of what is simply static in three dimensions; and the introduction of motion and the analysis of velocities and accelerations require the use of the time variable. Moreover, we are not to think of time and space as independent but are to consider the two together as furnishing the four-fold extension of a time-space continuum. This gives us, of course, a space of four dimensions; and in this space of four dimensions the movements of the natural world are represented by static figures. In this space of four dimensions we are to choose as a system of reference four warped three-dimensional spaces by means of which the location of points in this four-dimensional space shall be defined.

With these conceptions in mind we shall undertake to make clear the nature of the central ideal upon which Einstein insists. He wishes to have the laws of nature expressed in such form with respect to this four-dimensional continuum that there shall be no change in the form of these laws when we pass from one of these systems of reference to another; the statement is to be an invariant one when all quantities involved are changed in accordance with a transformation which carries us from any one of these systems of reference to another; let us say for convenience that the laws are to be stated in covariant form. When we have put them into such form we have abstracted from the statement whatever pertains to the particular system of reference employed.

It is a grave question whether the laws of nature are capable of formulation under such radical restrictions; and an affirmative answer can be maintained only after a searching examination. The best way for a just trial of it is to employ one of the best established and most satisfactory laws; none could be more suitable than the Newtonian law of gravitation. Hence one of the first efforts of Einstein to test out the theory was made in the attempt to apply it to celestial mechanics. It turned out that the Newtonian law of attraction does not accord with the ideal of covariance of the laws of nature; it is not capable of expression in precise covariant form. Is the principle then to be surrendered? Not without further evidence; it may be, after all, that the law of Newton is not exact.

The next task of the investigator, then, is to inquire whether there is some slight modification of the Newtonian law which will bring it into covariant form without making it false to experimental fact. It was not difficult to show that the Newtonian law was a very close approximation to a law which is indeed covariant; and the latter was then taken to be the law which should replace the Newtonian law.

Questions which force themselves upon our attention then are the following: Does the new form of the law have any definite advantages over the old? Can it be subjected to an experimental test to determine which of the two approximate laws is the correct one? Now it happens that the Newtonian law has long been known not to agree exactly with observation in the matter of the motion of the planets. In the case of Mercury the discrepancy is altogether too great to be attributed to experimental error. If the law of Einstein is applied to the problem it accounts for all these motions within the limits of experimental error. Here it scores its first victory over the Newtonian law.

A second crucial test of the theory is offered by its prediction of the deflection of a ray of light which passes through a strong gravitational field. This prediction was tested by observations made independently at two stations during the eclipse of the sun of May 29, 1919. The problem was to determine the amount of bending in a ray of light passing near the sun and hence through its strong gravitational field. The values for the deflection obtained at the two stations are 1.61 and 1.98 seconds of angular measure, resulting in fairly good agreement with the predicted value of 1.74 seconds of angular measure.

The ideal of the covariance of the laws of nature as a practical ideal thus passes successfully its first test, and indeed in a dramatic manner. That Maxwell's electromagnetic equations may be reduced to a covariant form and hence that all electromagnetic phenomena described by them are in agreement with the principle of relativity may be readily shown; and thus the ideal of covariance meets a second fundamental test. There is no known case in which it must certainly be surrendered, though there is an important one which remains still in doubt (see p. 105 of my "Relativity" already referred to).

If all the laws of nature can indeed be expressed in covariant form we have through this fact brought to light a certain profound unity in the laws of natural phenomena, one which will surely be satisfying in an esthetic way to every one who contemplates it with understanding.

We have insisted upon the importance of abstraction as a means of bringing the complexity of the phenomena contemplated within the power of the mind for purposes of systematic analysis. There is also another quite as important reason for making abstraction of certain elements involved in the general complex of the environment; and that is the necessity or desire to find a range of phenomena and objects of thought about which there can be at least a fairly good agreement. The propositions concerning which there is general agreement among competent persons are said to have an objective validity; others are called subjective. Upon being pressed for a definition of "objective" as employed in the phrase "objective character of science" the scientist sometimes asserts that the objective is that which pertains to the world which is external to ourselves or to the world of objects whose essential character is not affected by the subject who contemplates it. But if he is further pressed for a criterion to determine whether a given thing is objective he has to return to the conception of the objective as that about which there is general agreement among competent persons.

It may be objected that this definition describes merely that which is invariant and that we ought to refer to the invariant character of a scientific thought rather than to its objective character. But it seems to me that "objective" as applied to things of science has no scientifically definable sense except that which rests upon the idea of invariance, at least if one admits (as I think he must in matters of science) that a definition should be so stated that it is theoretically possible to determine whether or not a given thing meets that definition. Moreover, "objective," as the word opposed to "subjective," seems to be well suited to convey the connotation desired. At any rate, it is our purpose to proceed from this as a tentative definition to a more penetrating analysis of the ideal of the objectivity of science, an ideal which can be attained in any particular situation only by excluding from consideration a large portion of the attendant circumstances.

Regardless of the way in which we frame the definition it is agreed that an essential quality of scientific truth is its objectivity. It must depend solely upon the object studied and not upon the subject who investigates. It must be impersonal, having validity independently of the temperament or the peculiar disposition of the individual who reports it. What do we mean by such a demand as this? What can we mean? It is clear that the investigator can not be a mere passive recipient of impressions, a tablet on which nature registers her characteristics. He must be active in several ways; he chooses the things to which he shall direct his attention, his reason or intelligence is an essential element of the registering apparatus, and he is restricted by the limitations of his sensory equipment. He can obtain and convey only that information which his nature fits him to acquire and report upon. The demand for objectivity can not be a requirement that he shall do otherwise. But it is a call for the exclusion of the subjective element, the element which is peculiar to his individuality; and this exclusion is to be brought about by such comparison of his report with that of others as shall make it possible to determine those elements which are independent of his individuality.

But it is clear that such a procedure affords us no means of excluding what is peculiar to the human race as such. This would require the existence of many cognate races of widely different social characteristics by the comparison of whose scientific conclusions we could eliminate that which is peculiar to each, retaining as a residue only that which has objective validity relative to the group of races as a whole. Such a procedure, if the means were at hand for realizing it, would carry us one step further toward the far-off goal of absolute truth. But we shall have to be content to work without such means of removing from our body of knowledge the elements which are peculiar to our racial individuality. This affords no occasion for dissatisfaction, since the only use we have for our science is that which can be realized by human beings. But it is sufficient to assure us that we have no means of reaching absolute objectivity in our science, if such a thing is indeed conceivable.

The conclusions or observations which we shall admit as having the required objective validity are those which are invariant in the sense that they are reached by all normal human beings who investigate properly the pertinent matters. We can not get along without the qualification of normality of the individuals admitted to the group for which we seek the invariance in consideration nor can we omit the requirement of the proper investigation of pertinent matters. It is hard to see how we can altogether remove subjective considerations from the process of determining when these conditions are adequately met. We can not avoid the conclusion that the highest objectivity realizable in practice falls far short of the quality of being absolute. The conclusions and observations which have the requisite objective character are those only which are invariant for a properly determined group of individuals; and the determination of the group to be admitted can be effected only by the members of the group, since there is no external intelligence that sets them apart.

It is convenient to distinguish two types of objectivity, as here defined, differentiated as to range of time through which exists the group of individuals by means of which each is realized. We may call the one contemporary objectivity and the other historical objectivity, the former being asosciated with a group living contemporaneously and the other with a group scattered through a long period of time, say the whole historical period. All the general truth which is universally approved in a given age among people properly qualified to form a judgment upon it possesses this contemporary objectivity. That which meets with acceptance from age to age with unchanging uniformity has the higher order of historical objectivity. From the truth possessing contemporary objectivity that and that alone survives to attain to historical objectivity which impresses itself alike upon the peoples of succeeding ages.

The subjective character of matters of taste is notorious. Even the milder objectivity of the contemporary sort is seldom attained, and always only imperfectly. Universal agreement on such a judgment of values in a given age carries with it no assurance that succeeding ages will concur in the conclusion. Yet there are some judgments concerning matters of art which go far towards exhibiting the qualities of historical objectivity. There is an abiding unanimity, for instance, in ascribing a high excellence to the finer elements of Greek sculpture. The more magnificent creations of this art impress with their marvelous beauty the people of one age after another; and these all appear to obtain from them a joy of the same general character. It is true that individuals represent this to themselves variously and that they differ greatly when they seek to give an account of the way in which they are affected. But certain elements of the judgment of value seem to be invariant from age to age and from individual to individual. So far as this is true we have a manifestation of objectivity even in these matters of judgments of taste.

If we find thus a measure of objectivity in these things which are usually esteemed to be highly subjective in character, we also find certain elements of subjectivity even in the matters of science and marked elements in some bodies of truth considered objective by those who develop them. Merz, in his "History of European Thought in the Nineteenth Century," a work to which the present author is greatly indebted in several ways, says: "Most of the great historians whom our age has produced will, centuries hence, probably be more interesting as exhibiting special methods of research, special views on political, social, and literary progress, than as faithful and reliable chroniclers of events; and the objectivity on which some of them pride themselves will be looked upon not as freedom from but as unconsciousness on their part of the preconceived notions which have governed them." Thus the objectivity to which these historians have attained appears to be only contemporary in character.

In forming a judgment of the significance of modern science it is important to ascertain the character and measure of objectivity to which it has attained as a whole and to make a classification of it into parts according to the extent of its success in becoming objective. A large portion of what is now current has gained its position so recently and has so forcibly ejected the earlier explanations to make place for itself as to raise a reasonable question of doubt concerning the validity of the whole structure. When theories have changed so constantly, so long and so profoundly, we can not well believe that we have suddenly come to a state of stability. The changes are likely to continue. If they are retarded for a time they will probably break forth later with increased violence. It is not long since we witnessed a period of explosions in the theory of matter and motion; and indeed we do not yet appear to have come to the end of it.

In the midst of this rapid change what permanent truths are to be perceived? Which can maintain themselves through the present generation and achieve historical objectivity through the support of future thinkers? It seems clear that it can not be the theoretical explanations, except in relatively few instances if indeed in any, at least if the explanation is conceived to carry with it the means of affording a penetrating insight into the phenomena explained. If the theoretical explanations do not abide, what is there left? Simply and solely the account of relations among phenomena, however these are expressed, whether by means of the mere record of observations or through the more powerful tool of scientific theory conceived merely as a mnemonic device and a support to the weakness of the intellect in its deductions. The statement of relations has in many cases attained historical objectivity in natural science; but theoretical explanations have usually suffered change from age to age and the process seems likely to continue.

Mathematical truth, so far as it is expressed in definite theorems, has achieved almost complete historical objectivity. A result once attained abides through the ages. Errors are made with relative infrequency and these are usually corrected with such definiteness as to secure general and abiding agreement. The permanence of result has for a long time been considered one of the essential glories of the discipline. But there is lack of such complete objectivity concerning the character of the truth attained. Our conception of the position of Euclidean geometry in thought and philosophy, for instance, is far different from that of the ancients owing to the existence of the so-called non-Euclidean geometries of relatively recent times.

If we analyze the remoter origins and earlier bodies of thought by aid of the criteria which we are using, we shall find that we can not deny to the proto-science of savages a certain contemporary objectivity even though its explanations are framed in terms which we perceive to be anthropomorphic or mythological. That the "sun is the flaming chariot of the sun-god, driven day by day across the heavens" is an immediate fact of observation expressed in anthropomorphic language; and probably no more was read into this statement of fact than we are accustomed to transport from our theories into our account of what happens during an experiment or formerly into the similar statement that two bodies attract each other. The primitive explanations maintained their place for a long time; and much useful knowledge was acquired through their assistance and much skill was gained in logical analysis before it was possible to prove them insufficient. "A false theory which can be compared with facts may be more useful at a given stage of development than a true one beyond the comprehension of the time, and incapable of examination by observation or experiment by any means then known. The Newtonian theory of attraction might be useless to a savage, to whose mind the animate view of nature brought conviction and helpful ideas, which he could test by experience." We can deny to the savage neither the usefulness nor the contemporary objectivity of the proto-scientific explanations which he offered. They were objective to him in every defined sense in which our science is objective to us. If one points out the anthropomorphic element in them, our criticism will at once be hushed by the anthropomorphism of many of our current conceptions, as for instance that of force. If one objects to the mythical element in their thought let him first take up arms against the colossal myth of the ether in the science of the past century and cut off our thought from this fiction of the scientific imagination. As long as we find it necessary to transport into our theories such elaborate creations as that of the ether (brought in without a shred of direct evidence for their existence) we have little room to complain of the thinkers who formed the proto-science of the savage. Measured by the time through which their explanations maintained their contemporary objectivity, the period during which current scientific explanations have held their place is strikingly short.

The objectivity of truth is never absolute, but always relative to a group of thinkers or the age or ages to which the group belongs. We have no means of removing from our knowledge the marks of our racial characteristics or reaching further into our understanding of nature than to those elements which our sensory equipment enables us to perceive. We have to determine with the best standards we may the group of people in relation to whom we shall insist upon the invariant character of truth as recognized. Since at any time in our history future experience is yet to be evolved we can strictly speaking, have only a sequence of contemporary objectivities, as it were, and never a complete historical objectivity. We can have no logically certain means by which to choose securely those elements of thought in any age which make the nearest approach to complete historical objectivity. A subjective element, that is, an element which varies essentially from individual to individual, is necessarily present in every attempt to reach a means of determining what truth has the dignity of an objective character.

The sciences in coming from under the tutelage of philosophy have not completely shaken off the incubus of its unsupported speculations and prejudices. Phenomena are observed through the goggles of philosophical preconceptions, not only in psychology and biology, but also in chemistry and physics, and even in mathematics; and the conclusions or appreciations are affected in various ways and to different extents. In our generation, in the case of physics (the most advanced of the natural sciences) there is going on a veritable revolution in regard to the philosophical preconceptions on which it is based. As evidence we cite the current discussions of space and time and gravitation.

Again the objectivity of a natural science is relative to the character and measure of abstraction through which it was built up and the syntheses by which the separated elements were afterwards brought together and combined into a unity. This process of synthesis can never be carried to completion without the certain loss of objectivity in the resulting knowledge; and as long as it is not carried to completion we have no means by which to be assured that a matter first treated as essentially irrelevant shall not later come into the focus of attention. In fact, this very thing has recently happened in physics. In studying the properties of light physicists were for a long time content to leave out of account the gravitational field as having no appreciable (or even conceivable) influence; but the Einstein theory has forced them to a fundamental revision of this supposition and has led them to conceive of the ray of light as warped out of a straight path by the action of a powerful gravitational field.

The failure of science to obtain completely its universal ideal of objectivity does not diminish our interest in it. Indeed it is rendered more attractive to those of us who are pleased with a dynamic rather than a static world. Truth is never to be set off in tubes hermetically sealed. It is living and hence possesses the universal quality of life of doing the unexpected thing. Its growth is not hemmed in. We may look forward to its continued progress and novelty as long as we who develop it are finite intelligences.

THOMAS HARIOT—1560-1621

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THIS year marks the tercentenary of the death of Thomas Hariot, one of the most interesting of the Elizabethan scientists. He was born at Oxford, and went to St. Mary's Hall in times when there were "menne not werye of theyr paynes, but very sorye to leue theyr studye." The students being without fire were "fayne to walk or runne vp and downe half an houre to gette a heate on theyr feete whan they go to bed." In those times the birch was still in the buttery hatch and the proctors stalked outside the colleges with poleaxes for any "schollers" out after hours. Fines that now come from a student's patrimony were taken from his own skin. And in those far-off days in England there still survived the custom of hazing freshmen.

But apparently Hariot did not suffer overmuch from the discipline. At any rate he made somewhat of a name for himself in mathematics—in that subject then still allied to the black arts. Aubrey tells of a contemporary of Hariot's who studied mathematics that he was vulgarly supposed to be a conjuror, and the scout or college servant used to tell freshmen and other simple people that the spirits passed up and down his staircase thick as bees. A jocular mind could have played up the superstition and become another John Dee. Apparently Hariot was too skeptical to believe what would willingly have been credited to him and too honest to gain by what he did not believe. But this is speculation and the only fact to go on is his appointment as a bone fide mathematician with Sir Walter Raleigh.

How this appointment came about is not quite clear. We have for it the authority of Hakluyt addressing Raleigh in 1587 (translated):

> By your experience in navigation you saw clearly that our highest glory as an insular kingdom would be built up to its greatest splendor on the firm foundation of the mathematical sciences, and so for a long time you have nourished in your household, with a most liberal salary, a young man well trained in those studies, Thomas Hariot; so that under his guidance you might in spare hours learn those noble sciences, and your collaborating sea captains, who are many, might very profitably unite theory with practice. . . . [1]

Raleigh, one of the most remarkably versatile men of a time that specialized in versatility, had been collecting experts who would be use-

[1] Peter Martyr's *"De Orbe Novo"* (Paris, 1587). The preface, containing this passage, is by Hakluyt.

ful in his colonial schemes, and two years before this letter of Hakluyt's he had sent Hariot out in the big expedition to Virginia, or to what is now North Carolina. There Hariot stayed for a full year, acting as explorer and surveyor and reversing his previous position in adding practice to his theory. After that year among the savages he came back to England and fell into the society of the keenest minds of his time. For Raleigh had been prevented from going to Virginia and while his argosies were oversea he had amused himself, in intervals of court activities or fighting or retirement to the country, with an "office of address," apparently a sort of institution for the diffusion of knowledge and a liaison center for intellectuals. Whether or not this suggestion worked out in the Royal Society, there were in the group of men several scientists—Warner and Hues are usually mentioned—and into it came Hariot. But it was broader than a scientific society, as it would have to be to keep up with the interests of its patrons, Raleigh and Henry Percy, Earl of Northumberland. It had its literary side, with the leading and outstanding figure of Christopher Marlowe.

All information as to the group is exceptionally tenuous, resting largely on the gossip of contemporaries. But it is pretty clear that the members soon began to discuss religious subjects and it was here that they particularly scandalized the times. Rumors are thick about "Sir Walter Rawley's School of Atheisme,"[2] whose master was said to be a conjuror. The term of condemnation was very loosely used. There is nothing to show that Raleigh or Hariot had views more extreme than perhaps unitarian or deistic ones and there is much evidence that they were religious in a broad and tolerant sense. But they were great personal friends of the scornful and heterodoxical Marlowe. It has been clearly shown by Mr. F. K. Brown[3] that the dramatic poet was a vigorous exponent of extreme heresy and it was the expression of his views in reckless manner that caused the suppression of the club. Marlowe was killed before he could be convicted and probably the dagger saved him from the stake. Raleigh was kept under surveillance, his house searched, his private table-talk examined, and as he says, he was "tumbled down the hill by every practise." But he was too powerful a man to sit still under the cloud. After a burst of eloquence in Parliament on behalf of religious toleration he set forth in an adventurous pursuit of El Dorado across the Spanish Main and cleared his blood by letting some of the dons'.

Hariot, just as much implicated, behaved very differently. It is probable that he went to one of Raleigh's Irish estates and there worked

[2] See F. S. Boas, *"Works of Thomas Kyd,"* (Oxford, 1901), Introduction, pp. lxx ff.

[3] *"Marlowe and Kyd,"* Times Literary Supplement (London) June 2, 1921.

quietly at mathematics until the cloud blew over. We hear no protest from him unless long afterwards to Kepler (translated):

> For things are in such a pass with us, that still yet I may not freely philosophize. Still yet we stick in the mire. I hope the Good God will make an end to these things shortly. After which better things are to be expected. . . . [4]

And when he came again to London towards 1600 he was a man well known to contemporary scientists. He is mentioned in Hues' "*Globes*" (1593-4), in Davis' "*Seamen's Secrets*" (1595), in Torporley's "*Diclides Coelometricas*" (1602). He lived at Sion House, Percy's seat on the Thames near London, from some time shortly after 1604 until near his death in 1621. It was from there that he carried on his correspondence with Kepler on optical subjects and a more familiar and interesting correspondence with various pupils such as Sir William Lower. His purely mathematical work was apparently completed before he went to Sion House. The years there were interrupted by constant attendance on Raleigh and Percy, both confined to the Tower. Such time as he could find he put upon astronomy, but a great deal went to the carrying of books to the Tower when the insatiable Raleigh was writing his *History of the World*, and to similar services for his caged masters. He was with Raleigh up to the end, and present by the scaffold at the execution. He did not survive by long his first patron and his most gallant friend. Marlowe and Raleigh both gone, the third of the triumvirate passed away by a more cruel exit than either the dagger or the axe. He had suffered for a long time from cancer of the lips, and it came to a lingering end on July 2nd, 1621. He was buried in the churchyard at St. Christopher's, the spot since absorbed into the garden of the Bank of England.

* * *

Marlowe, Raleigh, and Hariot—none of the three lived to finish their work. It would not do to say that Hariot was as striking a figure as either of the others; but that does not take all of his tragedy away. He has not been quite fairly treated by posterity. The fault was largely with himself, for he published none of his own work. Most of his mathematics was, as has been said, thought out before 1604 and probably before the change of centuries. A reflection of his teachings is obtained from the letters from his pupils, such as in the passage from Sir William Lower in one dated February 6th, 1610:

> Kepler I read diligentlie, but therein I find what is to be so far from you. For as himself, he hath almost put me out of his wits. . . (I dream) not of his causes for I cannot phansie those magnetical natures, but aboute his theorie which me thinks . . . he establisheth soundlie and as you say overthrowes the circular Astronomie. Do you not here startle, to see every

[4] *"Epistolae ad Ioannem Kepplerum,"* Hanschius (1618) p. 380.

day some of your inventions taken from you: for I remember long since you told me as much, that the motions of the planets were not perfect circles, So you taught me the curious way to observe weight in Water, and within a while after Ghetaldi comes out with it in print. A little before Vieta prevented you of the gharland of the great Invention of Algebra. al these were your deues and manie others that I could mention; and yet to great reservedness had robd you of these glories, but although the inventions be greate . . . yet when I survei your storehouse, I see they are the smallest things and such as in comparison of manie others are of smal or no value. Onlie let this remember you, that it is possible by to much procrastination to be prevented in the honour of some of your rarest inventions and speculations. . . . [5]

Lower is accurate as regards the dates of the work on specific gravity; one of Hariot's paper is dated 1601 and Ghetaldi published in 1603. Vieta's algebra came out from 1591-1600, and we may fairly suppose that Hariot's work was contemporary.

It was his "to great reservednesse" and "to much procrastination" that has hindered us from knowing exactly what his work comprised. One attempt was made by his friends to salvage it from oblivion. The "Artis Analyticae Praxis" came out posthumously in 1631, in the same year as Oughtred's "Clavis." The latter was in many ways inferior in originality, in scope, in suggestiveness; but as a textbook it was excellent, small and available. It was moreover a living product of a well-known author, not a work patched up from the manuscripts of a man ten years dead. The "Clavis" had a more direct influence on English teaching; but it is a fair question as to which had the greater effect on the history of research. For the "Praxis" was read by Descartes and every line of Descartes' analysis bears token of the impression. The Frenchman carried to their conclusion, with typical French lucidity and brilliance, things that remained obscure to Hariot's executors. That there are omissions in the "*Praxis*" that Hariot would never have allowed is shown, for instance, by the general impression (fostered by Montucla) that he did not admit negative roots. But manuscripts in the Harleian collection of the British Museum show that on the other hand he was fully aware of them and accorded them equal rights. Such an omission a man of Descartes' genius would fill up and would be fired to more than simple reparation. No attempt should be made to detract from Descartes, except perhaps from his complete originality. It was fortunate that the work fell into such hands, and the fact is regretted only by those who like to think of genius as without a precedent.

As for the book itself, it appeared in a thin folio. Percy had made the publication possible, and the dedication was to him. On the final page appeared the following note (translated):

[5] The letter is quoted in full in Rigaud, "Supplement to Dr. Bradley's Works," (Oxford, 1833) pp. 42-45, and in Stevens, "Life of Hariot," (London, 1900) pp. 120-124.

To Mathematical Students

Out of all the mathematical writings of Thomas Hariot, not without good reason has this work on Analysis been published first. For all his remaining works, remarkable for their manifold novelties of discovery, are written in precisely the same logical style, hitherto seldom seen, as is this treatise; whch is entirely composed of all manner of specimens of brilliant reasoning. And this was done with valid reason, so that a preliminary treatise, besides its own inestimable value, might well serve as a necessary preparation or introduction to Hariot's remaining works, the publication of which is now under serious consideration. Of this accessory use of the treatise we have thought it worth while to remind mathematical students in these brief remarks.[6]

The contents followed in Vieta's footsteps, with improvements in notation and some simplification in technique. But the chief thing in the book, and one of great importance, was the bringing over to one side all the terms of an equation and equating them to zero. It was a simple and yet a real step ahead. As Whitehead says, it started the study of algebraic forms. The resolution of an equation of the *n*th degree into *n* simple factors gave immediate rise to the fundamental theorem of algebra. And though there is the real temptation to read into the terse statements what may not have been thought out, the warning against Tennyson's expression

I thowt 'a said whot 'a owt to 'a said

may be borne in mind, and yet much claimed for Hariot.

How much more the painful lips might have said, or might have been recorded if the "serious consideration" above mentioned had matured, is of course difficult to know. It would take very careful work to read, digest, and judge the eight large volumes of Hariot's manuscripts lying untouched in the British Museum. There are more, apparently, at Petworth. They consist of fragmentary calculations, with occasional connected notes on a diversity of subjects—on astronomy, physics, fortifications, shipbuilding, and all the branches then known of mathematics. And yet even a cursory glance will show some gleams of gold. There is a well-formed analytical geometry, with rectangular coordinates and a recognition of the equivalence of equations and curves. There are notes on combinations and the tables of binomial coefficients worked out in both the forms we now call "Pascal's triangle" and "Fermat's square." And there is one page, otherwise blank on which appears

1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000

6 "Artis Analyticae Praxis" (London, 1631) p. 180.

This is certainly prior to the usual dates given for binary numeration. There is no guarantee that these things were original with Hariot, and some may be much older. But at least it is an instance of his knowledge. We may take Lower's praise how we will, but there is little doubt that Hariot's executors would have had material as interesting as the preliminary treatise.

More publicity has been given to Hariot's astronomical work, partly because of the dramatic discovery of the papers by Baron de Zach; and the encyclopedias tell how he used his early training in navigation in his observations of Halley's comet with a cross-staff. Sun-spots he watched with the naked eye, though he admits this gave him pain. Both Hariot and Galileo seem to have borrowed the telescope from the Dutch very shortly after its invention and to have used it simultaneously. With the help of his servant and instrument maker, Christopher Tooke, Hariot seems to have supplied his pupils with telescopes and asked their aid in observation. His own recorded observations go back to July, 1609, a month after Galileo's first construction; and partly independently and partly with the knowledge of the Italian he, too, observed the moon, the satellites of Jupiter and later the comet of 1618.

Some time, perhaps, there will be published extracts from the correspondence of the time, for it throws delightful light on the mental attitude of the scientists. Lower's letters, for example, are charming in their naïve statements. In the letter above quoted he begins

> I have received the perspective Cylinder that you promised me and am sorrie that my man gave you not more warning, that I might have had also the 2 or 3 more that you mentioned to chuse for me. . . According as you wished I have observed the Mone in all his changes. . . . In the full she appears like a tarte that my Cooke made me the last Weeke. here a vaine of bright stuffe, and there of darke, and so confusedlie al over. I must confess I can see none of these without my cylinder. . . .

And when he wishes to compliment Hariot in another letter some five months later he says he has done more

> . . . then Magellane in opening the streightes to the South sea or the dutch men that weare eaten by beares in Nova Zembla. . . .

Perhaps this last is not too high a compliment; but when the compliments to Hariot are discussed the truth will be seen of a statement made above. He has not been fairly treated. There are errors on both sides, from Montucla's curt dismissal to the adulation of Baron de Zach. To the latter Hariot's use of the telescope was proof of his inventing it, and a mark of superiority to Galileo. In short, more harm has been done to Hariot by his admirers than by his opponents; as in the controversy started by Wallis to prove that Descartes borrowed all his algebra from Hariot without acknowledgement, and hence that Hariot was the greater man. The folly of these disputes is never more regrettable than in their reaction on the individuals who would have been loth to start them. In both cases, of the attempted detraction from Galileo and from Descartes, Hariot has suffered more than by his decent oblivion. But what might have been claimed for him is an interest and a high intelligence in his work, carried on under a tragic illness and under the sense of futility borne in upon him by the deaths of his friends, in those blood and thunder times a little more than three centuries ago.

DRU DRURY, AN EIGHTEENTH CENTURY ENTOMOLOGIST

By Professor T. D. A. COCKERELL
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ALL entomologists are familiar with the name of Dru Drury, one of the fathers of their science in England. Living in the time of Linnæus, when the discovery and description of new forms of life was rapidly increasing the bounds of zoology and botany, he entered fully into the spirit of the new knowledge and contributed largely to it. Something more than an amateur collector, he keenly interested himself in the natural history of insects, and did everything in his power to encourage biological investigations. He corresponded with some of the prominent zoologists of his day, and with many persons in foreign countries, who were interested in collecting insects. His letters were copied, nearly always in his own hand, in a large book. When at Funchal, Madeira, recently, I was greatly interested to find this letter-book in the possession of Mr. C. O. L. Power, of the firm of wine merchants, Power, Drury and Company. Henry Dru Drury, the former head of the business, was my father's greatest friend, and I was named Dru after him. He died in 1888, but Mrs. Power is also a descendant of the entomologist and the letter-book thus still remains in the family. Mr. Power kindly gave me the following pedigree. The known ancestry goes back to Thomas Drury of Fincham in Norfolk, who died in 1545. William Drury, who lived at Godmanchester and Tempsford, had a son Dru Drury, born in 1688. His son, born February 4, 1725, was Dru Drury the entomologist. He is described as of Wood street in the Parish of St. Alban, London, citizen and goldsmith; afterwards of the Strand, of Enfield and of Turnham Green, all in the county of Middlesex, and of Broxbourne, Hereford. He married Easter Pedley, daughter of John Pedley of London, soapmaker. He died January 15, 1804, and was buried at the church of St. Martins in the Fields. He had three children, Mary, born 1749; William (goldsmith, of Turnham Green), born 1752; and Dru, born 1767. William had a son, Henry Dru Drury, born 1799, whose sons were Henry Dru Drury, my father's friend, born 1837, and Charles Dru Drury. The last was the father of Mrs. Power (Gertrude F. Drury), now living at Funchal. Charles Dru Drury, who lived at Blackheath, and died at the early age of 32, was interested in entomology.

I was very kindly permitted to borrow the precious letter book for a number of days, and with my wife's assistance obtained copies of the more interesting letters. These I give in chronological order, but in many cases only portions of letters are quoted. It will be seen that Drury was indefatigable in seeking to enlarge his collection by corresponding with persons living abroad, but that while doing this, he also did his utmost to persuade them to study insects and discover their life-histories. With others, he raised funds to send Smeathman to Africa (letters 18, 19, 25), but he was somewhat embarassed because only insects were received, whereas some of the subscribers asked for and expected other things. He tried to get Thomas James of New York (letter 2) to study the "caterpillars" or nymphs of dragon flies, and in short do the sort of work which Professor Needham has been doing in that state in our own times. In his letters to Dr. Pallas, the eminent naturalist residing in Russia, he discussed the state of affairs in England, and many of his remarks would be pertinent today. We get an account of the circumstances connected with Captain Cook's first expedition, with which Banks and Solander sailed as naturalists. At first it seems a little surprising that there is no mention of Captain Cook, but he was not famous at that time and was not even a captain. We hear of the disappointment occasioned by Banks's failure to publish the expected volumes on the natural history of the voyage. The fact was, that although Sir Joseph Banks was a splendid man and one of the most useful citizens of England, he was not adapted to scientific research, with its continued attention to minute details. His position in relation to natural history was that of a patron and promoter, rather than a student. The correspondence with Moses Harris brings out some of the difficulties in getting the "Illustrations" properly illustrated. Harris, who here appears as the artist, was himself a very capable entomologist who introduced the method of studying the venation of the wings of insects. He published a large work on British Insects, giving names, with descriptions and figures, to a number not previously described. This work has been strangely ignored by subsequent taxonomists, though proper binomials are furnished in the index, as in Drury's Illustrations. Verrall, writing on Diptera, has restored several of the names proposed by Harris. The letter to Linnæus shows the respect Drury had for that great naturalist. In his Illustrations of Exotic Entomology, Drury gave no scientific names in the text, but in the index supplied a full set of binomials, using the strict Linnean method. Haworth, writing in 1807, said that Drury was the first in England to adopt the Linnean method throughout in this manner. Although Drury took so much interest in the correspondents who sent him insects he unaccountably failed to cite them in his book. Their names were, however, found by Westwood in a manuscript list of

Drury's, which also gave more exact localities. When editing a new edition of the Illustrations in 1837, Westwood published much of this information. Drury encouraged Fabricius to study and describe the insects in his collection. There is a good description of the zeal and industry of this great master of entomology, who described a prodigious number of species in a manner which we should now consider inadequate. The Fabrician types in the Banks collection may be seen at the British Museum today. In the preface to the third volume of the Illustrations, Drury complains that whereas he had always thrown his cabinet open to all students, advantage had been taken of this to describe and even figure some of the species without his consent. This was especially unfortunate since it involved a number of forms which were described in the volume and obliged him to suppress the names he had proposed to give them. No name is mentioned, but one has only to look at the index to see that Cramer was the culprit.

At the end, I have quoted a letter describing Drury's business failure, and his fortunate return to solvency or even prosperity. He lived many years longer, but the correspondence of his later years has apparently not been preserved.

Regarding Drury's life and work as a whole, we have an excellent example of that innate taste or passion for natural history which inspires a certain number of individuals in every generation and which the majority can neither appreciate nor understand. But we are also struck by the fact that favorable circumstances are needed to render such aptitudes fruitful and of benefit to mankind. Many such men as Drury, all through the ages, have lived and died without leaving any permanent memorials. The favorable circumstances in Drury's case were especially the organization of zoological and botanical knowledge led by Linnæus, combined with the penetration of nearly every part of the world by British commerce. It was possible to come by the materials for greatly enlarging our knowledge of insects, and a method had been devised for conveniently recording discoveries. Drury, taking advantage of these conditions, was able to make important and permanently valuable contributions to the science he loved so much.

(1) To Mr. Robt. Killingley at Antigua. Jan. 4. 1762.

The Beetles which were in ye spirits among the other things were very acceptable and exceeding pretty, insomuch that I cannot help placing them in ye foremost rank of all the specimens you have now sent, indeed Insects I must confess do really afford me the greatest pleasure of all animals, and as such I will take the liberty of begging a favor of you to try to breed some of the Libellas (vulgarly called horsestingers) [gives full directions for breeding].

(1-a) To Mr. Hough—going to Africa with Capt. Johnson [slaver to to take slaves to Jamaica] March 22, 1762.

The Locusts and Grasshoppers will be found to be very numerous in Africa and also in Jamaica where they differ in a very extraordinary manner from our European ones, some being just like leaf and branch of a tree, others like half a dozen straws joynd together, all of which are very acceptable to us.

(2) To Mr. Thomas James of New York. Apr. 25, 1767.

[Describes apparatus he sends for taking water insects, and continues]:

You may breed a great number of Insects, particularly Libellas, whose cats [nymphs] always live in ye water, for which a few directions will not be unnecessary. Get a large Buckett, pail, or washing tub and put in it some weeds that grow in ye water, fill it three parts full with water and in ye spring; search ye waters above mentioned for Insects and put in it as many Libella Cats as you please. Be sure to put in a great number of ye small sorts, because ye large sorts prey and feed on ye small ones as you will have many opportunities of observing. If you find ye number of small ones decrease very fast you must supply the tub with fresh ones, and once in three weeks or a month change ye water. You must make a contrivance of a frame covered with gauze to go over ye Buckett or Tub so that when ye Libellas are bred they cannot fly away.

(3) To the Rev. Mr. Devereux Jarratt, Virginia. May 13. 1767.

In my letter of July 12th I described ye method of killing Insects by dipping a needle in Aqua Fortis and sticking it into them, but I cannot neglect ye present opportunity of informing you that all that trouble may be saved and the insects may easily be killed by sticking them on ye end of a piece of board and holding them to ye fire, in doing which great care must be taken not to hold them too near, especially Moths or Butterflies, because it will make their wing crumple and contract so much as to spoil them.

(4) To Dr. Pallas. Nov. 12. 1767.

I don't know whether you have heard Mr. Dupont has relinquished collecting of Subjects of Natural History, but so it is, he has given it over and is now very busy making drawings of every specimen he has, and when that is finished intends to dispose of ye whole. Another piece of news I must inform you of is Mr. Da Costa is going to publish plates of nondescript animals—shells, Insects, etc. in periodical numbers, five plates with their descriptions being a complete number. Thus Natural History is I hope gaining ground by slow degrees in this Kingdom. I wish Gentlemen of Fortune studied it more and Politics less. It would I believe be better for us, but at present every man is a politician and sets up his opinion as ye Standard of Judgement, a practice that produces ye greatest distractions among our great men. I need not mention to you when this is ye case ye Arts and Sciences never flourish so rapidly as when assisted by Concord and Unanimity, but these disadvantages are not sufficient to prevent ye number of Naturalists increasing here and I hope to live to see ye time when ye name will be as respectable as that of a Judge or a Doctor.

(5) To Dr. Pallas. Feb. 28, 1768.

I am delighted with your account of Count Orlof's making natural researches in ye distant parts of ye kingdom. How I honor him for such an attempt! I wish we had a Count Orlof among our Ministers of State; what opportunities he might have in ye present age for discoveries! When all ye known parts of ye Globe are visited by our ships! But oh! these party affairs! These are ye bane of every practicable improvement. Believe me ye little Sphere of Life that I move in makes me neglect no opportunity that may be layd hold of for advancement of natural Knowledge. What then might those Personages do in those grand departments, on whose Nod numbers wait, and where happiness or misery is communicated to thousands by a little motion of a pen. Do you know that we are (the English) possessing ourselves of an island situated near ye Strait Magellan in South America [Falkland Islands], and intend to preserve it as a colony to England? Perhaps you may not have heard of it but so it is. And I have not been idle in endeavoring to get Articles of Natural History from thence. . . .

I have read over your paragraph concerning the India Company very carefully and am afraid your wishes outrun probability, for since I wrote my last I have learned some circumstances that I was then ignorant of. I do not find that they have ever sent out any Botanist or other Naturalist with a settled salary. It is ye curse of this Country for public Bodies seldom to reward ingenuity unless compelled to it by a sense or fear of shame. I could mention many instances of this kind. And their practice has been to send over persons in some inferior office whose circumstances have compelled them to accept it 'tho their merits entitle them to a superior reward. Nor do I know or hear of but one single Gentleman who has a soul generous enough to break through such a mean practice. Indeed if his interest was so great as to become a director (an event not impossible) he would most certainly as I am informed send out some Gentlemen to India with handsome salaries to make inquiries in Natural History. Mr. Sullivan is ye Gentleman I mean. . . .

I sincerely lament with you ye fall of ye Aurelian Society,[1] there wanted but two or three good members to have made it become respectable, but Da Costa's temper and principle was sufficient to overturn a

[1] This seems to have been the first entomological society. There was a later Aurelian Society, before the foundation of the Entomological Society of London.

Kingdom. I imagine ere this you have heard of his *Fate*. If not, I will tell you. He is no longer Librarian to ye Royal Society. He is dismissed from thence with ignominy and disgrace. He was deficient in his accounts above £1100, for which reason they siezed on all his effects, and they are to be sold by public auction. It was no uncommon practice with him to make many Gentlemen annual Fellows in his accounts who had paid their proper quotas to be perpetual ones, and thus by placing them on this footing he annually secreted large sums from ye society. I'll tell you how it was discovered. Dr. Hope of Edinburgh[2] having been chose a Fellow by ye recommendation of a gentleman in London (I believe Dr. Fothergill) was surprised to see his name omitted in ye annual list published, and wrote to London desiring his friend to inquire ye reason; who in examining into ye affair found he was himself entered in ye book as an annual member, tho' at ye same time knew he paid ye necessary sum to become a perpetual one. This neglect in ye librarian being discovered they proceeded to examine several others and found I am told upwards of thirty who were entered in that manner and their fines applied to his own private purpose. Hence ye periodical work he intended to publish, which I mentioned in my last, is entirely stopt; the circumstance I must own I am very sorry for on account of Natural History in general. But if it can not be promoted by men of better principles than him it is better perhaps for it to lye dormant.[3] . . .

I cannot conclude this long Epistle without conjuring you not to let ye summer pass without making captives of all ye insects that fall in ye way. Don't think me too troublesome thus repeating it, for I assure you my desires for knowing what kinds Russia affords are too great to be suppressed. Dr. Solander[4] who I saw yesterday desires his kind respects to you. We are trying to establish a Society upon a more general plan than ye late Aurelian, in which Mr. Fabricius,[5] a very ingenious worthy young Gentleman of Denmark, joins us, and [in] which I hope we shall succeed.

[Count Gregory Orloff, when he failed in his schemes at the Rus-

2 John Hope, born 1725; was professor of botany and superintendent of the Botanic Garden in Edinburgh. Died 1786.

3 Da Costa is still remembered by conchologists. For instance, the common *Helix virgata* was named by him.

4 Daniel Charles Solander was born in Sweden in 1736, and was a pupil of Linnæus at Upsala. In 1760 he went to England, and was chosen to accompany Banks on Cook's first voyage around the world. He died in 1782. He worked in zoology and botany, but is best known as a student and describer of plants.

5 John Christian Fabricius, born 1742. Died 1807. He was professor of rural and political economy at Copenhagen, but gave most of his time to the study of insects. The "very ingenious worthy young gentleman" was about 26 when the above letter was written.

sian Court, was ordered to travel, and seems to have had ambitious plans. Peter Simon Pallas was born in Berlin in 1741, and went to Russia at the request of the Empress Catharine II, to investigate the natural history of the Russian dominions. He died in Berlin in 1811, having produced works of first class importance, insuring him a permanent place among the great explorers and zoologists of the world. Catharine had a genuine interest in the progress of science and Pallas naturally gave Drury a very enthusiastic account of the work done and planned.]

(6) Dr. Pallas. Apr. 11. 1768.

I cannot help having a great impatience hanging about me to know how Count Orlof's Scheme goes on. I am as anxious for its success as some young Girls are for that of their Lovers: can't you oblige me with some information concerning it. We have a scheme on foot here that is somewhat akin to Count Orlof's, but not on so extensive a Plan. You know ye transit of Venus will happen in June 1769, and as an accurate and nice observation of it in different parts of ye World will be of great utility and consequence to Astronomy, some Gentlemen in that science are to go out this year from hence to ye South Seas in order to make those observations. Mr. Banks, a gentleman of considerable fortune, is extremely desirous of availing himself of this opportunity and going with them in ye same ship in order to make discoveries in Natural History, and to this end is actually making preparations for that purpose.

His being a strong naturalist, possessed of a large fortune, and being determined to spare no expense, are circumstances that give all well wishers to that study ye highest expectations of his success. The route is intended first to ye Madeira Islands, from thence they are to go by easy voyages along ye coast of Brazil, thro ye streights of Magellan, and to refresh at some of ye Spanish towns on ye western coast of South America, having already a passport or permission from ye King of Spain to do so. After they have made ye observation, which is to be done on some Island as much to ye southward as possible, they propose to return to Europe by ye way of ye East Indies. The whole will in all probability not take them less than two years and a half. Hence you perceive we have Gentlemen in Europe whose desires for ye improvement of Nat. Hist are equal to those of any Person in ye World. But I must inform you of one circumstance and that is that Mr. Banks has judgement enough to prevent his engaging in Affairs of State, and consequently by detaching himself from all parties has more leisure to pursue his darling Studies. I wish from my soul we had many more of his Stamp in this kingdom.

(7) Mr. Thomas James, New York. Aug. 1. 1768.

I have sent this (4 guineas) lest you should be in want of ye money and whatever arises more from ye sail of ye insects I shall certainly remit to you immediately upon my disposing of them. You mention in your last that you are removed forty miles from where you were before. This alteration probably may enable you to discover some new species, a circumstance that will give me great pleasure, particularly if you meet with any new beetles or Insects of ye transparent wing tribe. I shall trust to your ingenuity not to send me any more large *Flies* that you already stock'd me so plentifully with, particularly the large Emperor, the Great Fritillaries, the Black Swallow-Tails and a large Fly of a brown orange color having a black border spotted with white running along ye edges of ye wing both inside and out, ye tendons of wings being black; ye caterpillar is yellow ringed with black having two black horns and two black tails. [This is the milkweed butterfly, *Anosia plexippus*]. You once sent me a black Fritillary of a middling size, a little bigger than your Pearl Border but not near as big as ye great fritillaries, which was much wasted. I wish I could receive a pair or two that were fine.

(8) To Mr. Du Pont, going to Jamaica. Oct. 14. 1768.

Please to enquire for Robert Taylor at Mr. Archdeacon's in Spanish Town. He is there as gardener, and well versed in ye knowledge of Insects. I offered him in a letter I wrote to him in August six Pence apiece for ye insects he should send me provided there was not more than two of a sort. Perhaps he may think that price too small and may refuse sending me any on that account, if so I will get you to make ye best bargain ye can with him.

(9) To Dr. Giseke at Hamburg, Nov. 3, 1769. [We read the name Gische, but it is evidently Paul Dietrich Giseke, 1745-1796.]

Mr. Brunnich I find does not abate in his ardour. His resolution in surmounting ye dangers and difficulties of travelling surprises me. I am glad to hear he is in being; when he was in England he promised to write to me often and exchange some insects with me, but I suppose his active state of life prevents him. The Pap. Apollo [*Parnassius apollo*] he was to procure for me some specimens of; if you have an opportunity of sending a letter to him I will entreat you to mention that circumstance. I am sorry to hear of poor Dr. Slosser's death. If he had been of ye same opinion with me concerning inoculation we had not now mourned his loss. I am as ignorant as you of ye place of Mr. Fabricius existence, but I am in daily hopes of hearing from him. I wish I could also give you some account of Mr. Banks and Dr. Solander but I am of opinion we shall learn no news of them till their arrival in England. I can only say may Heaven be propitious to natural history and preserve such capital *Pillars* of it.

(10) To Dr. Pallas. Jan. 14. 1770.

You ask me of what news in Nat. Hist. in these parts. The best I can give you is that it is making great progress here, and the avidity with which books on that subject are bought here is surprising. I mentioned in one of my letters Da Costa's affair. He is now confined in ye King's Bench Prison at ye instance of Royal Society and has been there near a year, from whence, I imagine, he will never return. He is at present engaged in writing a history of shells which he hopes will make its appearance this summer. Pray have you heard of Dr. Schlosser's [6] death? Dr. Giseke, a physician of Hambourge and a great botanist, wrote me word ye 23rd of September, 1769, of this melancholy truth. He died about two months after his wife, who perished with an unborn infant, under ye operation of inoculation. I heartily lament the loss of such a worthy man's death but who can control his fate! I have just rec'd a letter from Mr. Brunnich, who returned from his travels to Copenhagen in October. He tells me he sent you a treatise on Fishes from Leipsic, which he wants to know if you received. He proposes to visit England sometime this year on his way to Scotland.

(11) To Moses Harris at Crayford. Mar. 15, 1770.

I have this day looked out two setts of prints col'd in ye best manner for Col. Gordon and Mrs. Robinson, and in looking them over I observed some plates of fig. I. plate 12 to be coloured in a manner far from ye original. Those three sets you did last you have made ye spots on each of ye under wings or rather ye patches that are of a beautiful Saxon green in ye fly, in ye plates are mazerine blue, and that part that runs over ye scarlet eyes on ye abdominal edges, you have made of a pea green instead of being ye same color with ye patch itself, which it is in ye natural subject. Likewise in two other sets this figure is coloured blue in one wing and green in ye other which makes it look of such an odd appearance that I dare not venture to send either of them to any person of my acquaintance.

(12) Moses Harris at Crayford. [On Apr. 5, 1770, he writes complaining to M. H. that he is so slow painting the plates and says:]

I wish to Heaven you was removed from that damned place where you are now buried and come to London, for then I could scold you by word of mouth, and now I am forced to employ a great deal of time in doing it by letter which I can but ill spare.

(13) To Dr. Linneus. Aug. 30. 1770.

Most excellent Sr. I cannot better express the strong inclination I have of testifying my respect to you as ye greatest *Master* of natural history now existing than by presenting you a copy of a work I have just published here. Believe me Sr it is not from vanity I take the

[6] Johann Albert Schlosser.

liberty of making you this offering, nor, poor as it is (for I am truly sensible of its defects), would I make it to any person that is inferior to Linneus in the study of Nature. But to whom should I pay my acknowledgements of this sort but to the *Father* of natural history? You Sr I consider as that *Father*, and therefore I beseech your kind acceptance hereof, a circumstance that will do me great honor and favor and at the same time countenance my weak endeavors to promote a study that I must confess to prefer to every other.

Permit me also to take this opportunity to congratulate you on the effects which your *Systema* has had among the followers of natural history here in London, ye number of which, although not equal to those found in many other countries, are yet every day increasing to such a degree as could not have been suspected a little time ago by its most sanguine well wishers. That it may still increase and flourish and that you may, with health, live to see its study carried to ye furtherest ends of ye Earth is ye hearty wish of Sr your sincere admirer and most humble servant.

P. S. The honour of a few lines addressed to me at no. 1, in Love Lane, Aldermanbury, informing me of the Packett having reached the place of its destination, will be exceedingly acceptable.

[In an accompanying list of documents is mentioned a letter, now lost, from Chas. Linnæus, son of the great naturalist. It is probably this letter, dated March 10, 1780, which is printed (pp. x-xi) in Westwood's edition (1837) of Drury's Illustrations of Exotic Entomology. Linæus named a fine Cimex after Drury.]

(14) To Dr. James Greenway. In Dinwiddie Co. Vir. Dec. 18. 1770.

I must not neglect ye present opportunity [to say] that the contents of one of ye vials you sent me was a most acceptable present. It contained some uncommon Insects. I never saw any Juli (for such they were) so large. Permit me to beg you would save for me any of that kind you chance to meet with. I don't mean ye lizards, they are animals I don't collect, but *Insects* are my darling pursuit, therefore any that come under that denomination either large or small will meet a hearty reception. [The Juli are millipedes, not now considered insects, but Drury used the term in the broader sense.]

(15) To Mr. Storm, Principal Gardener to the Hortus Medicus in Amsterdam.

July 19. 1770.

In England we are very fond of other insects besides *Butterflies* and *Moths*, and a small *Beetle* sometimes is more acceptable than a large butterfly.

(16) To Mr. Brunnich, at Copenhagen. Jan. 3. 1772. [Morten

Thrane Brünnich, 1737-1827, a well-known zoologist, especially remembered today in connection with ornithology.]

The little cargo of insects you sent me I received with great pleasure. There were many of them new to me. How happy I should be to have a sight of the *great* collection you certainly must have made in your travels. . . .

In your next letter pray inform me if you have heard anything of Dr. Pallas. I want very much to know whether he is alive, and how he does. I have not had a letter from him since he quitted Petersberg and entered onto that long and dangerous journey into Siberia. I shall also be glad if you will relate this part of my letter to Mr. Fabricius, perhaps he can tell you something concerning him. At the same time you communicate this to Mr. Fabricius I will beg you to present my sincere and best respects to him, and tell him I often think with the highest pleasure of ye many agreeable hours we spent together when he was here in England. How happy I should be to enjoy the same again.

(17) To James Greenway, Dinwiddie Co., Virginia. 1772.

On the 31st of Dec. I received a letter from Dr. Giseke advising me that he had sent a box of books for you, but by a subsequent letter I learned the ship put back by distress of weather after being out about a month. As soon as I receive them I shall convey them to you by the first ship that goes to James River. I suppose it is unnecessary to inform you that the Dr. has been chosen almost unanimously Professor of Natural Philosophy at Hambro', as I have no doubt but his letter will inform you of that matter and likewise ye great satisfaction it has given him, a satisfaction that all his friends cannot help participating. Public testimonies of approbation are seldomer given to men of merit than the undeserving. This is a melancholy truth that is every day seen on this side of the Atlantic and therefore cannot be supposed to come from an invidious pen, therefore what sober thinking mind can help rejoicing at seeing worth rewarded.

(18) To Mr. Thomas Bolton, Worley-Clough, near Halifax.

Feb. 9. 1772.

I take the liberty of recommending my good friend Mr. John Latham,[7] Surgeon at Dartford in Kent, to your friendship and cordiality. He is a gentleman every way deserving it and when I tell you he is a staunch Friend to Natural History I have no doubt but *that* would be sufficient to recommend him to your notice if he had no other amiable qualities, but believe me his general good character is such as will fix him a worthy correspondent. His great Forte is ornithology but other

[7] John Latham; born 1740, died 1837. Eminent as an ornithologist, publishing many important works. He began his General History of Birds, in ten quarto volumes, in his eighty-second year.

parts of Natural History he is acquainted with as *Fossills*, *Insects* and I think Botany.

I have the pleasure to inform you that I have almost completed the second Volume of Illustrations. A work I think preferable to the first because there are a great many more uncommon insects in it than there was in the former; indeed, it consists entirely of nondescripts, many of which I received from the Coast of Africa, and are such as were never before seen in Europe. I am only sorry I have it not in my power to give the nat. hist. of every one of them, how happy I should be to be able to do that! but so long as distant countries afford few or no men of speculation we must not expect it. A Banks and Solander are to be found only in an Age; and ye wonders of creation must not be expected to be opened and displayed but by slow and gradual means.

Men of Fortune indeed have it in their power to come at this knowledge easier than other people, but when luxury and dissipation fix themselves in any nation, little expectations can be formed in favor of nat. hist. unless it be with those who have wisdom enough to shun those dissolute paths, and secure a mode of entertainment and instruction that will always be found in the tracks of nature. 'Tis with much pleasure we may perceive a few of such persons existing at this time, as a proof of which I need only mention (what I suppose you have before heard) of a gentleman being sent to the coast of Africa to collect the subjects of natural history. His name is Smeathman, and as he is furnished with a general knowledge of nature we form great expectations of having new scenes disclosed to us that were never heard or thot of in that great theatre. He is a man of sense and Letters and therefore qualified to give juster accounts of things than what are at present to be depended on.

(19) Mr. Smeathman at Sierra Leone. Mar. 1. '72.

I desire when you send me the next letter you would be particularly careful to write small, I insist upon it you don't write larger than this. Let me have none of your damned large scrambling characters that won't allow you to put above six words in a line, and by that means prevent me from knowing in what manner you live, how you spend your time and what reception you have met with among the Blacks, how they relish your catching Birds and Flies, whether they laugh at you for so doing and whether you have yet made a journey into the interior parts of the country. In short I want to have ye whole history of ye present life compiled in a sheet of paper, and I am so anxious to hear from you that I most heartily curse this avarice of the Merchts for carrying their ships such an enormous way around as ye West Indies and not sending them directly to Europe. However I sincerely hope you don't neglect recording every circumstance that can enrich a History of Africa, for if you don't publish one when you come home I think you will deserve to live on "Sordid scraps on surly proud men's doors." Your judgment and abilities strongly enforce ye necessity of it, not only as an emolument to yourself but as a duty you owe to every speculative man, and depend on it much is due from every man of ability in his respective sphere. [In the third volume of the Illustrations Drury quotes many biological observations by Smeathman.]

(20) To Dr. Giseke. July 13, 1772.

I imagine you have heard before this of the situation of Mr. Banks and Dr. Solander with respect to their intended Voyage. They neither of them go any more a kingdom hunting; a misunderstanding between them and our government is the occasion, and Mr. Rheinhold Forster, who published several things, as Centuria Prima Descript. Insectorum, a translation Kalm's Travels in North America etc. is pitched on to go in their room, nay he is actually gone, and tho' his abilities are not considered as equal to those of Banks and Solander yet great expectations are formed by government from him. The event will prove whether they are well founded. I think if I am not mistaken I mentioned in one of my letters my desire of knowing what was become of Dr. Pallas, whether any letters had been received from him lately, and what success had attended his physical voyage? If you can give me any information of these matters I beg you will do it in your next letter. I have not received a line from him these three or four years nor have I been able to get any intelligence about him.

(21) To Mr. Latham, Surgeon in Dartford. July 31. 1772.

Mr. Whiting and Bartlet long to see your Collection of Birds, and if Thursday next will not be inconvenient we will all pack ourselves in a post chaise; but if that day should not be quite agreeable I will beg you to favor me with a line by Monday's post and we will appoint some other time.

(22) To Dr. Kerr at Calcutta. Feb. 12. 1773.

[Writes a long letter begging Dr. Kerr to obtain insects for him, and pointing out the interest of the subject.]

Let me observe further that if your speculations should extend so far as to inquire into the way of life of numberless insects you will have such [word lost] opend as will astonish you and at the same time that you receive the highest entertainment. Mankind may be improved by committing your observations to paper, for we in Europe are ignorant of the Nat. Hist of thousands of animals that live between the Tropics, particularly those of India.

(23) To the Rev. Mr. Devereux Jarrat, May 5, 1773.

I should think myself unpardonable to neglect writing to you by the opportunity that now offers itself. The bearer, Mr. Abbot, is a young Gentleman going to Virginia on purpose to collect the various articles in Natural History; in doing which he proposes to spend some months, perhaps years, according to the success he meets with in the various departments of that pursuit.

(24) To Mr. Thomas Boulton, at Werley Clough. June 24, 1773.

Mr. Banks and Dr. Solander brought home a very fine collection of insects, a great number of which are new to me and indeed to everybody else. They are not in general so large as one would expect Insects to be that are found in those hot countries they visited; but then many are extremely singular and remarkable. There are *Curculiones* exceeding long and slender like the *Anchraco*, some not less than three or four inches, besides many new species *Scarabei*, *Chrysomelae* and in short all ye *genera Coleoptrata*. The new species of Lepidoptera are not so numerous as I expected, but these are amply atoned by ye other Orders. I do not as yet know if they intend to publish figures of them among ye other things they intend to give ye world, but I hope they will if ye spirit of kingdom hunting does not possess them too strongly. The plants they brought are very numerous, of which I think Dr. Solander told me they had above seven hundred undescribed. These I know they intend figuring and therefore it is likely you will in time see them all. Mr. Banks is now going to Wales.

. . . .

I think you remember Mr. Fabricius. He is now in London and very busy in making descriptions from Mr. Banks' and my collections, where he will have employment for some months, a pleasure he seems to enjoy with as much glee as a Lover of Wine does ye sight of his Cellar when well stored with full Casks and Bottles, enjoying by anticipation ye pleasure he is to receive in emptying them. You seem to lament the want of a Friend with whom you may converse or correspond on the subject of entomology. Indeed, I am sorry for it and I judge of you by myself whose knowledge and delight therein would soon become trifling and flat if I had no one to talk to on that subject.

I can only say I will with much pleasure answer your letters though perhaps I may sometimes be late in doing it, but believe me I shall be glad to correspond at all times with a friend on these subjects. Your account of ye little Beetles I am much pleased with.

I have read it over a great many times and each time enjoy a pleasure equal to yours when collecting them. How happy are ye men that can thus converse with the great Author of the Universe! For certainly this is holding conversation with him. Can we do it by any other means? Can we consider ye investigation and observation of these his works in any other light than that of preserving and holding a friendly intercourse with him? If it can be explained in any other manner let those do it whose souls are not sufficiently capacious and susceptible of entertaining and grasping ye vast idea.

(25) To the Dowager Duchess of Portland. Aug. 13. 1773.

May it please your Grace, the subscription to Mr. Smeathman which your Grace inquires after is £100, being the same sum as paid by Dr. Fothergill etc, and which I have no doubt but the things he will send over in less than a twelve month will be more than sufficient to discharge.

(26) To Mr. Keuchan, at Jamaica. June 13, 1774.

You inquire after Mr. Smeathman, who is settled on the Coast of Africa. He has been there almost three years but has sent nothing over except insects, a circumstance which astonishes us, for his patrons expected a great variety of subjects long before this in ye different branches of Natural History. Many of the insects that he has sent are surprisingly fine. A great number entirely new, especially among the Coleoptera, some of which are very large.

(27) To Mr. Keuchan at Jamaica. Jan. 21, 1775.

I told you in my last of a young Gentleman gone to settle in Virginia in pursuit of Nat. Hist. His name is Abbot,[8] and by a letter lately sent I find he intends to remove to the southward, therefore don't be surprised if you should see him at Jamaica; perhaps he may touch there, but I recommended Surinam to him as yielding more wonderful insects etc. Whether he will go there I do not know.

(28) To Dr. Pallas. Nov. 4. 1775.

Mr. Banks's publication nobody can tell when it will make its appearance. Whenever it does it will be not only voluminous but expensive, a circumstance I am surprised he does not attempt to avoid. It has been 4 years preparing, and it seems to me that 4 years more will not complete it. Would it not therefore be best to publish a single volume first? The World thinks so, and he has been told this, but in vain. You require me not to publish any of the Insects you send me. Be assured this requisition shall be punctually observed, and I hope you have given ye same intimation to those Friends to whom you have sent some of your duplicates. Indeed I must inform you that I do not entertain the least inclination to publish any more Volumes, notwithstanding my Cabinet is so exceeding rich. If I was disposed to publish any more I could easily furnish three more volumes equally as

[8] John Abbott, who made many observations on the insects of Georgia, and beautifully figured numerous species. His work was published in part, edited by Sir J. E. Smith, in 1797, and the new species thus made known are credited in our lists to Abbott and Smith. His drawings are now preserved in the British Museum (Natural History).

good as those already done, without having recourse to any other, but my time is so much engrossed by my present business that I have no leisure to go through a work of that kind. If I had time to spare I should pursue it with infinite pleasure. I must give up all thoughts (notwithstanding the solicitations of my friends) of ever again engaging in that employment.

(29) To Mr. Robert Killingley, Mar. 23, 1776.

I shall make no apology for sending you the two books enclosed, Major Roger, Acco' of North America, and Hasselquist's Travels. I wish I could give you equal characters to the two, but ye former seems to me to be taken from Charlevoix Acco' of North America, several passages being copied almost verbatim,—the other I need not praise, you will immediately see ye Man of Letters in ye style and thoughts—the descriptions are charming in my opinion, notwithstanding they are so very short and concise, indeed, I cannot help being angry with him for not being more elaborate and prolix in places.

. . . .

I flatter myself you will enjoy a great joy in ye reading it, your taste for Natural History at all times gives you an opportunity of relishing subjects of this kind with a glee ten times stronger than that of an ordinary person. Need I mention this is ye person that Linneus so often quotes in his Systema Naturæ, and who was so eminently serviceable to him by furnishing so many subjects in that work? [Frederic Hasselquist, born 1722, was a pupil of Linnæus. He made large collections of plants and animals in Palestine and Egypt.]

(30) Dec. 21. 1778.

Last year I lost more than £16,000, the effect of which was, O! terrible to relate, I was obliged to be a Bankrupt. As my misfortunes did not arise from extravagance or dishonesty the world saw my distress and pitied me. By the assistance and kindness of my Friends I have got re-instated in my business, which I really think is much greater than it ever was. The civilities and kindness I have received from the public are beyond conception, and I have no doubt but a few years if Providence allows me Health will place me in a much happier and better situation than I ever was. Would you believe it? The Queen herself, to whom I am Goldsmith, has been so very kind as to say that "She hoped I should do well again."

GALEN: THE MAN AND HIS TIMES

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FOR about fifteen centuries the name of Galen dominated the study of medicine. But at the close of the nineteenth century an English student of the history of medicine said, "Galen is so inaccessible to English readers that it is difficult to learn about him at first hand." Another wrote, "There is, perhaps, no other instance of a man of equal intellectual rank who has been so persistently misunderstood and even misinterpreted." A third obstacle has been that while critical editions of some single works have recently been published by Helmreich and others, no complete edition even of the Greek text of Galen has appeared since that of Kühn of a century ago, which is now regarded as very faulty. A fourth reason for neglect or misunderstanding of Galen is probably that there is so much by him to be read. Athenaeus stated that Galen wrote more treatises than any other Greek, and although many are now lost, more particularly of his logical and philosophical writings, his collected extant works fill some twenty volumes averaging a thousand pages each. There are often no chapter headings or other brief clues to the contents, which must be ploughed through slowly and thoroughly, since some of the most valuable bits of information come in quite incidentally or by way of unexpected digression. Besides errors in the printed text there are numerous words not found in most classical dictionaries. It is therefore perhaps not surprising, in the words of one of the English historians of medicine quoted above, that "few physicians or even scholars in the present day can claim to have read through this vast collection."

Yet Galen deserves to be remembered, not merely as one of the great names, but as one of most original minds and attractive personalities in all the long history of medicine. It is not difficult to make out the the main events of his life, his works supply an unusual amount of personal information, and throughout them, unless he is merely transcribing past prescriptions, he talks like a living man, detailing incidents of daily life and making upon the reader a vivid and unaffected impression of reality. Daremberg said of Galen that the exuberance of his imagination and his vanity frequently make us smile. It is true that his pharmacology and therapeutics often strike the modern reader as ridiculous, but he did not imagine them; they were the medicine of his age. It is true that he mentions cases which he has cured and those where other physicians have been at fault, but official war despatches do the same in the case of their own side's victories and the enemy's defeats. *Vae victis!* In Galen's case, at least, posterity long confirmed his own verdict. And dull or obsolete as much of his medicine now is, his scholarly and intellectual ideals and love of hard work are still a living force, while the reader of his pages often feels himself carried back to the Roman world of the second century.

Galen, who does not seem to have been called Claudius until the time of the Italian Renaissance, was born about 129 A. D. at Pergamum in Asia Minor. His father, an architect and mathematician, transmitted much of this education to his son, but even more valuable, in Galen's opinion, were his precepts to follow no one sect or party but to hear and judge them all, to despise honor and glory, and to magnify truth alone. To this teaching Galen attributed his own peaceful and painless passage through life. He did not grieve over losses of property but managed to get along somehow. He did not mind it much when some vituperated him, but thought instead of those who praised him. In later life Galen looked back with great affection upon his father as the gentlest, justest, most honest and humane of men. On the other hand, the chief lesson he learned from his mother was to avoid her failings of a sharp temper and tongue, whereby she made life miserable for their household slaves and scolded his father worse than Xanthippe ever did Socrates.

In one of his works Galen speaks of the passionate love and enthusiasm for truth which have possessed him since boyhood, so that he has not stopped either by day or by night from quest of it. He realized that to become a true scholar required both high natural qualifications and a superior type of education from the very first. After his fourteenth year he heard the lectures of various philosophers, Platonist and Peripatetic, Stoic and Epicurean; but when about seventeen, warned by a dream of his father, he turned to the study of medicine. The incident of the dream, like many other passages in Galen's works, shows that even men of the finest education and intellectual standards were not free from the current beliefs in occult influences. Galen first studied medicine for four years under Satyrus in his native city of Pergamum; then after his father's death, under Pelops at Smyrna, and later under Numisianus at Corinth and Alexandria. This was about the time that the great mathematician and astronomer, Ptolemy, was completing his observations in the neighborhood of Alexandria, but Galen does not mention him, despite his own belief that a first-rate physician should also understand such subjects as geometry and astronomy, music and rhetoric. Galen's interest in philosophy continued, however, and he wrote many logical and philosophical treatises, most of which are lost.

Galen returned to Pergamum to practice and was, when but twenty-nine, given charge of the health of the gladiators by five successive pontiffs. During his thirties came his first residence in Rome. In two of his works he gives two different explanations for his departure from the capital city. In one he says, "When the great plague broke out there (in the reign of Marcus Aurelius) I hurriedly departed from the city for my native land." In another his explanation is that he became disgusted with the malice of the envious physicians of the capital and determined to return home as soon as the sedition there was over. Meanwhile he gained great fame by his cures, but the jealousy and opposition of the other physicians multiplied, so that presently, when he learned that the sedition was over, he went back to Pergamum.

His fame, however, had come to the imperial ears and he was soon summoned to Aquileia, north of the Adriatic, to meet the emperors on their way north against the Germans who had invaded the frontier. An outbreak of the plague there prevented them from proceeding with the campaign immediately and Galen states that the emperors fled for Rome with a few troops, leaving the rest to suffer from the plague and the cold winter. On the way Lucius Verus died, and when Marcus Aurelius finally returned to the front, he allowed Galen to go back to Rome as court physician to his son Commodus. The prevalence of the plague at this time is illustrated by a third encounter which Galen had with it in Asia, when he claims to have saved himself and others by thorough venesection. The war in which Marcus Aurelius was engaged lasted much longer than had been anticipated and meanwhile Galen was occupied chiefly in literary labors. In 192 some of his writings and other treasures were lost in a fire which destroyed the Temple of Peace on the Sacred Way and the great libraries on the Palatine hill. Of some of the works which thus perished he had no other copy himself. He began one of his works on compound medicines of which two books had been already published all over again because most of the published copies had been destroyed in the fire. Galen was still alive and writing during the early years of the dynasty of the Severi and probably did not die until about 200.

Although the envy of other physicians at Rome and their accusing Galen of resort to magic arts and divination in his marvelous prognostications and cures were perhaps neither the sole nor the true reason for his temporary withdrawal from the capital, there probably is a great deal of truth in the picture he paints of the medical profession and learned world of his day. Too many other ancients, from Vitruvius, Pliny the Elder and Juvenal to Firmicus Maternus in the fourth century, substantiate his charges to permit us to explain them away as the product of personal bitterness or pessimism. We feel that these men lived in an intellectual society where faction and villainy, superstition and petty-mindedness and personal enmity, were more manifest than in the quieter and, let us hope, more tolerant world of our time. The *status belli* may still characterize politics and the business world, but scholars seem able to live in substantial peace. Perhaps it is because there is less prospect of worldly gain for members of the learned professions than in Galen's day. Perhaps it is due to the growth of the impartial scientific spirit, of unwritten codes of courtesy and ethics within the leading learned professions, and of state laws concerning such matters as patents, copyright, professional degrees, pure food and pure drugs. Perhaps, in the unsatisfactory relations between those who should have been the best educated and most enlightened men of that time we may see a symptom of the general intellectual and ethical decline of the ancient world.

Galen states that many tire of the long struggle with crafty and wicked men which they have tried to carry on, relying upon their erudition and honest toil alone, and withdraw disgusted from the madding crowd to save themselves in dignified retirement. He especially marvels at the evil-mindedness of physicians of reputation at Rome. Though they live in the city, they are a band of robbers as truly as the brigands of the mountains. He is inclined to account for the roguery of Roman physicians compared to those in a smaller city by the facts that elsewhere men are not so tempted by the magnitude of possible gain, and that in a smaller town everyone is known by everyone else and so questionable practices cannot escape general notice. The rich men of Rome fall easy prey to unscrupulous practitioners who are ready to flatter them and to play up to their weaknesses. These rich men can see the use of arithmetic and geometry, which enable them to keep their books straight and to build houses for their domestic comfort, or of divination and astrology, from which they seek to learn whose heirs they will be; but they have no appreciation for pure philosophy aside from rhetorical sophistry.

Galen more than once complains that there are no real seekers after truth in his time, but that all are intent upon money, political power, or pleasure. You know very well, he writes to a friend in one of his works, that not five men of all those whom we have met prefer to be rather than to seem wise. Many who have no real knowledge make a great outward display and pretense in medicine and other arts. Galen several times expresses his scorn for those who spend their mornings in going about saluting their friends, and their evenings in drinking bouts or in dining with the rich and powerful. Yet even his friends have reproached him for studying too much and not "going out" more. But while they have wasted their hours thus, he has spent his, first in learning all that the ancients have discovered that is of value, then in testing and practicing the same. Moreover, now-a-days many are trying to teach others what they have never accomplished themselves. Thessalus not only toadies the rich but secured many pupils by offering to teach them medicine in six months. Hence it is that tailors and dyers and smiths are abandoning their arts to become physicians. Thessalus himself, Galen ungenerously taunts, was educated by a father who plucked wool badly in female apartments. Indeed, Galen himself by the violence of his invective and the occasional passionateness of his animosity in his controversies with other individuals or schools of medicine, illustrates that state of war in the intellectual world of his age to which I have adverted.

I suggested that possibly learning compared to other occupations was more remunerative in Galen's day than in ours, but there were poor physicians and medical students then as well as those who were greedy for gain or who associated with the rich. Many doctors could not afford to use the rarer or stronger simples and limited themselves to easily procured, inexpensive, and homely medicaments. Many of his fellow students regarded as a counsel of perfection unattainable by them Galen's plan of hearing all the different medical sects and comparing their merits and testing their validity. These students said tearfully that this course was all very well for him with his acute genius and his wealthy father behind him, but that they lacked the money to pursue an advanced education, perhaps had already lost valuable time under unsatisfactory teachers, or felt that they did not possess the discrimination to select for themselves what was profitable from several conflicting sects or schools.

Galen was, it has already been made apparent, an intellectual aristocrat, and possessed little patience with those stupid men who never learn anything for themselves, though they see a myriad cures worked before their eyes. But that, apart from his own work, the medical profession was not entirely stagnant in his time, he admits when he asserts that many things are known today which had not been discovered before, and when he mentions some curative methods recently invented at Rome.

Galen supplies considerable information concerning the drug trade in Rome itself and throughout the empire. He often complains of adulteration and fraud. The physician must know the medicinal simples and their properties himself and be able to detect adulterated medicines, or the merchants, perfumers, and *herbarii* will deceive him. Galen refuses to reveal the methods employed in adulterating opobalsam, which he had investigated personally, lest the evil practice spread further. At Rome at least there were dealers in unguents who corresponded roughly to our druggists. Galen says that there is not an unguent-dealer in Rome who is unacquainted with herbs from Crete, but he asserts that there are equally good medicinal plants growing in the very suburbs of Rome of which they are totally ignorant, and he taxes even those who prepare drugs for the emperors with the same oversight. He tells how the herbs come from Crete wrapped in cartons with the name of the herb written on the outside and sometimes the further statement that it is *campestris.* These Roman drug stores seem not to have kept open at night, for Galen speaks of the impossibility of procuring at once the medicines needed in a certain case, because "the lamps were already lighted."

The emperors kept a special store of drugs of their own and had botanists in Sicily, Crete, and Africa who supplied not only them with medicinal herbs, but, according to Galen, the city of Rome as well. However, the emperors appear to have reserved a large supply of the finest and rarest simples for their own use. Galen mentions a large amount of Hymettus honey in the imperial stores—εν ταις αυτοκρατορικαις αποθηκαις—whence our word "apothecary." He proves that cinnamon loses its potency with time by his own experience as imperial physician. An assignment of the spice sent to Marcus Aurelius "from Barbary" was superior to what had stood stored in wooden jars from the preceding reigns of Trajan, Hadrian, and Antoninus Pius while after Commodus had exhausted this recent supply and Galen had to turn again to the older store in preparing an antidote for Severus, he found it still weaker than before. That cinnamon was a commodity little known to the populace is indicated by Galen's mentioning his loss in the fire of 192 of a few precious branches which he had stored away in a chest along with other personal treasures. He praises the Severi, however, for permitting others to use theriac, the noted compound medicine and antidote. Thus, he says, they not only as emperors have received power from the gods, but in sharing their goods freely they resemble the gods, who rejoice the more, the more people they save.

Galen himself, and the same seems to have been true of other physicians, was not content to rely for medicines either upon the unguent sellers or the bounty of the imperial stores. He stored away oil and fat, leaving them to age, until he had enough to last him for a hundred years, including some from his father's lifetime. He used some forty years old in one prescription. He also travelled to many parts of the Roman Empire and procured rare drugs in the places where they were produced. Very interesting is his account of going out of his way in journeying back and forth between Rome and Pergamum in order to stop at Lemnos and procure a supply of the famous *terra sigillata*, a reddish clay stamped into pellets with the sacred seal of Diana. On his way to Rome, instead of journeying on foot through Thrace and Macedonia, he took ship from the Troad to Thessalonica; but the vessel stopped in Lemnos at Myrine on the wrong side of the island—Galen had failed to realize that Lemnos had more than one port, and the captain would not delay the voyage long enough to enable him to cross the island to the spot where *terra sigillata* was to be found. Upon his return from Rome through Macedonia, however, Galen took pains to visit the right port, and for the benefit of future travelers gives careful instructions concerning the route to follow and the distances between stated points.

Galen also describes the solemn procedure by which the priestess from the neighboring city gathered the red earth from the hill where it was found, sacrificing no animals, but wheat and barley to the earth. He brought away with him some twenty thousand of the little discs or seals, which were supposed to cure even lethal poisons and the bite of mad dogs. The inhabitants laughed, however, at the assertion which Galen had read in Dioscorides that the seals were made by mixing the blood of a goat with the earth. Berthelot, the historian of chemistry, believed that this earth was "an oxide of iron more or less hydrated and impure." C. J. S. Thompson, in a recent paper on "Terra Sigillata, a famous medicament of ancient times," tells of various medieval substitutes for the Lemnian earth, and of the interesting religious ceremony performed in the presence of Turkish officials on only one day in the year by Greek monks who had replaced the priestess of Diana. Pierre Belon witnessed this ceremony on August 6th, 1533, by which time there were many varieties of the tablets in existence, "because each lord of Lemnos had a distinct seal." When Tozer visited Lemnos in 1890, the ceremony was still performed annually on the same day, and must be completed before sunrise or the earth would lose its efficacy. Moslem *khodjas* now shared in the religious ceremony, sacrificing a lamb. But in the twentieth century the entire ceremony was abandoned. Through the early modern centuries *terra sigillata* continued to be held in high esteem in western Europe also, and was included in pharmacopeias as late as 1833 and 1848. Thompson gives a chemical analysis of a sixteenth century tablet of the earth and finds no evidence therein of its possessing any medicinal property.

To come back to Galen, in another passage he advises his readers, if they are ever in Pamphylia, to lay in a good supply of the drug *carpesium*. In a third passage he tells of three strata of sory, chalcite, and misy, which he had seen in a mine in Cyprus thirty years before and from which he had brought away a supply, and of the surprising alteration undergone by the misy in the course of those years. He speaks of receiving other drugs from Great Syria, Palestine, Egypt, Cappadocia, Pontus, Macedonia, Gaul, Spain, and Mauretania, from the Celts, and even from India. He names other places in Greece and Asia Minor than Mount Hymettus where good honey may be had. Much so-called Attic honey is really from the Cyclades, although it is brought to Athens and there sold or re-shipped. Similarly genuine

Falernian wine is produced in but a small section of Italy, but imitations are prepared by those skilled in such knavery. As the best iris is that of Illyricum and the best asphalt from Judaea, so the best petroselinos is that of Macedonia, and merchants export it to almost the entire world, just as they do Attic honey and Falernian wine. But the petroselinos crop of Epirus is sent to Thessalonica (Saloniki) and there passed off for Macedonian. The best turpentine is that of Chios, but a good variety may be obtained from Libya or Pontus. The best form of unguent was formerly made only in Laodicea, but now it is similarly compounded in many other cities of Asia Minor.

We are reminded that parts of animals as well as herbs and minerals were important constituents in ancient pharmacy by Galen's invective against the frauds of hunters and dealers in wild beasts as well as of unguent-sellers. They do not hunt the animals at the proper season for securing their medicinal virtues, but when they are no longer in their prime or just after their long period of hibernation, when they are emaciated. Then they fatten them upon improper food, feed them barley cakes to stuff up and dull their teeth, or force them to bite frequently so that virus will run out of their mouths. The beasts of course were also in demand for the games of the arena.

Besides the ancient drug trade, Galen gives us some interesting glimpses of the publishing trade, if we may so term it, of his time. Writing in old age, he says that he has never attached his name to his works and has never written for the popular ear or for fame, but fired by zeal for science and truth, or at the urgent request of friends, or as a useful exercise for himself, or, as now, in order to forget his old age. He regards popular fame as only an impediment to those who desire to live tranquilly and enjoy the fruits of philosophy. He asks Eugenianus not to praise him immoderately before men, as he has been wont to do, and not to inscribe his name in his works. His friends nevertheless prevailed upon Galen to write two treatises listing his works, and he also is free enough in many of his writings in mentioning others which it is essential to read before perusing the present volume. Perhaps he felt differently at different times on the question of fame and anonymity. He also objected to those who read his works, not to learn anything from them, but only in order to calumniate them.

It was in a shop on the Sacra Via that most of the copies of some of Galen's works were stored when they, together with the great libraries upon the Palatine, were consumed in the fire of 192. But in another passage he states that the street of the Sandal-makers is where most of the book-stores of Rome are located. There he saw some men disputing whether a certain treatise was his. It was duly inscribed *Galenus medicus* and one man, because the title was unfamiliar to him, had just purchased it as a new work by Galen. But another man who was something of a philologer asked to see the introduction, and, after reading a few lines, declared that the book was not one of Galen's works. When Galen was still young, he wrote three commentaries on the throat and lungs for a fellow student who wished to have something to pass off as his own work upon his return home. This friend died, however, and the books got into circulation. Galen also complains that notes of his lectures which he had not intended for publication have got abroad, that his servants have stolen and published some of his manuscripts, and that others have been altered, corrupted, and mutilated by those into whose possession they have come, or have been passed off by them in other lands as their own productions. On the other hand, some of his pupils keep his teachings to themselves and are unwilling to give others the benefit of them, so that if they should die suddenly, his doctrines would be lost. His own ideal has always been to share his knowledge freely with those who sought it, and if possible with all mankind. At least one of his works was taken down from his dictation by short-hand writers, when, after his convincing demonstration by dissection concerning respiration and the voice, Boëthus asked him for commentaries on the subject and sent for stenographers. Although Galen in his travels often purchased and carried home with him large quantities of drugs, when he made his first trip to Rome he left all his library in Asia.

Galen dates the practice of falsifying the title pages and contents of books back to the time when kings Ptolemy of Egypt and Attalus of Pergamum were bidding against each other for volumes for their respective libraries. At that time works were often interpolated in order to make them larger and so bring a better price. Galen speaks more than once of the deplorable ease with which numbers, signs, and other abbreviations are altered in manuscripts. A single stroke of the pen or slight erasure will completely change the meaning of a medical prescription. He thinks that such alterations are sometimes malicious and not mere mistakes. So common were they that Menecrates composed a medical work written out entirely in complete words and entitled *Autocrator Hologrammatos* because it was also dedicated to the emperor. Another writer, Damocrates, from whom Galen often quotes long passages, composed his book of medicaments in metrical form so that there might be no mistake made even in complete words.

Galen's works contain occasional historical information concerning many other matters than books and drugs. Clinton made much use of Galen for the chronology of the period in his *Fasti Romani*. Galen's allusions to several of the emperors with whom he had personal relations are valuable bits of source-material. Trajan was, of course, before his time, but he testifies to the great improvement of the roads in Italy which that emperor had effected, comparing his own systematic treatment of medicine to the emperor's great work in repairing and improving the roads, straightening them by cut-offs that saved distance, but sometimes abandoning an old road that went straight over hills for an easier route that avoided them, filling in wet and marshy spots with stone or crossing them by causeways, bridging impassable rivers, and altering routes that led through places now deserted and beset by wild beasts so that they would pass through populous towns and more frequented areas. The passage thus bears witness to a shifting of population. Galen also sheds a little light on the vexed question of the number of persons in the empire, if Pergamum is the city he refers to in his estimate of 40,000 citizens or 120,000 inhabitants, including women and slaves but perhaps not children.

The evils of ancient slavery are illustrated by an incident which Galen relates to show the inadvisability of giving way to one's passions, especially anger. Returning east from Rome, Galen fell in with a traveler from Gortyna in Crete. When they reached Corinth, the Cretan sent his baggage and slaves to Athens by boat, but himself with a hired vehicle and two slaves went by land with Galen through Megara, Eleusis, and Thriasa. On the way the Cretan became so angry at the two slaves that he hit them with his sheathed sword so hard that the sheath broke and they were badly wounded. Fearing that they would die, he then made off to escape the consequences of his act, leaving Galen to look after the wounded. But later he rejoined Galen in penitent mood and wished Galen to administer a beating to him for his cruelty. Galen adds that he himself, like his father, had never struck a slave with his own hand and had reproved friends who had broken their slaves' teeth with blows of their fists Other men were accustomed to kick their slaves or gouge their eyes out. The emperor Hadrian was said in a moment of anger to have blinded a slave with a stylus which he had in his hand. He, too, was sorry afterwards and offered the slave money, which the latter refused, telling the emperor that nothing could compensate him for the loss of an eye. In another passage Galen discusses how many slaves and how much clothing one really needs.

Galen also depicts the easy-going, sociable, and pleasure-loving society of his time. Not only physicians but men generally began the day with salutations and calls, then separated, some to the market-place and law courts, others to watch the dancers or charioteers. Others played at dice or pursued love-affairs, or passed the hours at the baths or in eating and drinking or some other bodily pleasure. In the evening they came together again at symposia which bore no resemblance to the intellectual feasts of Socrates and Plato but were mere drinking bouts. Galen, however, had no objection to the moderate use of wine, and mentions the varieties from different parts of the Mediterranean world which were especially noted for their medicinal properties. He believed that discreet indulgence in wine aided digestion and the blood, and relieved the mind from all worry and melancholy and refreshed it. "For we use it every day." He classed wine with such boons to humanity as medicine, "a sober and decent mode of life," and "the study of literature and liberal disciplines." His three books on food values (*De alimentorum facultatibus*) supply information concerning the ancient table and dietary science.

Galen's allusions to Judaism and Christianity are of considerable interest. He seems scarcely to have distinguished between them. In criticizing Archigenes for using vague and unintelligible language and not giving a sufficient explanation of the point in question, Galen says that it is "as if one had come to a school of Moses and Christ and had heard undemonstrated laws." And in criticizing opposing sects for obstinacy Galen says that it would be easier to win over the followers of Moses and Christ. In a third passage Galen criticized the Mosaic view of the relation of God to nature, resenting it as the opposite extreme to the Epicurean doctrine of a purely mechanistic and materialistic universe. This suggests that Galen had read some of the Old Testament, but he might have learned from other sources of the Dead Sea and of apples of Sodom, of which he speaks in yet another context. According to a thirteenth century Arabian biographer of Galen, he spoke more favorably of Christians in a lost commentary upon Plato's *Republic*, admiring their morals and admitting their miracles. This last is unlikely, since Galen believed in a Supreme Being who worked only through natural law.

Like most thoughtful men of his time, Galen tended to believe in one supreme deity, but he appears to have derived this conception from Greek rather than Hebraic sources. It was to philosophy and the Greek mysteries that he turned for revelation of the deity. Hopeless criminals were for him those whom neither the Muses nor Socrates could reform. It is Plato, not Christ, whom in another treatise he cites as describing the first and greatest God as ungenerated and good. "And we all naturally love Him, being such as He is from eternity."

But while Galen's monotheism cannot be regarded as of Christian or Jewish origin, it is possible that his argument from design and supporting theology by anatomy made him more acceptable both to Mohammedan and Christian readers. At any rate he had Christian readers at Rome at the opening of the third century, when a hostile controversialist complains that some of them even worship Galen. These early Christian enthusiasts for natural science, who also devoted much time to Aristotle and Euclid, were finally excommunicated; but Aristotle, Euclid, and Galen were to return in triumph in medieval learning.

THE MORTALITY OF FOREIGN RACE STOCKS[1]

A CONTRIBUTION TO THE QUANTITATIVE STUDY OF THE VIGOR OF THE RACIAL ELEMENTS IN THE POPULATION OF THE UNITED STATES

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MY interest in this subject arose in connection with another study. Some eight years ago, I began to investigate the reasons for the increasing mortality of the American people after age 45. The mortality figures for the previous decade had shown that, while there had been very marked declines in the mortality rates of our population in infancy, in childhood, and in early adult life, that beginning with the age period 45 and continuing well into old age, there had been a slight increase in mortality. This was very puzzling because such conditions did not appear in England, in Germany, or in the Scandinavian countries for which comparable data were at hand. This was evidently a condition characteristic of America. Why should there be such an adverse change in the death rate during a period of extraordinary activity in public health and when so much was being done to improve the sanitary conditions of the country? Living and working conditions were undoubtedly getting better all the time for the great mass of the population. But these improvements were not being reflected in the facts of the death rate for middle life and beyond. After much labor on this problem, it finally occurred to me that the facts could, perhaps, be explained very simply as the result of the character of our recent immigration. My hypothesis was that, if the foreign stocks that had been coming into the country in increasing numbers actually had a higher death rate than the native stock at the older ages of life, that the very fact of their coming would be sufficient to account for the increase in mortality of the whole population.

To test this hypothesis, it was necessary to construct tables of mortality for the several race stocks, including the native born of native parentage, the native born of foreign or mixed parentage and the foreign born. For the last group, it was necessary also to prepare a table for each one of the important foreign nativity classes. I turned to the data for the State of New York where there was a large representation of the three groups of the population, where registration of deaths was

[1] Read before the second International Congress of Eugenics, Sept. 21, 1921.

good, and where I was fairly familiar with the living and working conditions of the people. Data were for the year 1910. The results were published in the American Economic Review, Vol. VI, No. 3, 1916.[2] Later, assisted by Mr. G. W. Baker, I supplemented the findings for New York State with those for Pennsylvania.[3]

The following is a summary of our chief results. For more details, reference will have to be made to the two papers referred to above.

TABLE 1

Deaths per 1,000 white population among native born of native parentage, among native born of foreign or mixed parentage, and among foreign born, by sex and by age period: New York State, 1910.

Age Period	MALES			FEMALES		
	Native born of native parentage	Native born of foreign or mixed parentage	Foreign born	Native born of native parentage	Native born of foreign or mixed parentage	Foreign born
Ages 10 and over:						
Crude rate	13.8	13.2	17.5	12.4	9.7	16.6
Standardized rate	13.8	17.2	17.1	12.4	13.9	16.2
10-14	2.5	2.2	2.5	2.6	2.1	2.4
15-19	3.6	4.1	4.4	3.2	3.2	3.2
20-24	5.0	6.8	5.2	4.7	5.2	4.0
25-44	6.9	14.3	8.7	5.7	9.3	7.3
45-64	18.8	28.2	28.0	14.3	20.0	23.4
65-84	77.3	89.9	90.4	68.2	73.9	87.7
85 and over	268.9	323.0	272.7	242.3	324.9	270.5

Table 1 presents a comparison of the actual facts of mortality in three principal classes according to nativity in the population of New York State in 1910. In both sexes, the death rates of the foreign born and of their native born offspring are considerably in excess of those for the native born of native parents after the period of middle life is reached. There is little difference during the periods of childhood, of adolescence, and of early life; but there the similarity ceases. The excess mortality of the foreign stock reaches its maximum at about age 60 and continues to the end of life but to a less degree. In the important age period 45 to 64, the death rate of males (28.0) was 49 per cent. higher than that for native males of native parentage and that for foreign born females was 64 per cent. higher than for females of native stock. Similar conditions exist in the State of Pennsylvania.

In view of the fact that the foreign born and their native offspring make up a considerable proportion of the total population of both New York (63.9 per cent.) and Pennsylvania (43.5 per cent.), there is no room for doubt that our explanation of the increasing mortality

[2] Factors in American Mortality. A Study of Death Rates in the Race Stocks of New York State, 1910.

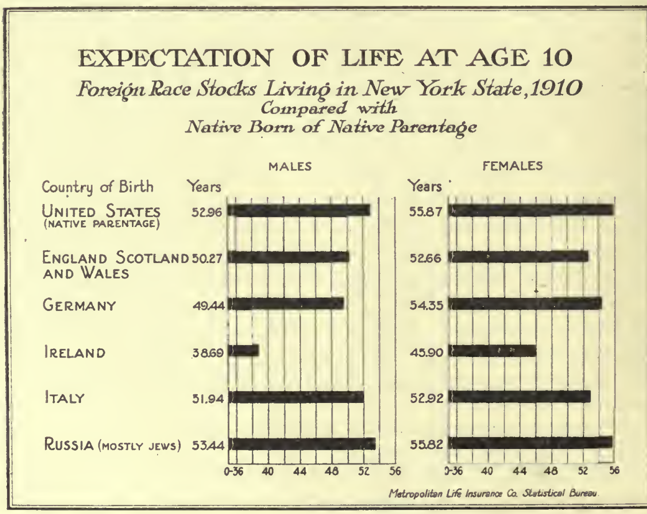
[3] The Mortality of Race Stocks in Pennsylvania and New York. Quarterly Publications American Statistical Association, March, 1920.

after age 45 is correct. The foreign born enter the United States, for the most part, as adults; they have lower vitality than the native stock and their addition to the population can have only one effect, namely, to increase the death rate at the middle ages of life and at the older ages.

Our problem today, however, is somewhat different. I propose to give you the results of our investigations with especial reference to the relative vigor of the several race groups that make up our newer immigration. Obviously, that is what will interest you as eugenists concerned as you are with the character and potentialities of the various groups which are making the American of the future.

To determine the relative vitality of the several race stocks, we constructed a series of life tables from the facts of mortality already referred to. There is no better test; for they tell us the average after lifetime of each group. The figures of expectation were calculated beginning at age 10 in each case because of the small number of foreign born persons living in New York State below this age. The figures for the five principal foreign races are given in the following charts, the countries of foreign birth being arranged alphabetically. The expectations for those born in the United States of native parentage are given for comparison.

With the exception of the Russian born, the native males of native parentage have a greater expectation at age 10 than any of the foreign groups. In New York State, the Russians are almost entirely Jews who are noted for their longevity. At age 10, the expectation



of Russian born males is 53.44 years, as compared with 52.96 years for native males of native parentage. Similar conditions have been described by various observers for Jews living in Germany, Russia and Hungary. They invariably have lower death rates and longer expectation of life than do the people among whom they live. Their addition to the population of New York State has, therefore, an effect very different from that of the other foreign peoples. They increase the longevity of the total population rather than decrease it. Next in order of longevity are the Italian males with a life span of nearly 52 years at age 10; next are the English, Scotch and Welsh, 50.27 years; the Germans, 49.44 years; and the Irish, 38.69 years. The surprising fact of this chart is the very low life expectation of the Irish males. It is actually two years less than the expectation of negro males living in the Registration States at the same age. We shall attempt later to give some of the causes which are responsible for very unfavorable conditions in this race.

Among foreign born females, very similar conditions appear. The greatest expectation is found among Russian born females, who, at age 10, have an average after lifetime of 55.82 years. This is almost identical with the expectation of females of native stock. Then follow in the order named the females born in Germany, Italy, England,

TABLE 2

Expectation of life at selected ages. By sex, for persons born in specified country and living in New York State, 1910:

Sex; country of birth	10	20	40	60
Males: Living in New York State, 1910, Born in:				
United States (native parentage)..	52.96	44.80	29.22	14.92
England, Scotland and Wales....	50.27	42.23	26.79	13.78
Germany	49.44	40.80	25.51	13.25
Ireland	38.60	31.35	18.16	11.25
Italy	51.94	44.26	28.75	15.08
Russia (mostly Jews)............	53.44	44.84	27.85	13.95
Living in specified country:				
England and Wales, 1910-1912.....	53.08	44.21	27.74	13.78
Scotland, 1911....................	51.86	43.27	27.25	13.54
Germany, 1901-1910................	51.16	42.56	26.64	13.14
Italy, 1901-1910....................	51.25	43.00	28.00	13.67
Females: Living in New York State, 1910, Born in:				
United States (native parentage)...	55.87	47.55	31.57	16.30
England, Scotland and Wales......	52.66	44.01	28.17	14.86
Germany	54.35	45.57	29.31	14.60
Ireland	45.90	37.40	22.20	11.30
Italy	52.92	44.94	29.68	15.66
Russia (mostly Jews)............	55.82	46.60	29.84	14.73
Living in specified country:				
England and Wales, 1910-1912.....	55.91	47.10	30.30	15.48
Scotland, 1911....................	53.83	45.35	29.48	15.17
Germany, 1901-1910................	53.35	44.84	29.16	14.17
Italy, 1901-1910....................	51.50	43.67	29.00	13.92

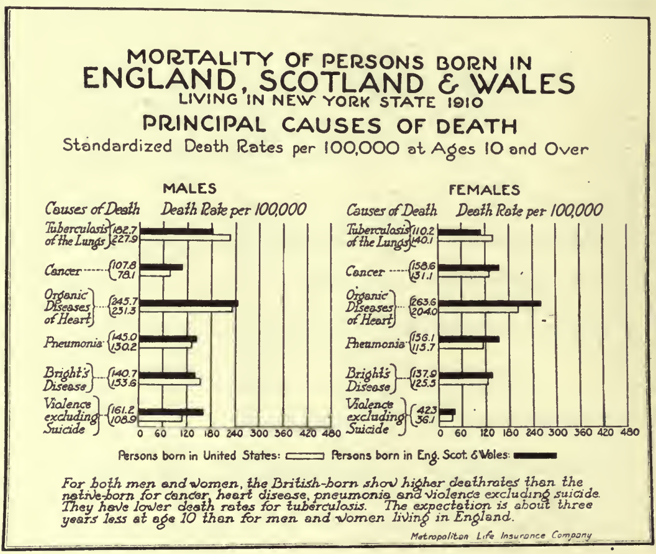
Scotland and Wales, and Ireland. In every case, the expectation of life for females is in excess of that for males of the same nativity group. The excess varies from seven years among the Irish to only about one year among the Italians.

The following table shows similarly the facts of the expectation at other age periods than 10 for each one of the foreign race stocks as compared with the native born of native parentage:

In view of the interest that attaches to the several race stocks, we present a chart for each of them which shows the facts of mortality for the principal causes of death.

English, Scotch and Welsh

The mortality rates of the British are among the most favorable in Europe. Their addition to the population of New York State might, therefore, be expected to be a favorable one. Yet, as we have seen, the expectation of life of both males and females of this nativity falls from two to three years short of that of the native stock at age 10. The fact is that the expectation of the British living in New York State is about three years less than for men and women living in England. Among the several causes of death, we find higher death rates among the British born for cancer, organic heart disease, pneumonia and violence. They have lower death rates for tuberculosis. The differences are never very great and it is difficult to single out any particular cause of death as especially responsible for the conditions described. For our purposes, however, it is important to remember that the



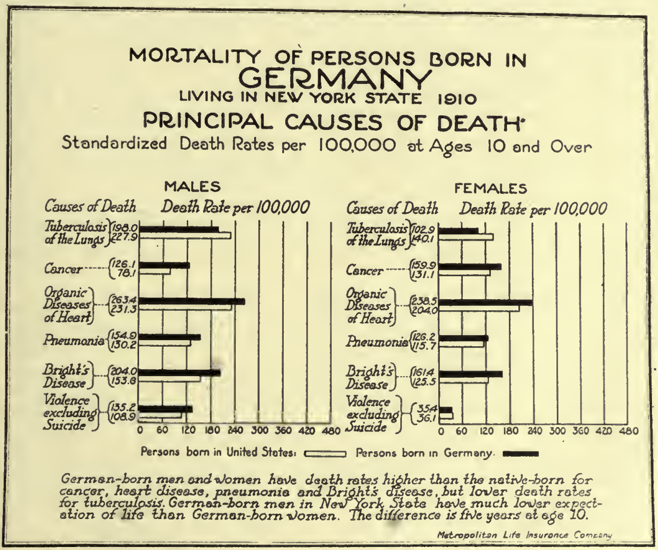
British immigrant living in New York State does not show up as favorably either as do his own people in his native country or as the native stock in the United States.

Immigration from England, Scotland and Wales into the State of New York has been of minor importance in recent years. In 1910, there were only 193,359 of these foreign born people in New York State, constituting 7.1 per cent. of the foreign born and only 2.2 per cent. of the total white population of the state.

GERMANS

The Germans constitute a very much larger group of the foreign stock in this state. In 1910, there were 436,874 German born persons, constituting 16.0 per cent. of the foreign born whites and 4.9 per cent. of the total white population.

In this group, the males show up much worse than do the females. The longevity of males, as measured by the life tables at age 10, is fully three and one-half years less than that of native males of native parentage; while the German born females have an expectation only one and one-half years less than that of females of native stock. With the exception of tuberculosis, German born men and women have higher death rates than the native born for all important causes of death. The so-called degenerative diseases play a very important part in their high mortality. Heart disease and Bright's disease both show excessive rates among males and females. Cancer is also much



higher among them than in the native population. Suicide is also an important element, although not shown in the chart. The mortality characteristics of the German born living in New York State recall similar facts for the native population of Germany, but to an exaggerated degree. The mortality rates of Germans living in their native country have shown remarkable improvement during the decades prior to the war and were among the most favorable in Europe. German males living in New York State showed an expectation of life almost two years less at age 10 and considerably higher death rates for the principal causes than are found for the Germans in their own country.

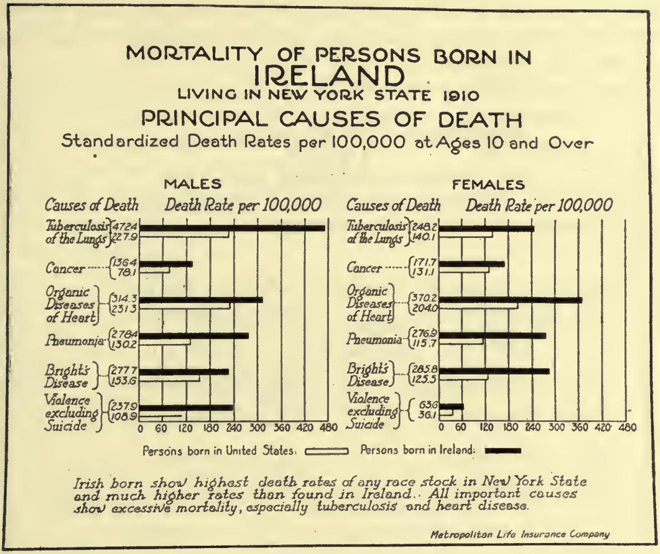
Irish

The Irish living in New York State present a very serious situation from the standpoint of longevity. They form an important part of the population, representing in 1910, 13.5 of the total foreign born and 4.1 per cent. of the total white population of the state. The high point in the immigration of this race was reached long ago, so that today we must consider not only those who were born abroad but their native born children as well. The Irish stock in New York State in 1910, thus considered, comprised 12.2 per cent. of the total white population in 1910.

A very high death rate is coupled with the numerical importance of this race. The effect on the mortality condition of the entire population is, therefore, considerable. As shown in Chart 1, the longevity as measured by the expectation of both Irish born males and females is least of any of the foreign stocks listed. Striking excesses of mortality exist. Thus, Irish males at the age period 25 to 44 have a death rate of 18.5 per thousand, or nearly three times that for native males of native parentage (6.9 per thousand). Irish born females at the same age period show a rate of 12.0 per thousand, much less than for Irish males, but nearly twice that of native females of native parentage. Taking all ages 10 and over together and with due regard to the differences of age distribution, we find that the standardized death rates for both Irish males and females are about twice that for natives of native parentage.

The following chart shows that these results follow from an excessive mortality from every principal cause of death, but especially so from tuberculosis, pneumonia, and violence:

It is difficult to understand these facts in view of the rather favorable mortality condition of the Irish in their own country. The figures for those living in New York State are not far from twice as high as those reported by the Registrar General of Ireland for the more important age periods of life. The factors which produce these differences will repay further study.



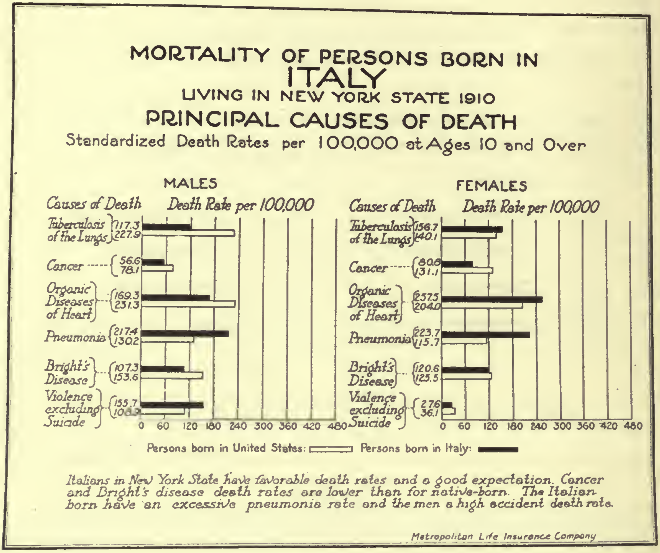
Italians

The Italians have very favorable death rates in New York State and enjoy a good expectation. In this respect, the Italian born males show up relatively better than do the females. Among the males, we observe especially low rates for tuberculosis, cancer, heart disease and Bright's disease. On the other hand, they have higher death rates from pneumonia and violence, both of which may well reflect the hazards peculiar to their occupations.

Italian born females, unlike the males, have relatively high death rates from tuberculosis of the lungs and organic heart disease. Like the males, they have high pneumonia rates. The figures indicate that the conditions of life in New York State are not particularly favorable for Italian women in spite of a good endowment of bodily vigor.

It is important to note that in spite of the marked change in the environmental conditions in New York State as compared with their native country, which, for the large majority of the Italian immigrants is the warm south, the Italian born live longer and suffer less from most serious diseases in their new abode than in their home country.

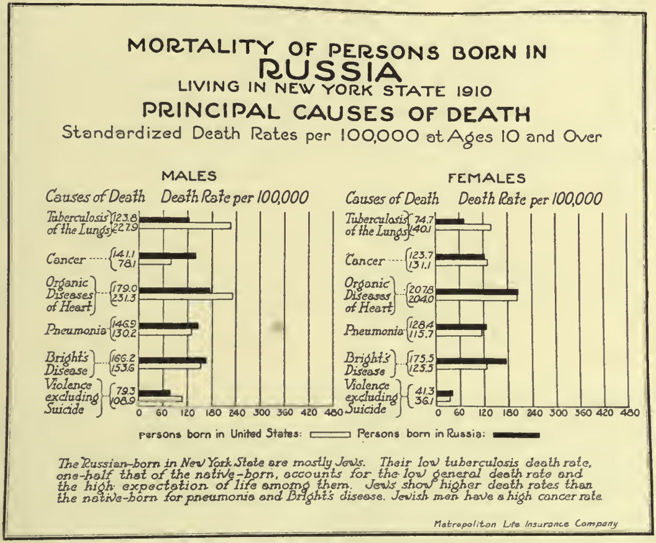
According to the 1910 census, the number of persons of Italian birth in New York State was 472,192. This was 17.3 per cent. of the foreign born whites and 5.3 per cent. of the total white population. This number is large in view of the recent date at which the Italian immigration began. A steady stream of this nativity may be expected to come to the United States. Their addition to the population from the point of view of longevity involves little, if any, loss to the total population.



Russians

The Russian born living in New York State form the largest group among the foreign stocks studied. In 1910, there were 558,952, or 20.5 per cent. of the total foreign born and 6.2 per cent. of the total white population. Although no absolutely trustworthy figures are available, it is obvious that in New York State, the Russian born are, for the most part, Jews, and it is this fact that explains the very low death rate and greater longevity which the Russian born enjoy. As shown in Chart 1, both males and females of this race have an expectation as good as the native born of native parentage; in fact, the males are slightly better than the native stock. The full significance of this fact appears when we consider the very favorable conditions of life of this people in their new environment. They are, for the most part, relatively newcomers and, many of them are still suffering from the difficulties arising out of poor housing and of bad economic status incidental to a period of adjustment in a new country. This fact again bears out what is generally known—that the Jews as a people have extraordinary vigor.

As shown in Chart 6, these Russian born in New York State have very much lower death rates from pulmonary tuberculosis than is found among the native born. In the age period 25 to 44, for example, males show a tuberculosis death rate of 117.1 per 100,000, as compared with 352 among natives. Females, likewise, at this same age period, show a tuberculosis death rate a little more than one-half that of native born females. It is this favorable condition as to tuberculosis which almost by itself explains the favorable mortality which is observed in this race. On the other hand, Bright's disease is higher among these people, especially in the later age periods. Likewise cancer has an excessive death rate among males. The low death rate from violent causes points to the absence of hazard in the occupations engaged in by them.



The Russian-born in New York State are mostly Jews. Their low tuberculosis death rate, one-half that of the native-born, accounts for the low general death rate and the high expectation of life among them. Jews show higher death rates than the native-born for pneumonia and Bright's disease. Jewish men have a high cancer rate.

Summary and Conclusion

We may, therefore, conclude that:

1. The several races that make up the foreign born population of New York are variable as to their natural vigor as measured by their mortality rates or by life tables.

2. With the exception of the Russians, who are, for the most part, Jews, the expectation of life of the foreign born is less than for the native born of native parentage.

3. Of the foreign born, Russians have the best expectation followed in order by the Italians, the English, Scotch and Welsh, the Germans, and the Irish. The last have a particularly low expectation.

4. With the exception of the Russians and Italians, the mortality

is higher among these races living in New York State than in their native country.

5. This condition may be due to the difficulties of adjustment to new conditions of life; or to the poorer quality of the immigrants as compared with their own people who stay at home, or to a combination of both these factors.

THE PROGRESS OF SCIENCE[1]

THE TORONTO MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

As guests of the University of Toronto and the Royal Canadian Institute, the American Association for the Advancement of Science holds its seventy-fourth meeting at the University of Toronto from December 27 to 31. Meeting with the various sections of the association and in many cases joining in their programs are twenty-five associated societies.

The association is American, its field covering North, Central and South America, but it has never met south of the United States. Its last meeting in Canada was at Toronto twenty-two years ago. Previous meetings had been held in Montreal in 1857 and 1882.

Professor Eliakim Hastings Moore, head of the department of mathematics at the University of Chicago, will preside at the general sessions. Dr. L. O. Howard, chief of the Bureau of Entomology of the U. S. Department of Agriculture, will deliver the address of the retiring president on the evening of the first day, his title being, (a) "On some presidential addresses; (b) "The War on the Insects."

At the joint invitation of the American Association and the American Society of Zoologists, Dr. William Bateson, director of the John Innes Horticultural Institution, England, will attend the meetings and

[1] Edited by Watson Davis, Science Service.

MAIN BUILDING, UNIVERSITY OF TORONTO

CONVOCATION HALL, UNIVERSITY OF TORONTO

HART HOUSE

will make his principal address before a general session on "The Evolutionary Faith and Modern Doubt."

Another address before a general session of the American Association will be delivered by Sir Adam Beck, chairman of the Hydro-electric Commission of Ontario, his subject being "Hydro-electric Developments in Ontario," illustrated by motion pictures. Sir Adam Beck's address will be under the auspices of Section M (Engineering) which has on its program other papers on engineering progress in Canada, including oil developments in the far north, mining operations in eastern Canada and problems of railway engineering.

Among the symposia, most of them arranged jointly by a section of the American Association and related societies, are: Insects as disseminators of plant diseases, origin of variations, utility of the species concept, orthogenesis, The quantum theory, Frost resistance and winter killing of plants, Synoptic weather charts, Cooperation of Canada and the United States in the field of agriculture, Crop zones, The structure of the atom, The child: Its health and development.

In addition to the scientific and technical programs, entertainments and social features have been arranged by the local committee, including a reception at the Royal Ontario Museum, which contains some of the finest scientific collections on the continent, an informal conversazione in Hart House, also boxing, wrestling, fencing, basket-ball, gymnastics, group games, diving, swimming, band music and bag-pipe music, water polo and indoor baseball in Hart House, an exhibition of artistic skating and an ice hockey match, and a showing of popular educational motion pictures on various subjects. An exhibition of new apparatus for scientific research and new scientific products will be held in the university's exhibition hall.

The facilities and entertainment offered the American Association by the University of Toronto and the Royal Canadian Institute promise to be a great factor in the success of the meeting. The University of Toronto compares favorably in size and equipment with the leading American universities. Hart House, the social and recreational center of the university, contains assembly halls, libraries, a complete gymnasium, dining halls and a well-equipped theater.

The Royal Canadian Institute, Canada's oldest scientific society, is made up of professional, scientific and business men interested in scientific progress. Jointly with the University of Toronto, this organization has made the arrangements for the meeting.

Several Canadian scientific societies will join with the American Association in its meeting, among them being the Royal Astronomical Society of Canada. The societies associated with the American Association which will join in the Toronto meeting are: The American Mathematical Society, The Mathematical Association of America, The American Physical Society, The American Meteorological Society, The American Society of Zoologists, The Entomological Society of America, The American Association of Economic Entomologists, The Botanical Society of America, The American Phytopathological Society, The American Society of Naturalists, The Ecological Society of America, The American Microscopical Society, The American Nature-Study Society, The American Metric Association, The Society of American Foresters, The American Society for Horticultural Science, The Association of Official Seed Analysts, The Society of Sigma Xi, The Gamma Alpha Graduate Scientific Fraternity, and the Phi Kappa Phi Fraternity.

THE AMERICAN ORNITHOLOGISTS' UNION

Ornithologists of the country gathered at Philadelphia from November 8 to 11 to attend the thirty-ninth annual meeting of the American Ornithologists' Union. Forty papers and eighteen reels of motion pictures were presented during the meeting and bird naturalists from as far away as Holland, England and the Pacific coast were in attendance.

A large number of papers were about South American and tropical birds, ranging in habitat from Panama to Patagonia. Bird banding in its various phases was considered in other papers and there was the usual quota of technical papers on bird names, life habits and history.

The union recorded a net gain of 264 members added to a membership which already at the beginning of the meeting numbered 1,350.

Four American Ornithologists were given the highest honor that can be conferred upon them by their fellow workers when they were elected to fellowship in the union. The number of fellows is limited to fifty, and with these four elections only one vacancy remains. Those honored were: Dr. W. H. Bergtold, an ornithologist and practicing physician of Denver, Colorado; Major Allan Brooks, of Okanagan, British Columbia; James P. Chapin, American Museum of Natural History, New York City, and Dr. Glover M. Allen, Boston Society of Natural History.

Five members, the grade of membership next lower than fellow, were elected as follows: S. Prentiss Baldwin, expert on banding birds, Cleveland, Ohio; George L. Fordyce, treasurer of the Wilson Ornithological Club, Youngstown, Ohio; F. C. Lincoln, Biological Survey, Washington, D. C.; C. H. Rogers, Princeton University, and Dr. Casey A. Wood, Chicago.

The entire quota of twenty-five honorary fellows from foreign lands was filled for the first time since 1890 by the election of five foreign ornithologists. Fourteen corresponding fellows, all foreign, were also elected.

Memorial addresses on three fellows who died during the past year were delivered. The deceased fellows are: Dr. J. A. Allen, American Museum of Natural History, New York City; Charles B. Cory, Field Museum, Chicago, Illinois, and William Palmer, U. S. National Museum, Washington, D. C.

The Brewster Memorial Medal was awarded to Robert Ridgway, of the U. S. National Museum, for his work on the "Birds of North and Middle America," vol. 8, which in the judgment of the council was the most meritorious work on American birds published during the last two years. This medal is to be awarded biennially, and this is the first award.

A feature of the annual banquet was the appearance in costume of representatives of Alexander Wilson, John James Audubon, and C. S. Rainesque, pioneer bird lovers who lived in Philadelphia in the early half of the nineteenth century.

The following were elected officers: Dr. Witmer Stone, Academy of Natural Sciences, Philadelphia, *president;* Dr. George Bird Grinnell, New York City, and Dr. Jonathan Dwight, New York City, *vice presidents;* Dr. T. S. Palmer, Biological Survey, Washington, D. C., *secretary;* and W. L. McAtee, Biological Survey, *treasurer.*

SUSPENSION OF GOVERNMENT SCIENTIFIC PERIODICALS

Important scientific periodicals of the Department of Agriculture have suspended publication owing to the failure of the Congress to give specific authority for their continuance after December 1, the date set by law for the death of all government periodicals not individually authorized by the Congress.

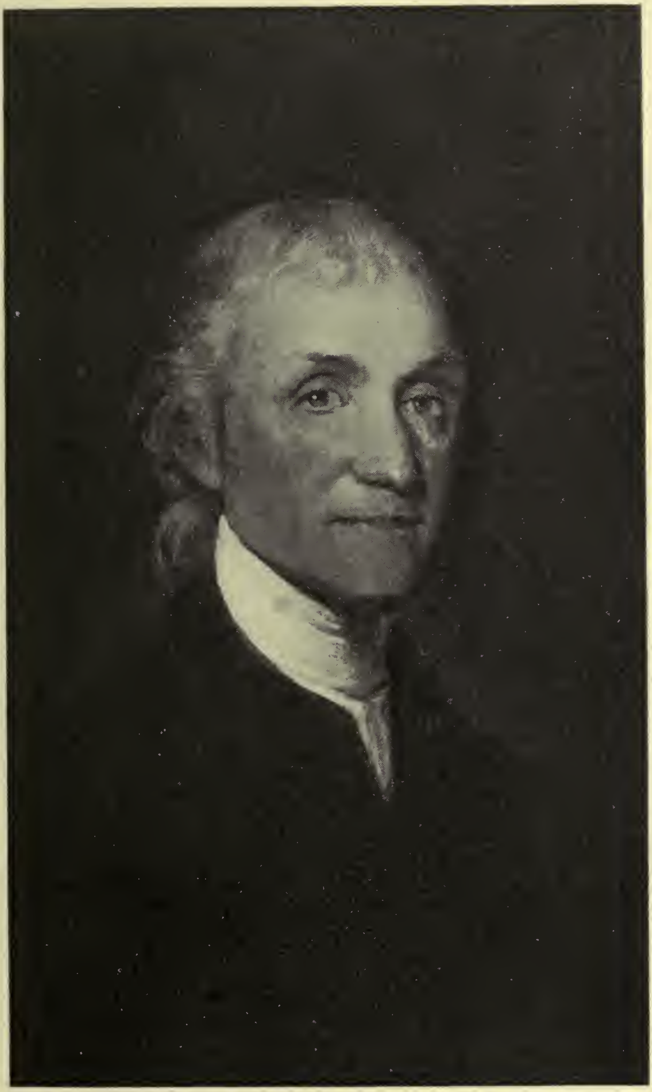
When the Congress adjourned without giving any committee authority to determine which periodicals should continue to appear, some forty-one publications issued by the government departments suspended publication, in most cases without any notice.

From a scientific standpoint, of those that are suspended, four Department of Agriculture publications are the most important. *The Experiment Station Record,* with its concisely written abstracts of agricultural literature, knitted together the research activities of the universities and agricultural experiment stations. *The Journal of Agricultural Research* was the medium for making public those researches that as yet would hardly be of general interest to the practical farmer. But in this journal have been announced some of the most important experimental work of the department and affiliated experiment stations. Meteorology in all its phases was the field of the *Monthly Weather Review,* edited from the Weather Bureau. *Public Roads* had a circulation of 4,000 copies a month and carried details and research of the federal aid program to engineers and road builders.

Four other Department of Agriculture periodicals were doing a real service. *The Weekly News Letter,* circulation 126,000, kept the 106,000 collaborators and employees of the department in touch with its activities and served to take current information to those especially interested in agriculture. Weather data were carried promptly to 3,300 by the weekly *National Weather and Crop Bulletin.* The weekly *Market Reporter* was published to give 11,200 bankers, colleges, economists and others prompt data on live stock, grain, produce and other agricultural prices. The *Monthly Crop Reporter,* with an edition of 114,500, was sent to libraries and organizations interested in agricultural estimates, but the bulk of the edition went to collaborators of the department who aid in compiling crop statistics.

By suspending the forty-one government periodicals, it has been estimated that from $500,000 to

JOSEPH LEIDY
Statue erected in the Medical School of the University of Pennsylvania in honor of the distinguished naturalist and anatomist



JOSEPH PRIESTLEY
Photograph from the copy of the portrait by Gilbert Stuart, recently presented to the United States National Museum by the American Chemical Society

$1,000,000 will be saved each year, but this may be mistaken economy. It is not inconceivable that even the temporary suspension of the periodicals mentioned may cause a much greater loss to the country than the saving on the forty-one periodicals.

The inability to publish the results of important government researches is becoming a serious situation, even apart from the suspension of the scientific periodicals. Printing appropriations of practically all government scientific bureaus have been greatly reduced, and only the manuscripts that are most important can be published, and these often after undue delay.

SCIENTIFIC ITEMS

We record with regret the death of Bert Holmes Hite, professor of agricultural chemistry in the University of West Virginia; of William Speirs Bruce, oceanographer and polar explorer; of Etienne Boutroux, professor of philosophy at the Sorbonne; of Dimitri Konstantinovitch Tschernoff of Petrograd, known for his work on the metallography of iron; of Ch. François-Franck, formerly lecturer on physiology at the Collège de France; and of Julius Hann, Austrian meteorologist.

Elimination of industrial waste was the principal topic discussed at the forty-second annual meeting of the American Society of Mechanical Engineers held in New York City from December 5 to 9. Separate sessions were held to consider the wastes of power generation, machine shops, railways, use of fuel, materials handling, textile manufacture, wood manufacture, and the aeronautic industry. A national program of industrial education and training as a fundamental necessity in the development of the industries of this country also had a place on the program. Honorary membership was awarded to Henry R. Towne, directing head of the Yale and Towne Manufacturing Co., and Nathaniel G. Herreshoff, who has played a large part in the development of the science of naval architecture both through his interest in yacht racing and his work on commercial and war vessels.

The relation of chemical engineering to national defense was the leading topic of the fourteenth annual meeting of the American Institute of Chemical Engineers held in Baltimore, December 6 to 9. Visits were made to Edgewood Arsenal and to various Baltimore industries.

THE SCIENTIFIC MONTHLY

FEBRUARY, 1922

GROWTH IN LIVING AND NON-LIVING SYSTEMS

By Professor RALPH S. LILLIE
THE NELA RESEARCH LABORATORY, CLEVELAND, OHIO

GROWTH has perhaps a better claim than any other life-process to be called "fundamental," since it is the indispensable basis or condition of all vitality. This is true not merely in the obvious sense that all organisms are products of growth; even when an animal or plant has ceased to "grow," *i. e.,* add to its total living or organized material, it continues automatically to renew its own substance and to repair losses and damage; without this continual renewal no life can persist. We may thus regard the adult organism as still "growing," but the growth is "latent"—masked by the simultaneous loss inseparable from all vital activity. Visible increase in size is thus not the only evidence of growth; whether an organism grows visibly or not is in fact determined by the relative rates of two opposed processes, one of which builds up and accumulates, while the other breaks down and dissipates. In all life the primary or fundamental process is the building-up of the specifically organized living substance by constructive metabolism; but this process is always accompanied by chemical breakdown or destructive metabolism, with loss of material to the surroundings. Briefly, therefore, we may describe the essential situation as follows: when metabolic construction exceeds destruction there is "growth" (in the ordinary sense of visible increase); when the two are equal there is balance, or simple maintenance; when destruction predominates there is regression or atrophy. Visible growth represents simply the accumulated excess of construction over destruction.

This constant association of destruction and repair has long been recognized as the essential or distinguishing peculiarity of the living state; while the organism "lives," the effects of loss or destruction are continually being offset or compensated (often over-compensated) by new construction. The life process is thus fundamentally a process of construction; it is a synthetic or creative agency; and all of its special peculiarities as a natural process are expressions of this characteristic power of specific synthesis. Claude Bernard has given perhaps the clearest and most comprehensive expression of this fundamental fact, which was already perceived by Lavoisier and in a vague way appreciated even in ancient times (*cf.* Heracleitus). The following passage is characteristic:[1]

> The synthetic act by which the organism maintains itself is at bottom of the same nature as that by which it repairs itself when it has undergone mutilation, or again by which it multiplies and reproduces itself. Organic synthesis, generation, regeneration, reintegration, healing of wounds (cicatrization) are different aspects of an identical phenomenon. . . .

Bernard's characterization is well known; "la vie, c'est la création;" he thus emphasizes the all-importance of construction or synthesis in the vital process.

Living material, then, is primarily *growing* material. In higher organisms this is sufficiently obvious in early development; later it becomes less and less evident because of the progressive increase of the destructive processes—relatively to the constructive—in the total metabolism. It is clear, however, that without the continuance of the synthetic processes which determine growth there can be no continued life at any stage. Growth therefore must be regarded as the universal index of the presence of life. We recognize this in the case of lower organisms like bacteria; and test their "livingness" by determining if they are capable of growth; if there is no proliferation in the culture medium the culture is a sterile one; either no organism were introduced, or those introduced were "dead."

Most multicellular animals and plants reach their final or adult stages through a process of progressively increasing size and complexity, beginning usually with a small and structurally simple germ (*e. g.* egg-cell); we describe this germ as "developing into" or "growing into" the adult form. This verbal usage expresses incidentally the necessary dependance of reproduction on growth. The growth involved in a single reproduction is often very extensive; thus the ratio between the mass of an adult human being and that of the fertilized egg-cell from which he develops is approximately fifteen billion to one;[2] this enormous accumulation of material occurs in each reproduction. There may, however, be reproduction without simultaneous growth (certain cases of fission) as

[1] Leçons sur les phénomènes de la vie, Vol. 2, p. 517.

[2] *I. e.*, the ratio of the mass of an individual of 60 kilo to the mass of an ovum of 200_{μ} diameter (volume about .000004 c.c.).

well as growth without reproduction, and it is important to realize clearly the general nature of the organic processes which these terms represent. This may best be done by considering the case of micro-organisms; here the two processes are less sharply distinguishable and the terms are often used synonymously; thus bacterial growth and bacterial reproduction are usually regarded as identical. In such cases, reproduction simply follows automatically and regularly upon growth, so that the two are not practically separable; the one involves the other. Reproduction has been defined as "discontinuous growth," and this phrase expresses a conception which seems to be universally applicable. The essential fact in every case of reproduction is that portions of the growing organism continue to grow after detachment from the parental stock, and in so doing give rise to other complete organisms of the same kind. Reproduction of higher plants by cuttings is a case in point and in animals asexual reproduction and regeneration of the whole from a fragment afford similar instances. From such cases the logical transition to cases of gametic reproduction is simple; in this case the detached portion is a specialized unicellular structure (egg-cell) requiring fertilization in order to start its cycle of growth; but it represents none the less a detached portion of the parental organism.

What we observe in the case of higher animals is that when we trace the organic individual back to its beginning—or at least to the stage usually regarded as the beginning of individual life—we come finally to a small often microscopic mass of protoplasm, usually a single cell (germ-cell) which itself is the product of growth from the parent organism. In this germ we see little or nothing of the characteristic organization of the adult. Yet it is by the progressive accumulation and transformation—through the activity of this at first minute portion of living substance—of materials taken from the surroundings that the adult organism is by degrees built up.

Let us now consider briefly, from the point of view of general physiology, the essential nature of this process of growth or upbuilding, which we call individual development or ontogeny.

The germ adds to its substance, or *grows,* by incorporation of non-living materials taken either from the surroundings or from its own reserves (yolk),—food, water, salts; these it transforms physically and chemically in a definite manner which is specific for each organism. The most remarkable chemical feature of this transformation is the predominance of certain complex syntheses, especially the synthesis of colloidal substances of high molecular weight and highly specific or individualized chemical constitution.

These are the proteins, which are regarded by most biologists as forming the basis of organic specificity. Part of these substances, together with certain other products of the metabolic transformation, are chemically stable under the conditions prevailing in the living system, and are laid down in definite situations and at definite times in the form of a more or less solid, resistant or permanent residuum or deposit which forms the structural substratum of the growing organism. And since the rate of these synthetic or constructive processes exceeds that of the accompanying destructive processes, especially in the early stages of development, the living and organized material steadily accumulates; in other words, the organism grows. The rate of growth is not uniform in different regions; usually certain regions proliferate actively at certain times; then, as their growth activity subsides, other regions become active; the existence of growing zones or growing apices (buds or shoots in plants) is in fact one of the most characteristic features of developing organisms. All of this growth proceeds in an orderly and definite manner, in regular sequence and with strict correlation between the rates of growth in the different regions. Eventually the whole system acquires a more or less permanent form and dimensions, corresponding to the adult state; after this stage is reached the constructive processes gradually become less and less active, and eventually they fail to offset the destructive processes. Natural death then follows.

As the germ or embryo grows it "differentiates," *i. e.*, becomes by degrees more and more diversified, structurally, chemically, and physiologically. Different regions are set apart as the seat of special formative processes which give rise to special morphological structure with corresponding special physiological activity, and by degrees the systems of organs so clearly distinguishable in the adult make their appearance. The development of correlating or integrative mechanisms goes hand in hand with this differentiation. It is customary to regard differentiation as a process distinct from growth, since its essential feature is the appearance of new qualitative characters, both structural and functional, *i. e.*, of diversification; while the term growth has a primarily quantitative significance and has reference to increase in size, considered as such. Differentiation in embryonic development is perhaps the most impressive and mysterious of all organic processes, and its apparently purposive character has long furnished the vitalists with their strongest arguments. In the multicellular organisms it appears to have acquired a special physiological basis or determinative mechanism which has become superposed on that of simple growth—as we find it in unicellular organisms where cells give rise typically only to other cells of the same kind. Apparently some additional factors, which impart definite and special directions to the formative processes in different cell-groups, are present in the higher organisms; and the evidence from genetic and cytological studies indicates that this special basis for differentiation is to be found in the specific differences between the chromosomes of the germ-cells. In some way, depending apparently on the manner in which the elementary chemical components of these structures are sorted or distributed in the series of mitotic cell-divisions, special kinds of structure-forming metabolism are localized in definite regions of the developing embryo.

The "chromosome theory of heredity" has performed notable services and is probably true, even if it is not the whole truth. But it should not be overlooked that growth and heredity, in their most general aspects, must be independent of special mechanisms of this kind. Specific growth and its manifestation in heredity are the final or visible expressions of the property of specific metabolic construction, which is based on specific chemical synthesis and is possessed by all forms of living matter—we may even say by all living structures which preserve their identity during the life of the cell or organism of which they form part. The chromosomes themselves grow and reproduce, and this capacity can hardly be referred to the existence of sub-chromosomes; in this respect chromosomes are like all other living structures. This, however, need not prevent their having a special function as repositories and distributors of substances which control the special nature of the structure-forming metabolism in different parts of the organism.

While in higher organisms growth and differentiation, considered abstractly, may be regarded as two distinct processes, in reality the two are inseparable, and on a strictly objective view these terms must be regarded as denoting two aspects of a single complex process rather than two essentially different processes. "Growth" is usually given a quantitative definition, as signifying increase in the quantity or mass of the living material; thus we may express the growth of an embryo in mass-units or weights and draw curves showing correctly, within certain ascertainable limits of error, the rate of growth from day to day. But while this growth is proceeding it is in fact associated with increase of complexity, with the continual appearance of new qualities and activities in the organism. These features of the total organic process differ from growth in not being representable in simple quantitative terms and in requiring special methods of description; yet they are all *based* upon growth. Such considerations illustrate the sense in which the growth-process is fundamental or foundational in all life-processes. Obviously without its occurrence the adult organism could never arise from the minute "undifferentiated" egg-cell. Whatever the special nature of the formative activities may be, it is at least clear that they must have material to work on, and this material is furnished by growth.

Increase in the quantity of organized or living material is simple growth, and proceeds automatically in all forms of protoplasm under favorable conditions. Increase in structural or organizational complexity is usual when growth is associated with *development*—as in higher organisms—but is not always present; thus we do not usually conceive of development as occurring in dividing bacteria or yeast cells. In the lowest organisms the result of growth is the formation of more and more living material of the same kind, simple and "undifferentiated," structurally and physiologically. For example, there is no progressive increase of complexity during the growth of bacteria in a culture medium—except in so far as this is necessarily involved in any quantitative increase; more and more protoplasm of the same kind, definite and specific in structure and activity, is built up from the environmental materials by a strictly repetitive kind of process. We may note here, as a matter of general or philosophical interest, that it is simply because the same series of transformations is repeated in each bacterium as it grows and divides that we conceive of the process of reproduction as involving "heredity." The daughter-cell repeats the life-cycle and hence the qualities and activities of the parent-cell. If we wish, we may express this fact by saying that it "inherits" its qualities from its parent; but this terminology need not confuse our conceptions of what really and objectively occurs. In higher organisms we have the same type of situation, except that a more complex cycle of metabolic and formative transformation is repeated in each reproduction. In either case the *constancy* of the metabolic syntheses which underlie the growth-processes forming the new living material is what makes possible the constancy of the outcome in the growth and development of the individual organism, whether this organism be a bacterium or a human being.

In many animals evidence of differentiation is seen early in development, *i. e.,* before the germ has proceeded far in its growth. Even uncleaved eggs show partial differentiation in many cases. In the vertebrate embryo the various systems of organs, nervous, skeletal, digestive, circulatory, are distinguishable soon after the germ layers are formed; these embryonic foundations, once established and partly individualized, continue to grow and soon exhibit secondary differentiations; their functional activity and interdependence increase at the same time. Each organ system is often described as if it developed independently by inherent potencies of its own; but this is merely an accident of descriptive procedure, where the whole is often disregarded in considering the details. In reality no organ system or other part develops in isolation. The growth and development of the organism as a whole is marvellously balanced and correlated; a system of checks and controls prevents the excessive growth of one region at the expense of another. The shape and proportions of the embryo at each stage of development are as constant as they are in the adult; and a similar constancy must characterize the underlying physiological processes. The problem of the physiological conditions determining the correlation of growth processes in organisms has many aspects of fundamental interest. It includes the special problem of the nature of transmissive processes in protoplasm (nervous and related transmissions), as well as the broader biological problem of the unification or integration of the various organic processes of the individual. The unity of the formative processes represents a special feature of organic unity in general, and cannot be considered apart from other cases of functional integration. Development is perhaps the most striking example of an organic activity which is at the same time highly complex and highly integrated.

The final or adult stage of even the highest animals is attained with a constancy and exactitude which never fail to arouse our wonder. We cannot trace the causal sequence in any detail and may never be able to do so. And yet when we consider the matter more closely, and especially when we observe the degree to which exactitude—constancy of repetition—is inherent in all natural processes (as the achievements of physics and astronomy show perhaps most clearly), it ceases to be a matter of special surprise that organic processes like growth and development should exhibit a similar regularity. If, as physiology assumes, the organism is a synthesis of simpler physical and chemical processes, its activities should partake of the regularity of the component processes. In fact, a similar quantitative regularity becomes apparent whenever single organic activities are isolated and presented to observation in a form suitable for measurement. Accordingly, with constancy of initial constitution and constancy of environing conditions we should expect a living germ, like any other natural growing system, to exhibit constancy in its cycle of development. That it does show such constancy is the very fact which we designate as "heredity." Many years ago Professor C. O. Whitman gave clear and striking expression to this thought in the following words: "Germ-cells behave alike in development, not because anything is transmitted to them, but because they represent identical material and constitution and are exposed to essentially like environmental conditions.'' And with respect to the exactitude of development he says: ''We easily forget that only physical processes can approach such exactness.''[3] We may safely assume that given a germ of a definite constitution and normal environmental conditions, a ''spiritus rector'' is as little needed to guide development along a constant course to a definite or predetermined end as to guide the course of the planets about the sun. Constancy in the initial constitution of the germ, and in the environmental conditions implies constancy in the sequence of physical and chemical transformations which form the basis of growth and development.

Although the developing organism is a highly unified or integrated system, yet many facts, especially those of tissue culture and certain departments of experimental embryology, show that the cells forming each system of organs have an independent power of growth; when they are isolated in sterile plasma and supplied with oxygen they will continue to proliferate and give rise to other cells of the same kind. An isolated part of an embryo will undergo differentiation; or if it is transferred from its normal position in the embryo to a distant region in the same or another embryo (as in grafting experiments) it will continue, for a time at least, with its usual development and differentiation. Such facts illustrate again the specific nature of the formative processes or powers of growth innate in each form of protoplasm; when it grows it gives rise to other protoplasm of the same kind, similarly constituted structurally and with a similar chemical organization and similar physiological activities. We have evidence, in the existence of specific cytolysins, of the chemical differentiation of the different tissue-proteins of the same animal, just as we have evidence of specific chemical differences between the corresponding proteins of different animals. While our most delicate means of discriminating between different native proteins are the biological tests, especially those of anaphylaxis and precipitin-formation, which do not give us direct information of chemical constitution, yet we cannot doubt that the structural proteins of each species of cell have specific or highly individualized peculiarities of composition and configuration; and that these peculiarities are related in a definite manner to the specific structural and physiological peculiarities of the cell. Reichert has shown that the hæmoglobins from different animals have specific crystallographic peculiarities; *i. e.*, in separating from solution they form aggregates of specific form and structure. No doubt the same process occurs in the case of

3 See Vol. 2, pp. 179, 180, of Whitman's posthumous Studies on Inheritance in Pigeons (Carnegie Institution, 1918, edited by O. Riddle).

the other cell-proteins as they are deposited during growth to form the protoplasmic structures characteristic of the species; if this is the case, the specific morphological or histological features of a given cell must depend ultimately upon the specific features of chemical structure and configuration possessed by the cell-proteins. The toxic effects of foreign proteins upon cell-structure, as seen (*e. g.*) in specific hæmolytic effects, are an indication of the incompatibility of such compounds with the normal cell-structure of the species.

In all cases the cell-proteins, like the majority of cell-constituents other than salts and water, are synthesized within the cell by the processes of specific constructive metabolism from materials furnished by the surroundings. Since in general every chemical compound, when it is deposited in solid form from a solution, forms a definite type of structure, seen in constancy of crystal form, it is to be expected that in living protoplasm the formation and deposition of chemical compounds with specific chemical characters will involve the origination of specific structure, and secondarily of specific physiological activities corresponding to that structure.

In general any solid material with a specific chemical composition must possess a specific physical structure. This conclusion is not merely a generalized inference from the facts of crystal-formation, special texture or other properties of solids, but has been brilliantly substantiated by the methods of X-ray analysis of crystal structure recently developed in England by W. H. and W. L. Bragg. And we may infer that the special features of the new structure formed in any growing system, whether living or non-living, will have a similar dependence on the chemical composition of the structural material.

The study of the structure and properties of growing inorganic systems, especially as related to the chemical composition of their components, may thus be expected to throw some light upon the more general features of the growth-process in organisms. Such systems may be regarded as elementary or generalized models of organic growth. Organic growth is peculiar in the complexity of its materials, conditions and outcome; it gives rise to the highest products of synthesis found in nature; but in other respects it shows various definite affinities with certain types of inorganic growth. It may be of interest, therefore, to consider briefly some results of a study which I have recently made of certain inorganic growth-models, and their bearing on some of the more general problems of organic growth.[4] In particular the conditions determining the structural specificity of these inorganic growths, and

[4] *Biological Bulletin*, 1917, Vol. 33, p. 135, and 1919, Vol. 36, p. 225.

the manner in which they are influenced by external conditions (electricity, contact, temperature, presence of foreign chemical substances), show certain resemblances to organic growth which seem to throw light on some of the more fundamental features and conditions of the latter.

It is well to realize that growth processes are by no means confined to living organisms, but are to be found everywhere in nature—in other words that organic growth is a special example of a universally distributed type of natural process. Hence the analysis of what growth is, in its more general and simpler aspects, must be a matter of great interest to all biologists. The more special problem of the nature and conditions of organic growth, as distinguished from other forms of growth, is likely to become more open to successful attack if the simpler cases are considered first.

By the term growth, as applied to ordinary physical objects, we usually mean simple increase in the quantity of some material forming a more or less definite system or aggregate; the system thus increases in size while retaining its special distinguishing properties or identity. Simple accretional growth are instances, *e. g.,* avalanches, stalactites, deltas, crystals. In the case of organic growth something additional and highly characteristic is involved. Growth is not the result of simple accumulation of materials already existing as such in the environment of the growing system; but the added material is chiefly of a kind not found in non-living nature and formed within the system itself through the specific chemical transformation of material taken from the surroundings. New chemical compounds are created in new and characteristic structural and other relationships. Part of the material thus synthesized, especially the protein and lipoid part, is built up to form the living and organized substratum of the growing cell or organism.

Such considerations show (incidentally) that the conception of organic development prevailing at one time, of an unfolding, increasing, or becoming evident of something already in existence or latent in the germ, is no longer a tenable one. The creation or new appearance of *novelty* seems to be an essential fact in most if not all natural occurrence; and this is notably the case in organic growth. To a modern biologist the epigenetic conception of development is the only one possible; new characters arise at each ontogenetic stage in correlation with the formation of new chemical compounds in new physical combinations.

In the case of inorganic growth, therefore, we should expect to find the closest resemblances to organic growth in those growing systems where growth is dependent on the chemical transformation of material incorporated from the surroundings, followed by deposition of the more permanent reaction-products within the growing system. It is well known how a crystal in a supersaturated solution increases in size while retaining definite form; the packing or mutual apposition of molecules similar in their shape and size and with their axes parallel explains the regularity in the structure of the whole resulting system; similarly an ice-crystal in subcooled water forms the center of deposition for further ice-crystals. In both of these cases material taken from the surroundings is transformed and deposited to build up a definite solid structure, but the transformation is physical rather than chemical. On the other hand in such examples of inorganic growth as the extension of a rust spot on a sheet of iron immersed in water, or the formation of "lead trees," the new material is formed by chemical transformation.

Inorganic growths dependent on such "germ-actions" often closely simulate organic forms; the frost patterns on window panes are a beautiful example; in this case the ice crystals are formed in apposition to one another and an apical growth results. The hexagonal crystal system of water is favorable to the formation of delicately branching arrangements; the characteristic "twinning," well seen in snow-flakes, also contributes to this result. The already formed crystal structure determines the formation of further crystalline deposit of the same kind, the apices or projecting angles of the structure forming the regions of most rapid deposition. In this manner long rows of crystal structure with lateral branches are built up by the opposition of new crystals at the extremities of the crystal-pattern already laid down. The resemblance to plant-growth depends on this peculiarity; a terminal or apical habit of growth is common to growing stems, leaves, roots and other plant organs, and determines the final structure of the whole system.

In the formation of tin-trees or lead-trees the form adopted by the growing system depends on a similar apical process of deposition, but in this case special electro-chemical factors enter. When a piece of zinc is placed in a solution of a lead salt, the zinc dissolves as Zn ions, and metallic lead separates out simultaneously; by continuation of this process there is built up by degrees a characteristic tree-like or branching structure. Each portion of lead as it is deposited forms a cathode in the zinc-lead couple; and hence more and more lead is separated from solution by a process of local electrolysis. The new metal is deposited in crystalline form and most rapidly at the apical regions, hence the deposit extends in a branching manner. A similar tendency to a branching or arborescent form of deposit is not infrequent in the electrolytic separation of metals at cathodes.

Closer analogies to organic growths are seen in the precipitation-structures formed from metals immersed in solutions of salts whose anions form insoluble compounds with the metals; structures are built up of a tubular or quasi-cellular structure with semi-permeable membranes for walls; and the resemblance both in appearance and conditions of formation to certain types of plant growth is in many respects surprisingly close. These structures are related to those investigated by Leduc and Herrera, and formed by introducing crystals or solutions of alkali-earth and heavy metal salts into solutions which form precipitation-membranes with the introduced salt. The growths obtained by placing copper sulphate in ferrocyanide solutions are good examples. Leduc's book, "the Mechanism of Life," gives a fascinating account of these phenomena. The growths formed from metals are, however, peculiar in the fact that the structure-forming precipitate is deposited as the result of local electrolysis at the metallic surface; the presence of this electric factor thus renders these inorganic growths amenable to electric control (acceleration, retardation, directive influence), and this feature gives them an additional interest as models of organic growth-processes.

The methods of producing these growths are very simple. When a piece of iron wire is placed in a solution of potassium ferricyanide (2 to 4 per cent.), containing some egg-white or gelatine to act as protective colloid and a little sodium chloride, delicate blue-green vesicles and tubules of ferrous ferricyanide are quickly formed; the tubules grow out rapidly into the solution, and within half an hour or less the whole wire is covered with a dense filamentous growth resembling blue-green algae. Iron is an especially favorable metal for such experiments, apparently because of the presence of numerous local electric couples between different areas of the metallic surface, and filaments several centimeters long are readily obtained. These often exhibit delicate and regular cross-striations and other appearances suggestive of organic structure. If instead of iron the related metals, cobalt and nickel, are used, a different type of growth is obtained, coarser and more vesicular in structure and with finer tubules; many of the latter follow a characteristic tortuous or zig-zag course. To produce rapid growth with these metals it is necessary to accelerate the reaction by the contact of a nobler metal, *e. g.*, copper or platinum; a copper wire wound about one end of a strip of nickel (or cobalt) greatly promotes the growth of precipitation-structures. This effect, which may be regarded as a kind of catalytic action, depends on the formation of a local couple, the nickel becoming anode and hence sending ions more rapidly into the solution; the accelerating influence of the copper is perceptible for some centimeters from the contact. Zinc and cadmium, another pair of closely related metals, also readily form highly characteristic vesicles and tubules, which frequently give rise to compound structures of quite remarkable beauty and symmetry, especially with zinc. Here also the contact of a nobler metal is necessary for rapid growth; the same effect may be produced by carbon, *e. g.*, by marking the strip of zinc with lead pencil. In all such experiments the growth is most rapid near the catalyzing metal or carbon, and a gradient in rate of growth is seen extending for several centimeters from the contact. Copper wires in contact with carbon or platinum also produce characteristic growths. Each metal in fact forms a definite type of precipitation-structure, having morphological characters which are specific for that metal; and it is interesting to note that the structures formed from closely related metals, *e. g.*, zinc and cadmium, or cobalt and nickel, resemble each other more closely in certain characteristic structural details (*e. g.*, the zig-zag tubules of cobalt and nickel) than when the chemical relationship is more distant. Something analogous to family resemblance is seen in such cases. In organisms also morphological similarity and chemical similarity are closely associated.

The resemblances between organic growths and precipitation-growths are of a general rather than particular kind, and too much emphasis should not be laid on superficial points of agreement. Yet when we consider the broad features of the transformative activity in the two cases and its fundamental determining and controlling conditions, certain identities appear which indicate that organic growth processes are largely conditioned by general factors of the same kind as those present in the above inorganic systems. In both cases the specific features of growth are referable to the specific peculiarities in the chemical composition of the structural material. We find that in the precipitation-growths a slight variation in chemical composition, *e. g.*, the substitution of cadmium for zinc, makes a definite change in the kind of structure developed; similarly it is possible that in organic growth a slight variation in the chemical composition of a structural protein, such as the substitution of one amino acid for another in the chain, may modify definitely the physical or other properties of the newly formed structure. One might suggest that the appearance of a sudden variation or mutation in an organism is the result of a chemical change of this kind. The formation of a new compound in formative metabolism may thus mean the appearance of a new structural and physiological character.[5]

But it is with respect to the problem of correlation, of the mutual influence exerted upon one another by growing parts of the same organism, that the metallic model shows perhaps its most striking resemblances to the growing and developing organism. We describe this phenomenon in organisms by saying, for example, that the growth of one region *inhibits* the growth of another, usually adjoining, region. Why it should do so is the problem. Why should a single blastomere of the 2-cell stage give rise to a half organism when the other blastomere develops by its side, but a whole organism when it develops in isolation? Or a plant bud begin growing only after an adjacent growing bud is removed or ceases active growth? Evidently some physiological influence of a repressive or inhibitory kind is exerted through a distance, and in at least some cases this influence can be shown to be independent of direct transfer of material between the two regions concerned. Such facts suggest that this type of control, like other forms of chemical control at a distance, may be electrical in nature. Is it possible that the bioelectric currents, always present in living organisms, influence the chemical processes underlying organic growth? Currents arising in association with the metabolic processes in a rapidly growing region might then control growth processes at a distance from this region, just as the electric currents in the iron-zinc-ferricyanide system control the formation of precipitation-tubules by one metal at a distance from the other.

The inhibiting influence exerted by an actively growing part of an organism upon the growth of adjacent parts is a phenomenon of too general occurrence to be referred to special conditions peculiar to any one organism or group of organisms. Its basis is apparently some physiological condition common to all organisms. The transport of growth-inhibiting substances is clearly not the condition in such well-known effects as the prevention of the growth of axillary buds in seedlings by the growth of the terminal bud. Recent experiments have shown that we can prevent the inhibitory influence from passing by conditions that do not interfere with the transport of material along the stem.[6] If the inhibitory influence is not due to transport, to what is it due?

[5] If closely related species can be distinguished by precipitin or anaphylaxis tests, it is probable that mutants can similarly be distinguished from their parent organisms, although apparently no experiments of this kind have been tried. Leo Loeb finds evidence that there even exists a chemical differential between individuals of the same species (*cf. Amer. Naturalist,* 1920(Vol. 54, pp. 45, 55).

[6] *Cf.* Child and Bellamy, *Science,* 1919, Vol. 50, p. 362; *Botan. Gazette,* 1920, Vol. 70, p. 249; E. N. Harvey, *Amer. Naturalist,* 1920, Vol. 54, p. 362.

We cannot answer this question fully at present, but it is perhaps sufficient to point out that the fundamental problem involved is the general problem of the transmission of physiological influence in living protoplasm. Through what means does a physiological process occurring at one region affect processes at other regions? If we leave out of consideration the numerous instances where the mechanism of physiological correlation is evidently of a transportative kind, as seen in the effects of the various growth-determining hormones (thyroid, pituitary, ovary, etc.,) or of the hormones determining glandular secretion or rate of respiration, we have remaining a large class of effects highly characteristic of living matter in all of its forms, namely, those transmissions of local states of activity or excitation known generally as protoplasmic transmissions. Sherrington points out that in higher animals there exist two chief methods by which the various chemical and physiological activities are integrated or made to work in harmony, namely (1) integration by transport of chemical substances (usually special metabolic products) from region to region, chiefly in the blood stream, and (2) integration by transmission of physiological influence, excitatory and inhibitory, to a distance through the living protoplasm without material transport between the regions; the chief example of this type of process is nervous transmission. The nervous system is the chief integrating and coordinating system in higher animals; nervous transmission, however, is merely a specialized form of a type of transmission present everywhere in protoplasm. If the metabolic processes underlying (*e. g.*) muscular contraction can be thus controlled at a distance, it is not difficult to believe that those underlying growth can be similarly controlled. This mode of influence has been called physiological distance-action, after the analogy of chemical distance-action, and our problem is to determine its physico-chemical nature. One of its most characteristic manifestations is seen in the transmission of growth-inhibiting and other formative and correlating influence in growing and developing organisms.

For our purpose the most instructive instances are those in which the growth of one region controls that of an adjoining region. How can a growing bud on a piece of stem in a Bryophyllum prevent the growth of roots or shoots on an attached leaf,[7] or one growing axis inhibit another in the blastodisc of a Fundulus egg,[8] unless there is transfer of inhibiting substances from the actively growing to the inhibited area? or unless the actively growing region appropriates all of the available nutriment? Yet both of

[7] J. Loeb, *Botan. Gazette*, 1915, Vol. 60, p. 253.

[8] C. R. Stockard, *Amer. Journ. Anatomy*, 1921, Vol. 28, p. 115.

these modes of explanation are apparently inapplicable in many cases. The only general physical conception which seems to me to throw some light on this and related problems is the one which regards physiological distance-action as a special case of the phenomenon called by Ostwald "chemical distance-action," and well known to all students of electrochemistry. By this term is meant the influence which the chemical reaction at one electrode-area of a circuit exerts upon those at the other electrode-area. This influence has a reciprocal character, dependent ultimately on the fact that the flow of electricity around the circuit is in one direction; hence oxidation at one electrode is associated with the reverse process, reduction, at the other. According to Faraday's law the rates of the two opposite electrochemical reactions must be equal, hence variation in the one involves a corresponding variation in the other. The above precipitation-growths from metals furnish many striking examples of this influence; the contact of a piece of zinc with an iron wire immersed in a ferricyanide solution prevents the outgrowth of precipitation-filaments from the iron, even at a distance of several centimeters from the contact; at the same time their formation from the zinc is promoted. In this case it is not possible to assume that inhibitory substances are derived from the zinc, where growth of filaments is rapid, and transported to the iron. Yet there is a definite influence, exerted through a distance, which inhibits the outgrowth of precipitation-filaments from the iron so long as they are being rapidly formed from the zinc. This influence is electrical and depends simply on the passage of the electric current around the circuit constituted by the two metals and the salt solution. Metallic zinc in contact with the solution is electrically negative or anodic; the zinc ions given off to the solution form the precipitate of zinc ferricyanide which builds up the filaments. The iron is cathodic, *i. e.*, the positive current is in the direction from solution to metal, thus preventing the passage of iron ions into solution; hence no precipitate forms. If, however, we sever the iron wire from metallic connection with the zinc, *e. g.*, by cutting off its projecting extremity, the isolated portion at once develops filaments. The compensating or inhibiting condition is removed when the electrical circuit between the two metals is broken.

In cases of regeneration in animals or plants the removal of a portion of the organism frequently initiates an extensive process of growth and development at the cut surface. We may infer therefore that many stationary or quiescent regions of the organism are capable of active growth or proliferation, but do not manifest this power until they are removed from the influence of other regions. Is it possible that in such cases what prevents growth is the passage of electric currents between regions of different growth-activity, the more active regions—which are those of greater metabolic or synthetic activity—inhibiting the less active through the currents associated with their growth?

There are many facts which point in this direction. Hermann and Müller-Hettlingen found that in seedlings the regions near the actively growing zones—terminal buds or root-tips—were negative relatively to those near the cotyledons;[9] regenerating hydranth heads are negative to the stems;[10] the growing zones in planarians and annelids are negative to intermediate regions.[11] Further studies in this field are desirable, but all of the evidence now available agrees in indicating that regions where growth and cell-division are active are in general negative to inactive regions—negative, that is, in the same sense as the stimulated region of a muscle or nerve is negative to the unstimulated. The regions where the positive stream of the bioelectric circuit enters the living system from the surrounding medium are the regions of most active growth; those where it leaves are the quiescent or less active regions. The physiological or metabolic asymmetry is associated with an electrical assymmetry or potential difference. Such actively growing regions, in addition to their electro-negativity, show in general a higher oxygen-consumption and carbon-dioxide output and a greater susceptibility to poisons than less active regions. A connection between the metabolic processes underlying growth and the bioelectric currents is thus indicated. In plants removal of oxygen has been shown to abolish these currents, a fact indicating that oxidation-processes are concerned in their production.

If the bioelectric currents have a direct influence on growth, we should expect that electric currents led into the growing systems from outside sources would have a similar influence. Regions where the positive stream enters the growing system from the surroundings should be favorably influenced in their growth, since such regions correspond to the "negative" regions in the bioelectric circuits of growing organisms; these regions, as just shown, are those of most rapid growth. Recently it has been found by Lund that regeneration of new polyps from the cut stems of the hydroid Obelia may be experimentally controlled by weak electric currents passing lengthwise through the stem; the formation of hydranths is promoted where the current passes so as to enter the stem, *i. e.*, at the cut end facing the anode, and inhibited at the

[9] *Pflüger's Archiv.*, 1883, Vol. 31, p. 193.

[10] A. P. Mathews, *Amer. Journ. Physiol.*, 1903, Vol. 8, p. 294.

[11] *Cf.* C. M. Child, *Biol. Bulletin*, 1921, Vol. 41, p. 90.

other end. A polar influence on formative processes, corresponding to that on stimulation processes, is thus shown.[12] These interesting observations agree with those of the Indian investigator, Bose, who finds that the electric current influences growth-movements in higher plants in a polar manner, the anode enhancing and the cathode depressing the normal rate;[13] and also with the recent experiments of Sven Ingvar in the Yale laboratory, which have shown that weak constant currents exert a directive influence on the outgrowth of the processes from embryonic nerve cells; here also a polar influence is seen, the processes growing toward the anode being morphologically different from those growing toward the cathode.[14]

If the growth processes in living organisms are thus subject to artificial electrical control, it seems reasonable to infer that the natural or physiological methods of control in normal growth and development are also in large part electrical. The bioelectric currents would thus become essential formative factors, just as they are essential factors in excitation and transmission; organic polarity, as Mathews suggested, would become electrical polarity. This, however, would again be referred to chemical polarity, since we must assume that the bioelectric currents, like the currents in metallic couples or other current-yielding systems (where the energy of the current is derived from chemical reactions at surfaces) are the expression or accompaniment of chemical processes in the living system. The metabolic processes underlying growth are of complex and largely unanalyzed nature, but we know that they are typically associated with the consumption of oxygen and include specific syntheses by which the new structure-forming compounds are built up. Can we then say that the chief method of construction of such compounds is electro-synthesis? Such a characterization may not in itself add much to our knowledge, but it suggests directions in which research may be profitable. It implies, especially, that the basis of all such effects, like the basis of other manifestations of irritability, is to be sought in the conditions determining the electrical sensitivity of living matter, one of its most fundamental characteristics. This in turn is almost certainly conditioned by the polyphasic and film-pervaded structure of the protoplasmic system.[15]

12 E. J. Lund, *Journ. Exper. Zoology,* 1921, Vol. 34, p. 471.

13 J. C. Bose, *Proc. Roy. Soc.,* B. 1918, Vol. 90, p. 364

14 S. Ingvar, *Proc. Soc. Exper. Biol. and Medicine,* N. Y., 1920, Vol. 17, p. 198.

15 *Cf.* my discussion of the basis of protoplasmic irritability and transmission in THE SCIENTIFIC MONTHLY, 1919, Vol. 8, pp. 457 and 552.

MENTAL AND PHYSICAL EFFECTS OF FRESH AIR

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BILL NYE'S History of the United States shows two drawings which compare the Indian women of fancy with the Indian women of fact. It is a pity that Nye did not think of cartooning the ventilation of fancy and the ventilation of fact. After the customary school instruction plus a deep draught of tradition we were caught unawares by a recent article in THE SCIENTIFIC MONTHLY asserting that human life could continue in the same room with oxygen-consuming plants. Perhaps some one will yet have the temerity to assert that the nostrils were made smaller than the mouth to prevent the breathing of all out-of-doors at one gasp, thus suffocating ourselves with too much fresh air. Is fresh air really essential? Are mental and physical prosperity greatest in 100 per cent. fresh air? Is it open air that human nature craves or is the primeval association of open air?

What is man's attitude toward the open air, as shown in the history of the race? Back somewhere in the time when man dwelt in the "well ventilated arboreal tenements" of the tree tops, some individuals, finding more to interest them on the ground, moved down from their leafy heights, and learned to walk upright. Beset, however, by countless enemies, he was compelled to seek some shelter, and so began the life in caves which has persisted ever since. Deserting the forests for more open country, man found his original covering of hair inadequate, and betook himself to clothing, the second step in the complete enclosure of his body.

Officially, man was a troglodyte, or cave dweller, up to a recent era in his history. As an actual, but unadmitted, fact, he is one yet. The ancient cliff-dwellers in their caves, and the more modern Moqui in his pueblo, are not so very different from the up-to-date apartment-house denizen, or shall we say, inmate. It does seem as though man for ages past had thriven in a completely enclosed state. Even in the matter of clothing to this day we go about protected to the utmost, the only exceptions being the rags of poverty and vice versa.

Ventilation has been for eons either unknown or unheeded. In most cases entirely different considerations have fixed the construction of the buildings in which humans pass a great part of their time. In northern lands, for defense against cold, the Eskimos build their igloos, and the Lapps their huts, with one undersized door as the only opening. Many other examples are familiar. Ventilation as we know it, is truly a modern notion. In 1660, Sir Christopher Wren devised a crude system of ventilation for the Parliament Buildings in London, seemingly the first official recognition of the idea; but the spread of the idea has taken many years. In fact, those of us who have visited the halls of our own congress, will agree that those halls are to this day ventilated solely by the newspapers. The old four-poster bed, with its heavy canopy and impermeable curtains, is a commonplace of a day not far gone. It is but yesterday since we kept our windows shut at night, for fear of some poisonous "miasma" in the night air.

The modern preference for open windows, open-air schools and so on is due to one or the other of the following causes; either the desired sensation of being different from our fathers and mothers or the realization of some actual benefit to be derived from the new order of things. Let us see, then, what sort of opinions are actually held about the conditions which fix the desirability of the kind of air with which we surround ourselves.

Mr. Ellsworth Huntington, in a 1915 publication of the Yale University Press, says:

> To-day a certain peculiar type of climate prevails wherever civilization is high. In the past, the same type seems to have prevailed wherever a great civilization arose. Therefore, such a climate seems to be a necessary condition of great progress.

The foregoing, part of an attempt to show the part played by climate in human development, is unfortunate, for a moment's thought will show that while each particular civilization may have its peculiar climate, these respective climates differed more widely than the civilizations they represented. Ancient Egypt, a country of great heat and dryness, is rated as a civilization, along with ancient Greece, with its temperate climate and adequate rainfall. A high civilization arose in Rome and along the warm, sunny slopes of Italy, but this fact proves nothing against the greatness of fog-visited Britain. In New York City, a more or less active hive of human effort, both extremes and all possible means of climate are experienced from one day to the next!

It is an acknowledged fact that warm air makes us sleepy. It is equally undisputed that we find it difficult to sleep on a warm night. When we suffer from certain ailments, our doctors, recommending a change of climate, send us to Colorado, Arizona, or some place with an equally dry atmosphere. Yet we have authorities who regard dry air with dread. Watt, in 1910, wrote as follows:

> Insanity grows on those who live in hot, dry air, do exasperating work, and feel abused. . . . Men are breaking down in business by too much attention to it, they think. The real trouble is, they are conducting their business in hot, dry rooms during the cold months of the year.

The same writer gives dryness as a cause of the falling-off in church attendance. It is to be hoped that the increased "dryness" to which the country is being subjected, will have the opposite effect. We are used to regarding dampness of air or climate as an unhealthful condition, but dryness seems to be just as bad, in the opinion of many. Early writers went to great extremes in both directions, attributing to air conditions all sorts of things, "from the color of a man's skin and the contour of his face, to the prevalence of religious ideas, and the (supposed) fact that more twins are born in Egypt than elsewhere," to quote from Stecher, in "The Effect of Humidity on General Efficiency."

Popular opinion is an excellent way to give permanence to prejudice. Bliss claims that so thoroughly has the fresh-air taken hold of many, that neither facts nor figures to the contrary are of the slightest interest. A remarkable example of this is found in the description of an experiment made in 1913-14 by D. C. Bliss, superintendent of schools of Montclair, N. J. He says:

> A surprising feature of the whole experiment with the open-window classes is the attitude of the parents. Almost without exception they are convinced that their own children benefited greatly by the plan. This conviction is so positive that it is not affected in the least by the statistics of the classes.

These statistics, which showed a slight balance against the open-window classes, will be referred to later.

Many of us, then, believe that for health, atmospheric conditions should be thus and so. Clearly, however, a consideration of opinion from all sources shows about half of us in favor of "thus," and the rest of us firm believers in "so." In other words, public opinion, the strongest of forces in a discussion like this, is at the same time the least reliable. With the two camps of believers arranged back to back, it is at least possible that one is in the right, but opinion itself furnishes no safe ground for judgment. That opinion will often unconsciously pervert fact to serve its own ends was rather amusingly shown by press and other comments on an address recently made by the writer before the International Conference of Women Physicians. The newspaper writers took just enough actual words from the address to make some humorous reading which had no especial connection with the speaker's meaning. A telegram was received from an association in a small city, asking for a statement of the speaker's true position. He replied that he was in favor of rightly controlled open-air schools *for experimental purposes.* The secretary of the association wrote back, much pleased with the speaker's "implied permission to quote you as favoring a rightly controlled open-air school." Using the same words, nearly, but with a vast difference in meaning, this little episode illustrates perfectly what might be called "auto-interpretation."

Since children are probably more sensitive to environmental conditions perhaps the best way to study the effects of fresh air *versus* various degrees of non-fresh air is to investigate experience and experiments with open-air, open-window, and otherwise fresh-air schools. The first open-air school was opened in the woods at Charlottenburg, a suburb of Berlin, and soon spread all over Germany. Not long afterward, the first English open-air school was opened at Bostall Wood, near London. Then came the Bradford School, since which many others have been established in England. The first open-air school in the United States was at Providence, R. I.; we now have them all over the United States. There are some in Boston; there is one on the roof of the Horace Mann School at Teachers' College, Columbia University; there are some on abandoned New York City ferry boats. There are specially endowed schools of this open-air type in Chicago. Hence comes the argument that the schools must be satisfactory, because they have spread so rapidly.

Secondly, we have no record of a single open-air school which has been abandoned; another argument worth noting.

Third, every account, except one, gives most glowing descriptions of the success of this work.

Fourth, children gain rapidly in weight. Here is a sample from one of the open-air schools. In two and one half months the children in this school gained 3.6 pounds on the average, whereas the children in the ordinary schools gained but one pound on the average.

The fifth proof is that the open-air schools have considerable therapeutic value. Here are some figures from some of the German schools. Of thirty-four children who were anemic, after being in the open-air schools for some time, one case was aggravated, nine were unchanged, eleven were improved and thirteen cured. Of 38 cases of scrofula, none was aggravated, eight were unchanged, 22 were improved and eight cured. Of 14 cases of heart-disease, none was aggravated, seven unchanged, seven improved and none cured. Of 21 cases of pulmonary disease, one was aggravated, eight were unchanged, eight were improved, and four were cured. This makes a total of 107 children that were studied; of which number but two were aggravated, 32 were unchanged, 38 improved and 25 cured.

Next, there comes the claim from England and Germany that education is twice as efficient, in the sense that the pupils spend but half their time on regular school work, and still keep up with their corresponding grades in the ordinary schools.

A number of other claims are made, such as increased happiness of the children; improvement in attendance; and one statement is made that truthfulness rose several degrees!

A critical inspection of these claims reveals that they are largely claims and nothing more. They may be true, they may not be true. Open-air schools are such a radical departure that their very novelty appeals to radicals and enthusiasts. This alone might account for the rapid spread of the idea.

The claim that education in open-air schools is twice as efficient does not appear to have been checked by objective tests. Subjective estimates of mental changes are known to be extremely unreliable, particularly when made by interested though honest individuals.

The increase in attendance recorded for the open-air schools, it must be said, took place entirely during those months of the year when the weather is at its best. This is typical of most of the arguments advanced; they are not checked against certain other possible explanations of the results besides the presence of fresh air.

Here is a typical day for the pupils in the ordinary school, which may be compared with the typical day of the open-air school scholars. In the ordinary school, the pupils spend all their time during the best part of the day, that is, from nine to twelve o'clock and from one o'clock to three, in the classroom. The medical, dental and optical care they receive from the school authorities is inadequate to put it as charitably as possible, and they receive little other attention aside from their regular lessons. Here is the program of the open-air school for a day. Reports state that the enthusiastic cooperation of the best dentists, physicians and oculists in town is readily secured, so that the children are constantly receiving better attention than they would in their own homes. At eight a. m., an hour before the ordinary schools begin, the open-air pupils are served with hot soup, bread and butter. After every half-hour, they have vigorous exercise. At ten a. m. they have two glasses of milk, bread and butter. At 12:30 they have a good dinner, followed by sleep. At 4 p. m. there is milk, rye bread and jam. At 7 p. m.—notice how late—the pupils are given a good supper, and sent home. Of course, the regular lessons are given in the intervals between the items noted above. The program outlined is actually followed in many schools, and all adhere to a similar schedule in greater or less degree.

We find in one of the glowing descriptions of these schools the following unintentional admission—quoted exactly:

"There is unanimous agreement that if children are to be benefited by open air, they must be well-fed." This statement is typical of the weak points in the arguments thus far given: Is it fresh air that produces the results, or is it superior feeding and physical care; and would it be possible to produce the same effect in the ordinary schools, by an equally increased care? The arguments do not tell us.

What light do carefully-controlled researches throw upon this whole question? Experimental results tend to show that mental activity, obviously one of the main factors in education, is not readily subject to outside influences. Poffenberger, administering strychnine in moderate doses, noted that no effect was produced on the mental powers of his subjects. Hollingworth reached the same conclusion with regard to caffein in the proportions found in coffee and certain other beverages. Results are not yet available from the national experiment conducted to discover the effect of reducing the national percentage of alcohol to 2.75. On the whole, mentality appears to be a peculiarly well insulated function. The writer after years as a teacher, has found the insulation impenetrable in many cases.

But there are experiments dealing with open-air directly. A study was made by Norsworthy, Hillegas, McCall and others at the Horace Mann School, New York City. On the roof of the building were constructed two classrooms, each having its southern side completely open, and large windows in its other sides and roof. Provision was made to shield books and blackboard from the direct glare of the sun, but otherwise the children were exposed to sunshine and air. The southern exposure could be closed off by a canvas cover during a driving rain. A playground was provided on the adjoining roof.

The open-air test was begun with a third grade and a fourth grade class. After the first year a fifth grade class was held in a room in the building below, this room having its windows open wide at all times. There were throughout the test several control classes in ordinary indoor classrooms, for purposes of comparison. The test continued through the four school years from 1912 to 1916. Psychological tests were made in each December and May by Norsworthy and Hillegas. At the same time, Dr. H. B. Keyes gave each child a thorough physical examination. There were eight of the psychological tests given each time. The scores of these tests were summarized into a combined score for the four years. This result showed a small, but real, balance in favor of the open-air classes. This was also true for the physical tests for the first year, those for the other three years not being available. We must accept these results, however, with proper caution, because of the possibility that other factors than those tested were responsible for the result. The children who made up the open-air group were selected from those having physical or nervous weaknesses or tendencies. There were extra lunches and frequent outdoor play; these were denied the indoor classes, which might have had them about as well as the outdoor pupils. In any case, we must be careful about comparing the performances of more or less incomparable groups.

Consider now the experiment conducted by D. C. Bliss, superintendent of schools of Montclair, N. J., to determine the possible advantage of open-window classes. In this experiment, the same types of children were selected for both open-window and control classes. One class each from the second, third and fifth grades, were selected for the open-window group, each grade being located in a different building, and each checked by a control class of the same grade and size in the same building but under indoor conditions. During the cold months, the open-window groups were well wrapped, and protected against strong drafts, though their classrooms were maintained at a temperature of 50 degrees Fahrenheit. During the experiment, the open-window pupils were provided with light forenoon lunches at the parents' expense.

The tests measured three items: degree of nutrition, measured by fluctuations in weight; general health, indicated by attendance; and mental condition, shown by simple tests given twice each day.

A summary of Bliss's results shows no difference between the open-window and control groups in the psychological tests, and a small, but notable superiority in health for the control groups. In the previous year, an experiment had been made in which the open-window class was unprovided with the special lunch, and the room-temperature allowed to go as low as it would. Under these conditions, the health of the open-window classes showed up even less favorably.

Whatever our previous idea, then, the contradictory results of the two experiments cited should give us pause. More information is evidently needed. To this end, we ought to note the interesting and expertly directed experiment made by the New York State Commission on Ventilation, to determine the effect on mental work, of recirculated air versus plenty of fresh air. The Board of Education of New York City permitted the commission to fit up especially for the test a couple of rooms in a school building that was in the course of erection. Hence the desired air conditions could be perfectly maintained. In one room, ventilating ducts provided a continuous influx of fresh air, the used air being drawn out. In the other room, the used air was drawn out, washed, and sent back again, so that the greater part of the air in the second room was used over and over. Only enough fresh air was introduced to prevent noticeable odor. The washing took out the dust, and probably the germs and some, at least, of the carbon-dioxide. Even so the CO_2 content of the air in the recirculating room was always much higher than in the fresh-air room, occasionally rising to twice as much. In both rooms, the purity of the air and the steam used by the heating-plant were constantly noted. A standard comfortable temperature of 68° and humidity of 50 per cent. were maintained in both the experimental and control rooms.

The experiment lasted from February to June of one year, and to make conclusions doubly reliable was repeated during the following school year. An unusually elaborate series of educational, psychological and physical measurements were made. The directors of these experiments were national authorities in their respective fields of education, psychology, medicine, physiology, sanitation, physics and engineering. No technique that these scientists could devise was omitted. Every effort was made to make the conclusion from these experiments final. What was the conclusion? The results from all the educational and psychological measurements when carefully summarized, showed roughly two per cent. greater progress and achievement for the pupils who were in the partly fresh air. The results from the medical measurements substantially agreed with those from the mental measurements, and the second experiment agreed with the first.

In addition to having no demonstrable deleterious mental or physical effects, the recirculation plan required only half the coal for heating that was needed for the fresh-air room. This enormous saving, widely applied, would buy for children many things of known mental and physical worth.

Glancing back over the propaganda for and against open-air schools we are tempted to paraphrase Pinckney: "Millions for defense but not one cent for" . . . . *the truth.* There has never been a really valid experiment to show whether open-air schools are desirable or undesirable. It is undoubtedly true that anemic pupils in open-air schools have more rapidly improved in weight, health, hemoglobin and the like, but the thinnest readers of this article have a good chance of growing fat and hemogloby on the sanitary and feeding schedule of the best open-air schools! Personally we are inclined to favor open-air schools, not for the surplus of fresh air but because that seems to be the only way to secure for a few pupils a scientific attention which should be the privilege of all pupils. But such a policy is altogether too much like the Chinaman who burned his house to roast his pig.

Not even the admirable experiments of the New York State Commission on Ventilation tell us whether open-air schools are or are not advisable. Open- air schools usually bring sunshine to their pupils as well as fresh air. Furthermore the Ventilation Commission's experiments used typical pupils as subjects. Though it does not appear probable, it may be that anemic and diseased pupils prosper better on fresh air than normal pupils. But as matters now stand undiluted fresh air for children is on the defensive. The only trustworthy experiments to date have gone against absolute fresh air. Verily we are by nature Cave Dwellers still!

PROGRESS OF PUBLIC HEALTH WORK

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PUBLIC health work is as old as history. Among the ancients a part of it was purposeful; a part without intention,—both were valuable in the preservation of mankind.

The Egyptians filtered the muddy water of the Nile which rendered it potable, and in a measure prevented the spread of disease. Their custom of mummifying the dead by keeping them in brine for seventy days, then drying and placing them in tombs in the hills above the over-flow of the Nile was not without sanitary significance. They had rules concerning meat inspection, bathing, clothing, diet, and care of infants. Joseph's Well near the pyramid of Gizeh was excavated through solid rock for 297 feet, and is an excellent example of their efforts to obtain pure water.

The ruins of antiquity show that large reservoirs were common in ancient times. It is well known that the Chinese, for thousands of years, have used alum as a coagulant in the clarification of muddy water. The inhabitants of India, over 4,000 years ago, knew, "It is good to keep water in copper vessels, to expose it to sunlight, and to filter it through charcoal."

The Hebrews were the founders of public health work. Their methods were influenced by the practices of the nations that lived in the valleys of the Tigris and Euphrates, and probably by Persia. The Apostle Luke, a physician, says, "Moses was learned in all the wisdom of the Egyptians." The Hebrews obtained excellent results in wholesome living by making hygiene a part of their religion. The high priests were sanitary police. Their mandates covered diet, the touching of unclean objects, prevention of contagious disease, isolation, disinfection, sanitary inspection, removal of nuisances, certain industrial practices, personal hygiene, and medical jurisprudence.

The teachings of the Greek philosophers and physicians contained principles which promoted the well-being of the people as a whole. The laws of Solon and Lycurgus were especially helpful in improving the health of the masses. The Spartan requirements for warriors, the Olympic games and the emphasis placed upon the winning of distinction in them, together with the prominence given to physical perfection in sculpture, art and literature inspired the youth to maintain a high degree of health.

The Romans were among the first of the ancients to provide methods for good ventilation of houses. Cremation, systems of drains and public baths were important contributions to sanitation and hygiene. The cloacae of the Romans were the forerunners of our sewerage systems. The great aqueducta, which brought fresh mountain water to Rome, played an important part in the prevention of epidemics. Their analogues are found today in the water supply of New York which has its source in the Catskills and is carried to the city by the Croton and Catskill aqueducts.

The Crusades, mis-rule, and innumerable wars prepared the soil and sowed the seed of the great epidemics in the middle ages which threatened man with extinction and gave the fatal thrust to tottering civilizations. Crowded conditions, the bad sanitation of the walled medieval towns, and gross immorality were the great predisposing factors. Gorton tells us that as late as the 16th century the English housewives swept the refuse from their dwellings into the streets. People seldom bathed or washed their clothes. Even eminent ecclesiastics swarmed with vermin. The garbage was emptied into unpaved streets and ground to mush when it rained. At nightfall shutters were opened and sewage poured into the streets.

The intellectuals of Rome, Alexandria and Constantinople were lost in a maze of theological controversy. Epidemics were regarded as a "visitation from God" inflicted alike upon the innocent and the guilty, to chasten a sinful world. As a result, no great effort was made to prevent them. Humanity escaped from the severe ravages of ergotism, scurvy, and influenza to be swept off by black death. Bubonic plague appeared in 1346 and killed sixty million people, over one-fourth of the earth's inhabitants. Plague visited London many times and would have depopulated it had not the people fled. Burning of the city killed the rats and reduced the plague. In 1495 syphilis appeared at the siege of Naples in epidemic form. In a few years, it had spread over the world,—a sad commentary on the morality of the time.

In the midst of the ravages of the plague, the first guardians of public health were appointed, and quarantine was attempted. It was tried in Venice and later extended to other Mediterranean ports, and to the North and Baltic seaboards. Health ordinances were promulgated and pest houses erected. During this period leprosy was at the height of its virulence and leprosaria were founded for the isolation of its victims. Each leper was compelled to carry a rattle, and to give notice of his presence by sounding an alarm. The crude quarantine of the middle ages became the modern procedure based on scientific knowledge; the scavenger and the nuisance inspector specially trained live again in the expert sanitarians of today.

Although measures for the prevention of nuisances and for the imposition of quarantine were adopted in colonial days, as far back as 1647, it was not until 1849 that the State authorities began to consider seriously their duties in connection with public health. In May of this year the Governor of Massachusetts appointed a commission under Lemuel Shattuck to ascertain the health needs of the commonwealth and to make recommendations.

The Shattuck commission advised the establishment of a central Board of Health charged with the general execution of the health laws of the State, the creation of local Boards of Health, the taking of a census of the people, and a systematic registration of marriages, births and deaths. It recommended an investigation into the cause of disease, abatement of the smoke nuisance, adoption of means for public health education, and other far-reaching measures. The report of the committee to the legislature was pigeonholed for twenty years, but in 1869, the State Board of Health of Massachusetts began work under a broad charter, which has been the model for other states. In 1877 Illinois became the second state to establish a Board of Health.

Permanent governmental health organizations in the country came into existence to combat repeated outbreaks of cholera, typhus and yellow fevers. They were created when disease was supposed to have its origin in filth; when sewer gas and foul odors were thought to be the cause of epidemics and night air to carry illness and death.

Sanitation

Under the influence of the filth theory of disease, the efforts of public health officials were concentrated on the abatement of nuisances by scavenging, by constructing sewers, and by building water-closets. They enforced measures to prevent overcrowding, to insure better housing, to promote ventilation, and to provide for a supply of safe milk and of unpolluted water. Such was the nature of public health work until the decade of the 80's, when the rapid, brilliant discoveries of bacteriology, showing the relation of microorganisms to diseases, gave to the world a different conception of the cause of contagion.

The "sewer-gas-foul-odor-night-air era" of public health work was one of considerable progress. In their vigorous attempts to eliminate "emanations which polluted the air," sanitarians made great contributions to comfort, common decency, and public health.

We know now the safe disposal of sewage and the provision of pure water supplies were great factors in the eradication of cholera, and in the reduction of typhoid fever and the "diarrheas." Less crowded living conditions and cleaner houses did much to decrease vermin and louse-borne typhus fever. General cleanliness may have slightly diminished the incidence of disease spread by the secretions from the nose and throat. It had little effect upon the occurrence of yellow fever.

While the pioneers in public health did much for comfort, convenience, and civic betterment, their erroneous conception as to the cause of disease has remained an unhappy legacy to succeeding generations. There are many today who fail to distinguish between filth, contaminated with disease germs, and unsightly rubbish, in itself incapable of causing illness. Believers in sewer gas are not entirely extinct even among the medical profession. Emphasis upon air as a carrier of disease kept down bed-room windows and delayed the building of sleeping-porches for several generations. Fear of air-borne disease still causes a great waste of formaldehyde gas in fumigation which is often more effective in the production of psychic calm than in the destruction of pathogenic bacteria.

In 1893 Smith and Kilbourne brought to the attention of the world the role of the tick in the spread of Texas fever in cattle. Within a few years the relation of the mosquito to malaria and yellow fever, of the rat and the flea to plague, of the tsetse fly to African sleeping-sickness, and of the louse to typhus fever were shown. These discoveries of insect transmission of disease were of as far-reaching importance to the world as those of Copernicus, Columbus, or of Edison. Ross, Reed, Nicolle, Kitasato, McCoy and others showed insects to be the center of a system around which revolved the great pestilences which have scourged the race from antiquity. They did not discover unknown continents, but they made it possible to create a new world within the tropics. The practical use of their researches made the Panama Canal possible, saved the South from yellow fever, reduced disease and increased progress wherever the flea, louse, or mosquito are to be found.

The knowledge of the relation of insects to disease intensified sanitation. Stagnant pools were drained or filled, swamps ditched, rain barrels screened, and tin-cans destroyed to eliminate the breeding places of the yellow fever and malaria producing mosquito. In screening against the mosquito, the danger from the fly was reduced. To prevent plague, the rat was destroyed along with his fleas, to the great saving of food stuffs. Domestic sanitation and personal hygiene made new progress, as it became generally known that typhus fever was carried by the louse.

Isolation

Following the demonstration that communicable disease was due to specific micro-organisms, over-emphasis on the environment as the origin of disease gave way to control of man in preventing it. Rules and laws for the isolation of patients and carriers were enacted. Enforcement of these regulations gave rise to compulsory notification of communicable disease and the establishment of laboratories to ascertain the presence or absence of the specific bacteria. The length of incubation, the period of communicability, and the manner in which the disease is transmitted became the factors determining the length and nature of quarantine.

A great deal was expected from thorough isolation. Much was accomplished, but careful observation soon revealed that complete eradication of disease by this method was not to be realized. Isolation with bacteriological control, in all probability, will eliminate typhoid, paratyphoid, and the dysenteries. It has kept cholera beyond the seaboard, and in connection with sanitation, has made typhus fever a comparatively negligible disease in this country.

The failure of the discovery of the cause of chickenpox, smallpox, measles, German measles, and scarlet fever make it impossible to obtain the results first expected from isolation, because of the inability to recognize all cases before they have become communicable, and to determine with certainty the exact period at which they cease to be infectious. For a similar reason mild cases and carriers are missed. Scarlet fever and infantile paralysis present typical forms which are frequently overlooked. Whooping cough and mumps are often transmissible before symptoms are sufficiently developed for diagnosis.

In dealing with sputum-borne disease, isolation is very helpful, but often ineffective. The epidemic of poliomyelitis of 1916 taught health officers their inability to suppress it. It was stopped by the falling temperature of autumn rather than by the will of applied science. Influenza swept the world in 1918 and burned out before means could be found to control it. Meningitis exacted a deadly toll in the armies of both Europe and America; measles, complicated by pneumonia, proved one of the most fatal of diseases to soldiers in cantonments.

Experience with isolation in the prevention of disease has shown that to be effective it must be early. The failure to isolate promptly the first patient cannot be off-set by the most rigid quarantine of subsequent cases. Isolation has probably done a great deal to eliminate virulent strains of many communicable diseases since they are usually quickly recognized. "Every case of tuberculosis isolated means an average of three less new infections."

Group Practice

For centuries medical practice has been individual. The patient sent for the doctor, was cared for by him, and paid the bill. As little was known concerning the cause, method of spread, or means of prevention of disease, the physician had little responsibility to the community beyond the observing of a crude quarantine and the giving of an opinion as to the relation of nuisances to illness. The rapid advances in biology, chemistry and preventive medicine have shown the social and economic aspects of disease, and are rapidly changing medicine from being paramountly personal to predominantly public.

If a child should have infantile paralysis in a community, the public would insist upon it receiving every consideration essential to comfort and an early recovery, but the people would want to be sure that the case was so managed that other children would not lose their lives or be crippled for life. The citizens of any city would be greatly interested in a single case of Asiatic cholera occuring in their midst because it might prove the match for an explosive epidemic that would effect the lives of thousands and turn millions in trade from the channels of business.

As a result of this public appreciation of the importance of disease, there have arisen numerous agencies endeavoring to prevent accidents and illness in particular groups of individuals. These organizations are rendering a fine service in the education of the public, in the improvement of health, and in civic betterment, but they greatly need to be correlated, and to be given responsibility commensurate with their relative importance. It is essential for them to become a unified force for health in order to secure a synchronous attack upon disease with the best available methods.

Maternal and Child Welfare

The United States loses one mother for every 154 births, the highest rate of the seventeen principal countries of the world. Over 23,000 women died in 1918 on the altar of maternity, at least 50 percent. a needless sacrifice to poverty, ignorance, and inadequate medical and nursing attention. The United States stands eleventh in infant mortality, losing one in every ten during the first year of life, which is twice that of New Zealand, the lowest. In the United States a new born child has less chance of living a week than a man of ninety; of living a year than a man of eighty.

The great enemy of the mother and baby is poverty. The smaller the wage of the father, the poorer the family, the greater the hardships upon the mother, and the less the chance of the child to survive the first year. Income plays the chief role in locating the home and in determining its kind. Low income often sends the mother to work, substitutes artificial for natural food, encourages bad housing, and promotes insanitary surroundings. Studies of infant mortality, made by the Children's Bureau in Waterbury, Connecticut, showed that children born in rear houses or in houses on alleys had a death rate of 172 per 1000; those located on the street, 120.6. In Manchester, New Hampshire, the rate was 123, where the number of persons averaged less than one per room, and 261.7 where they averaged more than two but less than three. The mortality for babies whose mothers were employed outside of the home was 312.9 per thousand while the rate was 122 for those whose mothers had no occupation but the care of their households.

From surveys in small cities, in rural districts, and in the large city of Baltimore, it was found that regardless of color, race, or nationality, the infant death rate varies inversely with the income of the father. When the father's income represents the ability to insure care and comfort ($1850 a year or more), the death rate was one-fourth as high as when the father's earnings fell into the lowest wage group ($450 or less).

Ignorance, as exhibited in the feeding and care of the infant, is an important factor in the death rate. It is not, however, limited to any one class of society, but operates most viciously in the group whose means of defense are most weakened by poverty. The mother, both ignorant and poverty stricken, is a menace because she is socially helpless unless the community or a philanthropist takes the responsibility of providing her adequate medical and nursing care, proper instruction in hygiene of maternity and of infancy, and decent housing.

Application of available knowledge will reduce maternal and infant mortality by 50 per cent.; possible 75 per cent. The great public health problem is to educate the individual to demand, and the community to supply the necessary protection for mothers and children by providing prenatal and postnatal clinics and maternity hospitals or wards in a general hospital. It is necessary to supervise rigidly the training of midwives, and to provide better education for medical students in obstetrics.

A comprehensive plan in maternal and child welfare must include teaching and practical demonstrations for mothers in the household arts essential to her welfare and to that of her child. Consultation centers or welfare clinics for children must provide for periodical examinations and instruction as to nutrition, health, exercise, and recreation. It must take into consideration the welfare of the defective, delinquent, and dependent children. It must conserve the rights of children in reference to person, labor, education, and law. It must guarantee the interest of the child will be paramount in marriage and divorce, and that it shall receive justice whether legitimate or illegitimate.

Rural Health Work

It is estimated for the country at large that for every composite group of 71 persons, one will die during the year; two will be in bed constantly; thirty will have impairment of health, ranging all the way from the person who is just able to be out of bed to the one not quite up to normal; twenty-five will be what we call healthy, while thirteen will have that vigor essential to rendering dynamic the inspiration of high ideals. This general average applied to the rural sections which contain 48.1 per cent. of the population of the country, makes it possible to visualize the problem of rural health work and its relation to the ability of the rural population to pursue its vocation effectively. As the rural population feeds and clothes the state and is the foundation upon which cities and industries are erected, its illness presents a striking phase of the economics of disease.

The problem of rural health work can be successfully approached only by education of the individual to appreciate the importance of disease and to adopt the methods necessary to prevent it. The most effective educational agency is an adequate county health organization directed by a full time health officer with a sufficient number of properly trained public health nurses, sanitary inspectors and clerical assistants to do the work.

The first duty of the organization is the education of the public in respect to hygiene and sanitation. To this end, lectures and demonstrations are given, pamphlets and folders distributed, and articles on live health topics are prepared for the county papers. Exhibits are arranged in the schools and at the county fairs. The assistance of the movie is obtained and cooperation is given to every organization in teaching the facts concerning health.

Another important function of the county health organization deals with the control and prevention of communicable disease. In cooperation with attending physicians, the county health officer enforces the quarantine regulations of the state, determines the sources of contagion, and in collaboration with the public health nurses, visits schools and homes; in cooperation with teachers and parents he institutes measures for prevention of disease, arranges for physical examinations of children, and advises as to corrective measures. The public health nurses carry out the follow-up work. The health officer ascertains the occurrence of tuberculosis in the county, adopts measures to prevent its spread, and arranges with local physicians to establish clinics for persons with suspicious symptoms of the disease.

As far as practical, each home in the county is visited by the health officer, and a survey made of the construction and use of latrines, the safeguarding of the water supply, and the handling of milk. He inspects the screening and advises as to the means to be employed for the elimination of the breeding places of the fly and the mosquito. A nurse visits each house where bottle-fed children are suffering from digestive disturbances, and gives instruction to mothers in the essentials of home sanitation and infant care.

As only 56 per cent. of the 3,027 counties in the United States have hospitals, a number of the directors of county health organizations find it necessary to give considerable time to the creating of public sentiment favorable to the establishment of adequate hospital facilities or centers where clinics may be held. These clinics are held in cooperation with the local physicians and with specialists from the State Department of Health or from the state medical schools.

Industrial Hygiene

The wide use of chemistry in industry, the substitution of steam for water-power, the evolution of refrigeration, the increasing application of very high temperatures in working metals, the necessity of working in rarified and compressed air, the almost universal use of electrical energy in the mechanical arts, the development of rapid transportation, the extensive employment of artificial light, the strenuousness of a machine-set pace, and the overcrowding in manufacturing centers and in factories have produced new types of illness, have intensified the ravages of communicable disease, and have created industrial hygiene as an important branch of public health work.

Far-seeing managers of modern industries have found it to be as important to conserve, stabilize and render efficient their working forces as to prevent waste, adopt better methods of manufacturing, or to improve their salesmanship. They have noticed that output increases, their labor troubles diminish, and their overhead expenses decrease where human and mechanical engineering are best coordinated. They know that the most capable workman is healthy, contented, and is able to do his work rapidly and well.

The number of industries that are establishing welfare departments to deal with their employees is steadily increasing. Greater efforts are being made to improve the morale among workers by providing better sanitary conditions in work-shops, and by the construction of adequate safe-guards against accident, dust and fumes. Men and women are given medical attention and surgical care where the employer is responsible. Precaution is taken to prevent and to control communicable disease.

Sanitary lunch-rooms are provided to furnish adequate food at cost. The employees are given instruction in safety-first, first aid, and hygiene. When the labor is monotonous and exhausting, arrangement is made for rotation in work, period for relaxation permitted, and time allowed for recuperation.

The director of industrial welfare gives advice to the employees in the adjustment of social and financial difficulties. He endeavors to provide profitable recreation, and he encourages thrift, domesticity, and morality. There is a close relation between the home and the community life of a man and his industrial efficiency and reliability. While the worries which beset a workman are his private affair, they take a great deal of his attention from his job at the expense of his employer, and sooner or later become a problem for his physician. Tactful advice leading to contentment and constructive living is neither meddlesomeness nor paternalism,—it pays dividends to both employer and employee.

Medical Inspection of Schools

Preventive medicine does some of its best work in connection with public schools. Proper medical supervision of schools includes a school nurse service as well as medical inspectors. It applies to buildings and to equipment, as well as to the mind and to the body of the child. About twenty million children, nearly one fifth of the population of the country, are compelled to spend, on an average, five hours a day in school one hundred and sixty-five days in the year. Under such circumstances, as effective precautions should be taken to insure ventilation, lighting, heating, proper furniture and general sanitary conditions in the school to provide for the child's physical welfare as to enforce its attendance. It is obviously unfair to require a child to occupy a seat likely to produce body deformity or to study in a light that may impair its vision. It is equally unjust to bring together a number of young persons at an age when most susceptible to communicable diseases without medical supervision, unless the school is to provide a great disease exchange for the community. It must be remembered that the twenty million children of elementary-school age come in contact more or less intimately, with approximately twelve million others of pre-school age. These younger children are very susceptible to infectious diseases and are in the age group in which eighty-five per cent. of the mortality occurs.

When medical inspection is properly done, a disease history of the child is obtained on entry, and a number of defects and functional diseases will be discovered on examination that may be corrected. It provides a careful medical record preliminary to physical training, will determine in what individuals corrective gymnastics are needed, and, by periodical examination, will ascertain the physical progress of the child. The community should realize, however, that it is of little value to spend money to discover defects unless provision is made to remedy them when they are found. Each school district should provide a dispensary service for school children and parents must be educated to consult their family doctor on questions of prevention before their children become ill.

Physical Education

Physical education is preventive medicine in action. It should have for its purpose the development of the functional power of the child to the highest level consistent with the most successful training of its intellect; it should meet the needs of the weak, who require it most, as well as of the strong; it should be graded for various ages; its progress should be determined by tests and measures of development, strength, agility, endurance and ability to do. Its proficiency should be based upon well-defined accomplishments, not upon certain periods of exercise.

In general, provision must be made for the physical education of three classes of individuals: (1) the physically normal, (2) the subnormal, (3) the abnormal and physically defective.

The physically normal individual should be required to take general exercise, but should be encouraged to select some form of sport and to acquire a fondness for it. In the primary school it may mean games and outdoor exercise; in the high school or college the development of an "athletic hobby" to keep him in "fighting trim" when required to lead a sedentary life.

The subnormal individual, underweight and understrength, for his age, undeveloped but organically sound, will require special and general exercise to meet the tests of normal. Having shown his ability by passing the required efficiency tests, he may be further educated in that group.

The abnormal group is composed of individuals distorted as to posture or carriage, but who may become greatly improved by corrective gymnastics. In this class are also those with heart lesions, hernia, diseases of the joints, marked flat feet, etc. A considerable number of these could be cured by proper surgery, and would be, if their parents were so advised by a medical inspector in whom they had confidence. All would be greatly benefited by special calisthenics and other light forms of exercise under medical supervision. In many instances members of this group have been led to attach too much importance to their condition. Nothing will do more than safe, beneficial exercise to lift them from the despair of chronic invalidism to the enthusiasm of physical well-being.

Physical education is a great antidote for antisocial tendencies. It teaches temperance, self-control, courage and endurance. It produces the ability to play the game to the end and to lose with a smile or to take victory with modesty and magnanimity. It Americanizes and de-hyphenizes by the democracy of the playground and by the catholicity of its games. It places the nation on the solid foundation of physical soundness, morality, and vitality.

Organizations Promoting Public Health

Organizations promoting intelligent child labor legislation and passage of wise laws improving working conditions, particularly of women, are engaged in important public health work. Military training, the Boy Scout and Camp Fire Girl movements and mass athletics lead to physical vigor and constructive thinking. The practical application of mental tests and careful study of factors influencing their results stimulate interest in the social and physical welfare of children in the largest sense. The creation of parks and playgrounds provides fresh air, exercise, and shade essential for the well-being of children, especially of small children. City zoning tends to ventilate dwellings, to introduce sunlight into the home, to reduce noise and to purify the air. It leads to that restfulness essential to complete recuperation from a day's work.

The Demonstrative Method

Nothing equals in effectiveness a clear-cut demonstration of what can be done. The International Health Board is actively engaged in showing what results may be obtained by intensive practical application of preventive medicine. For example, it enters a community where malaria is prevalent, and concentrates its attack upon the disease by destruction of the breeding places of the mosquito, treatment of persons with malaria, and by screening all houses. It drains swamps, ditches, meadows, fills in or oils stagnant pools, clears away underbrush, and stocks the creek with top minnows to eat the mosquito larvae.

Its agents in cooperation with the local health organizations, visit every home in the community in search for defective drain pipes, uncovered rain barrels, and for bottles, cans, or other objects that may hold water in which mosquitoes may breed. The screening of the house is examined and advice is given as to how to make it most effective. If members of the family have malaria or give a history suspicious of the disease, they are examined clinically, and a course of quinine administered.

Such an intensive attack is invariably followed by a most significant reduction in the occurrence of malaria. As every home is visited, the work receives wide publicity. It becomes the chief topic of conversation at the meeting of the sewing circle, on the golf links, and at the corner grocery. On conclusion of his work, the director summarizes his findings, estimates the cost, and shows that the prevention of malaria saves both money and suffering. He calls attention to the increased value of the drained land and the general improvement in appearance of the community by the removal of the underbrush and the stagnant pools. The people at first are skeptical, later become curious, and in the end are convinced that public health work of this type is of immediate value to them. They know what has been done and how it was accomplished, and are usually ready to see that the proper measures are adopted to prevent the return of the disease.

The intensive method has been widely used by the Rockefeller Foundation in its campaign against malaria and hookworm. In Framingham, Massachusetts, it is being utilized in the study and prevention of tuberculosis. The United States Public Health Service uses it in certain counties and towns for educational purposes and it has been employed by other organizations in the promotion of child welfare.

Disease Extermination

In certain strata of the earth are to be found the remains of animals and plants which once inhabited it, but were unable to survive the conditions of their environment. They perished for lack of food, could not adapt themselves to the variations of the soil, could not withstand the unfavorable alterations of temperature and moisture, or were unable to resist their enemies, both animal and vegetable. It is within the power of man to so alter his living conditions and to so change the environment of micro-organisms as to enforce either their biological modification or extinction.

The virus of smallpox would have a hazardous existence in a vaccinated world. The Schick test, toxin-antitoxin immunization and antitoxin administration present to the virulent diphtheria bacillus the problem of the American bison. Asiatic cholera and typhoid fever await the coup-de-grace of sanitation and inoculation. Successful warfare on the cootie brings extinction to typhus fever. Malaria and yellow fever are ready for the fate of the dinosaur, when means available are universally used in their eradication. Bubonic plague, the giant of pestilences, takes its place with the mastodon, when measures adopted to control it in America are used throughout the world.

Economics, sociology, and preventive medicine point to a hundred ways for the promotion of the public welfare,—to a thousand paths for the successful pursuit of health and happiness. It is futile to seek a far distant Utopia through a maze of "isms" and "pathies," when education to appreciate and to use the fruits of the research laboratories of the world will produce those living conditions and that healing which are the very essence of practical Christianity.

ELECTRONS AND ETHER WAVES[1]

By Sir WILLIAM BRAGG, F.R.S.

I PROPOSE to ask you this evening to consider for a short time one of the outstanding problems in physics. I am justified, I think, in saying that so far it has proved insoluble, but for all that, it lacks neither interest nor importance. It is important because it relates to very fundamental things with which we are deeply concerned, and as to its interest, it comes in many ways.

Man's interest in radiation is naturally very old indeed. The warmth of the sun, the light that it gives by day, and the light of the moon and stars by night, fill a first place in their importance to him. When experimental science began to grow rapidly its first efforts were devoted to an attempt to unravel the laws of propagation of light and heat. Among the famous pioneers Newton and Huyghens represented two opposing schools of thought. The former advocated a corpuscular theory of light, the latter maintained that light consisted of a wave motion. In a restricted sense, the wave theory has completely triumphed; it explains the ordinary phenomena of light and especially of the intricate effects which depend on interference of waves with the greatest satisfaction and precision. But, on a wider view of light phenomena, the victory of the wave theory is not so absolute, for it is certain that a great part is played by corpuscular radiations, the corpuscles being the electrons of recent discovery. It seems that we must admit the importance of each view and, to a certain extent, we can accurately define the part that each must play: but, there is one great exception. There is one problem in connection with the interrelations of electron waves and corpuscles which seems to ridicule all our attempts to understand it. If we could solve it we should have made an immense advance, both in knowledge and in our power of handling materials. We should perhaps have added a new province to the realms of physical thought. And it is because of this obvious importance and because of our failures to find the solution that I hope you will be interested in looking at the question once again in the light of recently acquired knowledge.

We are going to consider the relations between the energies

[1] The Robert Boyle Lecture at Oxford University for the year 1921.

carried by ether waves and the energy carried by electrons. Let us first set down the distinctive features of each form of radiation. As regards wave radiation, we must say that the energy spreads outwards and weakens as it spreads, just as a sound dies away in the open air. And next we must add that all waves show the extraordinary phenomenon of interference. Two sets of waves can tend to destroy each other's actions at certain places and times, making good such losses by increased actions at other places and other times. By the aid of this principle, Young and Fresnel, and a host of workers who have followed them, have built up optical theories of great power and completeness. Note that the characteristics of a simple wave are its length and its amplitude: it has no others.

Corpuscular radiations have been obvious to us on the grand scale only since the discovery of radium and of X-rays. Beside the X-rays, the projection of helium atoms from the bursting atoms of radio-active substances, we find in the general radiation of radio-active substances streams of high speed electrons. The main features of these rays which concern us now can also be stated briefly:

Electrons are to be found everywhere forming part of every atom. They can be set in motion by electric forces, as in the X-ray tube, or they may be expelled from radio-active substances. Such radiation like light radiation has qualities. The flying particles may be more or less in number, and the speed of each can fall between wide limits. In other respects it is, at present, assumed that they are all like each other. We have not been acquainted with electron movements so long as we have been acquainted with wave motions in ether. The reason is perhaps a simple one:

An electron can only maintain a separate existence if it is traveling at an immense rate from one three-hundredth of the velocity of light upwards, that is to say, at least 600 miles a second or thereabouts. Otherwise the electron sticks to the first atom it meets. The action of a powerful induction coil and space to move in freely, where there are no atoms to impede it, provide favorable circumstances for observation, and we have only been able to realize these conditions with sufficient success in more recent years.

We now know, therefore, radiation in two forms, and each is independently full of interest. But it is the extraordinary connection between them that is so fascinating and yet beats us when we try to explain it. We have known for many years that there is some connection between waves and electrons because light, especially of short wave length, can cause a discharge of negative electricity, that is to say, of electrons, from substances on which it falls. This, which is known as the photo-electric effect, has been carefully examined with a view to discovering relations between the wave length of the ether radiations and the velocity of the ejected electrons. But the experimental difficulties of obtaining a close insight into the effect were always considerable until we had to do with the new variety of light which Röntgen discovered. The very short wave length which is associated with X-rays goes with a photo-electric effect which is so greatly intensified that we can examine it in detail, and now the relation between wave and electron takes on an importance which arrests attention.

We can take the question in two stages: in the first as a general question. In the second we bring in effects which depend on details of atomic structure.

The general question can be stated quite simply. We have seen that a wave motion is defined by two qualities. The one, the wave length; the other the amplitude. When an X-ray falls upon any material substance we find that electrons are ejected: the wave radiation has produced an electron radiation. Electron radiation has characteristics also, namely, number and speed. In what way then are the characteristics of the waves related to the characteristics of the electron movements which are excited by them? The answer is simple but surely unexpected. The velocity of the electron depends on the wave length only; the number of electrons depends on the intensity, but not on the wave length. Moreover, the relation between the wave length of the one radiation and the velocity of the other is of the simplest kind. If we define the wave length by stating the number of waves that pass by a given point in a second and call this number the frequency, then the energy of the electron is equal to the frequency multiplied by a constant quantity. This constant is not new to us, it had already turned up in connection with investigation of interchange of energy, where waves are concerned, and is well known as Planck's constant. That, however, need not concern us now.

The essential point is that a wave radiation falling on matter of any kind whatever and in any physical condition, liquid or solid or gaseous, hot or cold, causes the ejection of electrons. In actual experiment we cannot usually examine the speed of the electron at the instant of its production. We have generally to wait for the electrons to get outside the body in which they arise before we can handle them in our experiments. Those that have come through the deeps of the material have lost speed by collision with the atoms on their way out. Consequently, we have in response to the incidence of waves of a definite frequency, that is to say, of so-called monochromatic radiation, an output of electrons of various speeds ranging downwards from a maximum which is given by the above-mentioned relation. There does not seem to be any doubt that the electrons all had originally quite the same definite speed, and that the differences in speed are acquired subsequently.

In this process we see energy of wave radiation replaced by energy of electron radiation. There is an exactly converse process. If we direct a stream of electrons against any material substance we can call into being ether waves. They arise at the point of impact and their quality is, in the general sense, determined by the velocity which we have given the electron stream.

Among the waves so originated there are some whose frequency is related to the energy of the individual electron in the electron stream by the same constant as before. There are others of lesser frequency, such as we might suppose to be originated by electrons that belonged to the original stream, but have lost energy by collisions with the atoms of matter. Here again, there is no doubt that the electrons produce waves for which the frequency is exactly determined by the use of Planck's constant as above.

In order to realize the full significance of these extraordinary results, let us picture the double process as it occurs whenever we use an X-ray bulb. By the imposition of great electrical forces we hurl electrons in a stream across the bulb. One of these electrons, let us say, starts a wave where it falls. This action is quite unaffected by the presence of similar actions in the neighborhood, so that we can fix our minds upon this one electron, and the wave which it alone causes to arise. The wave spreads away, it passes through the walls of the bulb, through the air outside, and somewhere or other in its path in one of the many atoms it passes over an electron springs into existence, having the same speed as the original electron in the X-ray bulb. The equality of the two speeds is not necessary to the significance of this extraordinary effect; it would have been just as wonderful if one speed had only been one half or one quarter or any reasonable fraction of the other. The equality is more an indication to us of how to look for an explanation than an additional difficulty to be overcome.

Let me take an analogy. I drop a log of wood into the sea from a height, let us say, of 100 feet. A wave radiates away from where it falls. Here is the corpuscular radiation producing a wave. The wave spreads, its energy is more and more widely distributed, the ripples get less and less in height. At a short distance, a few hundred yards perhaps, the effect will apparently have disappeared. If the water were perfectly free from viscosity and there were no other causes to fritter away the energy of the waves, they would travel, let us say, 1,000 miles. By which time the height of the ripples would be, as we can readily imagine, extremely small. Then, at some one point on its circumference, the ripple encounters a wooden ship. It may have encountered thousands of ships before that and nothing has happened, but in this one particular case the unexpected happens. One of the ship's timbers suddenly flies up in the air to exactly 100 feet, that is to say, if it got clear away from the ship without having to crash through parts of the rigging or something else of the structure. The problem is, where did the energy come from that shot this plank into the air, and why was its velocity so exactly related to that of the plank which was dropped into the water 1,000 miles away? It is this problem that leaves us guessing.

Shall we suppose that there was an explosive charge in the ship ready to go off, and that the ripple pulled the trigger. If we take this line of explanation we have to arrange in some way that there are explosive charges of all varieties of strength, each one ready to go off when the right ripple comes along. The right ripple, it is to be remembered, is the one whose frequency multiplied by the constant factor is equal to the energy set free by the explosion. The ship carries about all these charges at all times, or at least there are a large number of ships each of which carries some of the charges, and externally the ships are exactly alike. Also we have to explain why, if we may drop our analogy and come back to the real thing, the ejected electron tends to start its career in the direction from which the wave came. This is a very marked effect when the waves are very short.

Dropping the analogy, how do the electrons acquire their energy and their direction of movement from waves whose energy and momentum have become infinitesimally small at the spot where they are affected, unless the atom has a mechanism of the most complicated kind? And if the intervention of the atom is so important, why is it that in these effects a consequence of the intervention does not depend upon each atom itself—whether, for example, it is oxygen or copper or lead?

We may try another line of explanation and suppose that the energy is actually transferred by the wave from the one electron to the other. If it is the atom which pulls the trigger and causes the transformation, then how does it happen that the whole of the energy collected by the wave at its origin can be delivered at one spot? Rayleigh has told us that an electron over which a wave is passing can collect the energy from an area round about it whose linear dimensions are of the order of the wave length. But any explanation of this kind is entirely inadequate. Whatever process goes on it is powerful enough on occasion to transfer the whole of the energy of the one electron to the other. Nor can there be any question of storing up energy for a long period of time until sufficient is acquired for the explosion. For it is not difficult to show that when an X-ray bulb is started and its rays radiate out, the actual amount of energy which can be picked up by an atom a few feet away would not be sufficient for the ejected electron, though the tube were running for months; whereas we find the result to be instantaneous.

I think it is fair to say that in all optical questions concerned with the general distribution of energy from a radiating source the wave theory is clearly a full explanation. It is only when we come to consider the movements of the electrons which both cause waves and are caused by them that we find ourselves at a loss for an explanation. The effects are as if the energy were conveyed from place to place in entities, such as Newton's old corpuscular theory of light provides. This is the problem for which no satisfactory solution has been provided as yet: that at least is how it seems to me.

No known theory can be distorted so as to provide even an approximate explanation. There must be some fact of which we are entirely ignorant and whose discovery may revolutionize our views of the relations between waves and ether and matter. For the present we have to work on both theories. On Mondays, Wednesdays, and Fridays we use the wave theory; on Tuesdays, Thursdays, and Saturdays we think in streams of flying energy quanta or corpuscles. That is after all a very proper attitude to take. We cannot state the whole truth since we have only partial statements, each covering a portion of the field. When we want to work in any one portion of the field or other, we must take out the right map. Some day we shall piece all the maps together.

Meanwhile, even if we cannot explain the phenomena we must accept their existence and take account of them in our investigations. We must recognize that wave radiation and electron radiation are in a sense mutually convertible. Whenever there is one there must be the other, provided only there is matter to do the transforming. We do not yet know more than a little of the part that this process of interchange plays, but we know that it is very prominent when the waves are very short, or, what is the same thing, the electrons moving swiftly. It is the movement of the electrons in the X-ray bulb that originates the X-rays themselves. They as waves pass easily through the wall in the tube and through materials outside: their energy finally disappears and is replaced by moving electrons. It is the latter alone that produce directly the effects which we ascribe to X-rays. We may suspect that similar effects to these take place when the waves are long, but the corresponding electron velocities are so small that it is difficult to measure them or observe their effects. Nevertheless, the carrying forward to these regions of experience gained elsewhere has led to extraordinary results, as for example, in the theories of Bohr regarding the relations between the structure of an atom and the radiation it emits.

I have spoken of the first stage in this examination of the relations between ether waves and electrons. May I now go one step further and bring in certain curious and lately discovered relations between the interchanges and the nature of the atom itself. All that I have said before is mainly independent of atomic nature; I want now to consider certain experimental results which are superimposed upon the former without in the least invalidating them and which obviously have a first importance on our appreciation of atomic structure.

When an X-ray of given wave length strikes an atom, it may result in the ejection of an electron of equivalent energy as described above. And in such a relation between wave length and energy there can be no trace of any influence of the nature of the atom. But it may sometimes happen that the energy instead of being handed over or transformed in one complete whole is transformed in a series of successive stages, and these stages are really characteristic of the atom. Let me give an illustration:

Let us imagine an X-ray of wave length equal to two-tenths of an Angström unit (100-millionth of a centimeter), such as comes, under ordinary circumstances, from a powerful X-ray bulb. It falls on a silver atom; it may, as in the general process, produce an electron of energy equivalent to itself, but it may also divide up this energy into two parts. One part is characteristic of the silver atom. It is an amount which the silver atom is for some reason especially liable to absorb or develop. It is peculiar to the silver atom, no other atom absorbs just that quantity. Leaving out of account for the moment the balance, let us follow the course of happenings to this particular quantity of energy. It excites in the atom a series of rays characteristic of the atom. These rays are divided into groups characteristic of the atom, but of a general arrangement which is the same for all atoms. It appears that the absorbed energy is divided up between various rays, probably giving rise to one out of each group, and in that way its whole total is spent.

These rays we now analyse with an X-ray spectrometer using a crystal as our diffraction grating. It is by their use that we have been able to study the architecture of crystals and to find the way in which the atoms, under the influence of their mutual force, arrange themselves in crystalline form.

Going back for a moment to the balance, the difference between the energy characteristic of the original X-ray and that amount of energy which was used up in the way just described, this energy it appears is found in the possession of an electron whose velocity can be measured with accuracy. Here we have an extraordinary instance of a partition of energy between wave and electron. We find the action of a wave resulting in the initiation of both electrons and waves, but the simple relation which we had in the general case is only modified to a slight degree. There may be several items instead of one in our balance sheet, but the balance is still good. This action follows just as well as a consequence of the impact of an electron having the necessary energy as it does from the incidence of an X-ray in the way I have described. We should notice in addition that when X-rays or electrons fall short in their associated energy of the amount characteristic of the atoms, there is no result at all, and this is reflected in the fact that neither of them is absorbed in the atom so much as if they were respectively a little higher in frequency or a little greater in velocity.

The curious and essential feature of all this mass of information which I have been trying to put before you in a rough and summary form is the interchangeability of ether waves and electrons. Energy can be transferred from one to another through the agency of matter. The transference is governed by the simplest arithmetical rules. In the exchange it is the frequency of the wave which is to be set against the energy of the electron, and it is just this that makes the greatest puzzle in modern physics. It is the block at one point which is choking the entire traffic and on which, therefore, all our interests must concentrate.

CHEMISTRY OF THE BLOOD ONE HUNDRED YEARS AGO

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THE recent appearance of a paper[1] discussing the chemical changes which occur in the blood concomitant with various disease conditions calls to mind a series of studies of this fluid made one hundred years ago. In 1821, the leading Swiss scientist of the time, J. L. Prévost, and his student, J. B. A. Dumas, who became the foremost French chemist during the middle of the nineteenth century, published in the "Bibliothéque Universelle, Sciences et Arts," volumes seventeen and eighteen, a series of three papers entitled "Examen du Sang et Son Action dans les Divers Phénomènes de la Vie."[2] To the present-day mind these papers are interesting not merely because they are accounts of studies made one hundred years ago, but because they touch upon a variety of topics, each of which in the course of a century's progress has attained to a greater or lesser degree the rank of a separate science. It would serve no purpose to point out the several paths followed in this development; those who are at all familiar with the history of the natural sciences, particularly chemistry, realize that they must read the nineteenth century in its entirety if they would know the complete story of that development.

In their earliest communication Prévost and Dumas state that the relation of the blood to the nervous system is primarily the subject of their research. Inasmuch as the changes occurring in this master tissue were believed to be slight and difficult to detect, the blood was made the special object of study. The first paper of the series deals with certain purely physiological and morphological aspects of the study together with an account of some experiments concerning blood transfusion. In the second article are presented the results of chemical analyses, while the last communication deals essentially with the phenomenon of secretion.

The conception of the general character of the blood as a fluid containing many minute red globules suspended therein was an

[1] Myers, V. C.: *Journ. Lab. Clin. Med.,* V, 343 (1920).
[2] XVII, 215, 294. XVIII, 208.

inheritance from the early micrographers. Prévost and Dumas were unable to see how the fluid portion of the blood could influence the nervous system, and therefore easily persuaded themselves that a study of the *red globules* could furnish the desired information regarding the action of the blood during life. In the morphological studies which were made, the shape of the blood corpuscles was the first point to receive attention. Sir E. Home had set forth the view in his Croonian Lecture for 1818[3] that the red blood cells are spherical bodies "composed of a central globule and a coloring-matter envelope." During the latter part of the eighteenth century Hewson had published an account of observations of the blood and had considered the corpuscles as flat plates furnished with a "saillant" point in their center. By this "saillant" point was doubtless meant what we now understand as the nucleus, for, as Prévost and Dumas remark, Hewson was led to this view as a result of examining the blood of the toad and the frog, forms in which the erythrocytes are recognized by present-day histologists as being nucleated. In order to determine which of these two views was the correct one, Prévost and Dumas examined the blood of forty-five different species of animals. Descriptions were given for each sample and the corpuscles were measured. The measurements were made by means of a camera-lucida arrangement, the object being traced on the camera-lucida field and its real dimensions deduced by a knowledge of the magnification employed. It is interesting to compare the diameter of the human erythrocyte as determined by these investigators with that given in modern textbooks. Prévost and Dumas obtained 6.6 microns as their result while present-day textbooks state approximately 7.5 microns. The smallest value noted by these workers was 3.8 microns, this being the diameter of the erythrocyte in the goat *Capra Hircus*.

Some of the conclusions reached were as follows: the globules are circular in shape in all mammals, their size varying among different species; they are elliptic in birds with but slight variation in size in this class; in all cold-blooded animals the erythrocytes are elliptic in shape.

Blood transfusion as a therapeutic measure has had a long history. The success of the operation was never assured, however, until comparatively recent times; there were unknown factors operating, when blood from one individual was introduced into the vessels of another, which too often led to fatal results. This was particularly true a century ago and earlier, when the blood of animals was occasionally transfused into the human being. With

[3] *Philosophical Transactions, 1818,* 172 & 185.

the discovery by Prévost and Dumas that demonstrable morphological differences exist among the bloods of different animals, it was natural for them to assume that such differences accounted for the varying results obtained when blood was transfused. They performed a series of experiments to test this idea. It was shown: (1) that in general, transfusion of blood between animals of the same species is a complete success; (2) that between animals having "globules" of the same shape but of different dimensions transfusion after severe hemorrhage results in only a partial relief of short duration; while (3) injection of circular "globules" into a bird results in death following "violent nervous symptoms comparable to those obtained after the administration of the most intense poisons."

In their chemical examination of the blood Prévost and Dumas fixed their attention upon "l'albumine"[4] of the serum and the "coloring matter which surrounds the globule." As would be expected, no very exhaustive examination of these substances could be made considering the fact that suitable methods for analyzing organic compounds were not available. The name "l'albumine" was being applied to a complex something contained in the blood serum largely because it possessed the property of coagulating under the influence of heat in a manner similar to egg-white, and indeed, very little more was known concerning this substance. The coagulation temperature of "l'albumine" of the serum was determined to be 75° Centigrade.

Analyses of a general character were made upon the blood of twenty different species of animals; both the whole blood and the serum were analyzed for "eau, particules," and "albumine et sels solubles." In analyzing different samples of blood from the same animal it was noticed that the results did not always agree. It was reasoned that under certain conditions the veins must absorb considerable blood material; experiments were therefore performed to see how quickly the animal body could regenerate blood. Successive hemorrhages were made and the blood samples which were drawn at intervals were analyzed. The only change worthy of note was the content of corpuscles in the whole blood; the difference was slight, however, and Prévost and Dumas concluded that the veins are able to absorb blood material rapidly. In the light of modern physiology it would be said that these experimenters obtained a decrease in the erythrocyte content of the blood. An examination of the serum analyses submitted shows that remarkably constant

[4] This should doubtless be translated as "albumen," which is used by modern physiological chemists in a generic sense; it is quite clear, however, that Prévost and Dumas considered "l'albumine" to be a single substance.

values were obtained for the water and the albumen. The following conclusions are of interest: (1) arterial blood contains more "particules" than does venous blood; (2) the blood of birds contains relatively the largest number of "particules"; (3) the blood of mammals comes next and among them the carnivora seem to have more than the herbivora, while (4) the cold-blooded animals appear to possess relatively the smallest number.

Three experiments were performed in studying the coloring matter of the blood.

"(1) When ashed in an open crucible . . . . there resulted a considerable quantity of red powder more or less rich in peroxide of iron according to the nature of the blood employed; (2) when treated by boiling nitric acid so as to destroy the animal matter, a clear colorless fluid resulted in which a few drops of prussiate of ammonia formed a large amount of blue precipitate; (3) when dissolved by means of caustic potash and the resulting solution boiled with prussiate of ammonia, a brown liquor was obtained, in which the addition of a quantity of oxalic acid sufficient to saturate the potash brought about a precipitate of a greenish-blue color, which was nothing else than the albumen colored by the prussian blue."

All of these experiments confirmed the idea that the coloring matter of the blood "est formée d'une substance animale en combinaison avec le péroxide de fer." It was suggested that this animal matter might be "l'albumine" although the caution of these authors prevented them from being dogmatic on this point; they preferred to leave the question open for future research to decide.

When considering the phenomenon of secretion and the behavior of egg-white through which is passed a galvanic current, Prévost and Dumas approached the problem with the formula which was current at that time. The interesting topic of the day was electricity. Davy discovered the power of the electric current to decompose potash and soda in 1806; Oersted observed the effect of an electric current on a magnet in 1819; Ampère followed this in 1820 by showing that the direction in which a magnet moves depends upon the direction in which the electric current flows relative to the magnet. This dominating interest in electricity in 1821 is easily revealed by a perusal of the volumes in which the papers of Prévost and Dumas appeared; there are to be found papers by such men as Ampère, Arago, Oersted, Davy and Faraday.

Prévost and Dumas were not immune against this electric virus; they were interested in the experiments reported by an investigator who had tested the effect of a galvanic current on egg-white. The current had decomposed the egg- white, "the coagulated albumen wandered to the positive pole, and the caustic soda to the negative pole." This experiment was interpreted by the students of that early day to mean "that the white of egg is to be regarded as an albuminate of soda with excess of base.'' Prévost and Dumas repeated this experiment and examined microscopically the coagulum which collected about the positive pole. They found globules similar to those found in milk, pus, blood and muscle. This observation led them to make a generalization concerning the phenomenon of secretion.

Nous considérons la surface circulante de chaque organe sécréteur comme douée d'une polarité constante en vertu de laquelle les produits de la sécrétion sont formés et isolés. Et si l'on se rappelle que les mucus et les produits non globuleux sont généralement alkalins; que, d'un autre coté le lait, le pus trés-sain, le chyme, et les muscles, sont globuleux et acides, on reconnoitra la plus grande analogie entre leur formation et celle des deux corps que nous obtenons dans l'experience galvanique sur l'albumine.

Just as evolution has been the formula of the past half century with which to explain all things, physical or metaphysical, animate or inanimate, and appears about to give way to a new formula, namely, relativity, so electricity was the formula one hundred years ago. There is in the passage cited above, in which polarity was brought into relation with secretion, simply an attempt at using the formula of the time. Another very interesting use of this formula is to be found in the closing chapter of Thomson's History of Chemistry published in 1830.[5]

From the mouth the food passes into the stomach, where it is changed to a kind of pap called *chyme*. The nature of the food can readily be distinguished after mastication; but, when converted into chyme, it loses its characteristic properties. This conversion is produced by the action of the eight pair of nerves, which are partly distributed on the stomach; for when they are cut, the process is stopped: but if a current of electricity, by means of a small voltaic battery, be made to pass through the stomach, the process goes on as usual. Hence the process is obviously connected with the action of electricity. A current of electricity, by means of the nerves, seems to pass through the food in the stomach, and to decompose the common salt which is always mixed with the food. The muriatic acid is set at liberty, and dissolves the food; for *chyme* appears to be simply a solution of the food in muriatic acid.

The first definite proof—as far as the writer has been able to determine—that urea exists in the blood was furnished by Prévost and Dumas exactly one hundred years ago. In the third paper of the series under consideration, these authors described certain experiments in which both kidneys were removed from animals (dogs, cats and rabbits). Analysis of the blood of such animals showed the presence of a large amount of urea which was separated by means of the nitrate method; the urea was identified by determining its properties and by performing an elementary

[5] Page 319.

analysis. From the blood of unoperated animals, on the other hand, no such substance could be isolated.

The significance of their discovery was fully appreciated and the authors discussed its bearing on the theory of renal secretion. The failure of other experimenters to show the presence of urea in the blood of normal animals had been interpreted to mean that the substance was not present in the blood but was formed in the kidney; the same idea of kidney function was held by Berzelius who maintained that the kidney was the organ for oxidizing sulphur and phosphorus (considered by him to be elements of albumin) since sulphates and phosphates were found in the kidney secretion in relatively large amounts but were absent from normal blood. Prévost and Dumas concluded that urea was eliminated by the kidney to a degree corresponding to its formation *elsewhere in the body:* ablation of both kidneys, as had been performed in their experiments, resulted in a failure of the body to eliminate this substance and consequently its accumulation in the blood in a quantity sufficient to enable its isolation and identification. This new point of view, namely, that the kidney functions to eliminate substances which are already present in the blood, they felt was supported by the evidence obtained from the study of gout. The existence of sodium "lithate" calculi in the joints was considered as evidence for the existence of sodium "lithate" in the blood. Since the secretion from the kidney contained sodium "lithate," it was considered possible that the calculi form in the joints because the blood contains too much for the kidneys to eliminate, and this idea for many decades has been the principle underlying the therapy of gout.

Prévost and Dumas thus enunciated a new view of kidney function. That view has come down to the present as the working principle which guides the physiological chemist in much of his work on the chemistry of the blood and of the kidney secretion. In the course of a hundred years, however, with the development of organic chemistry and the invention of methods there has appeared such a refinement of procedure that micro methods have in a great many cases taken the place of the more cumbersome—but not less accurate—macro or gravimetric methods. Instead of the modern physiological chemist being required to perform operations of a drastic sort such as the complete removal of both kidneys, or compelled to work with large quantities of material, or to perform combustions over a coal fire, he takes, as is indicated in one of the current methods,[6] such a small quantity as ten cubic centimeters

[6] Folin and Wu: *Journ. Biol. Chem.*, XXXVIII, 91 (1919).

of blood and analyzes it for non-protein nitrogen, urea, creatine, creatinine, uric acid, and sugar, some of which are present in as small quantities as a few milligrams per one hundred cubic centimeters of blood. To these might be added calcium, chlorides, phosphates, amino nitrogen, cholesterol and the acetone bodies and still the list would be incomplete.

Following the lead of Prévost and Dumas, and others who might be mentioned, the modern physiological chemist, armed with new weapons for research, is pushing his chemical studies back beyond the membranes of the kidney glomeruli and tubules to the blood, and discovering relations of inestimable value to medical science. The following words, written in 1821, are still worthy of attention in 1921:

> General hydropsy, hematuria and many other affections enter a new day when considered from this particular point of view. The characters of the kidney secretion acquire a very powerful interest in that they serve to indicate the condition of the mass of the blood and the typical changes to which this important fluid is subject.

For the scientist especially, the story of the past is the record of progress in methods through which problems are approached and in ideas which direct the activities of the investigator. He who inherits by virtue of his scientific lineage all of the achievements of by-gone days would do well not to exalt unduly his own efforts or fail to appreciate his debt to those who laid the foundations upon which the more modern structure is built. The substance that seems relatively simple to the modern chemist has not always appeared in this light; it has often been necessary to unravel a mass of seemingly conflicting data in order to reveal this simplicity. The chemistry of the blood in 1821 consisted essentially of a small body of facts concerning the blood-clot, the coagulable proteins, the coloring-matter, and a few soluble salts; the passing of a century has resulted in the advancement of this particular branch of knowledge almost to the rank of a separate science. The only standard by which the work of the present may be compared with that performed one hundred years ago is that of the scientific method itself; that our fore-fathers in 1821 used this method well is certified by the fact that their results have stood the test of time; whether or not the contribution of 1921 shall possess the same clear title to longevity depends upon the degree of keen insight into problems, the skill in the use of methods, and finally the measure of self criticism which may be existent among the present generation of investigators.

ENUMERATION ERRORS IN NEGRO POPULATION

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THE Bureau of the Census was established for the purpose of enumerating the population of the United States, and for the collection and collation of other statistical data bearing on the social welfare of the nation. The government bases its calculations upon the information furnished by this bureau. The basis for congressional representation, military conscription and other federal regulations are based upon the census enumeration within the limits of the several states. Publicists and social philosophers base their conclusions upon the same data. It is, therefore, a matter of the greatest importance that the enumeration should be reliable and trustworthy. The Bureau of the Census ranks as a scientific department of the government. Constantly repeated errors of this bureau tend to impeach its scientific reputation and to vitiate the conclusions based upon its output. Numerous complaints have been made by competent critics not only repudiating the results, but also impugning the motive. Manipulation in behalf of sectional and partisan advantage has been freely charged. Senator Roger Q. Mills, in an article in *The Forum,* bitterly complained that the south was deprived of its due quota of representation by the imperfection of the enumeration of 1890. Indeed, the alleged inaccuracies of the eleventh census provoked a flood of condemnatory literature.

Various enumerations of the negro population by the Census Office since 1860 have not been very flattering to the scientific reputation of that bureau. These enumerations have been not only inherently erroneous, but so conflicting and inconsistent as to demand calculated corrections. It may be taken for granted that the enumerations up to 1860 were reasonably accurate and reliable. The negroes, up to that time, were in a state of slavery, and the master had merely to hand the list of his slaves to the enumerator, just as he would the list of his cattle or other forms of chattel. There was every facility and every reason for accurate returns. The negro population up to 1860 was inflated by importation of slaves from Africa, and, consequently, it was impossible to check the accuracy of the count by the ordinary statistical tests. Beginning, however, with the census of 1870, this population has been cut off from outside reinforcement and has had to depend upon its inherent productivity for growth and expansion. It, therefore, becomes an easy matter to apply the ordinary statistical checks to test the accuracy of enumeration.

It is conceded that the enumerations of 1860, 1880, 1900 and 1910 were accurate within the allowable limit of error. According to these enumerations, the growth was more or less normal and regular, and conformed to the requirements of statistical expectation. But the enumerations of 1870, 1890 and 1920 are so flagrantly discrepant as to demand special explanation and correction. A miscount at one enumeration upsets the balance for two decades. If it be an undercount, it makes the increase too small for the preceding decade and too large for the succeeding one. Accordingly, the only consecutive decades upon which we can rely for accuracy concerning the growth of the negro population would be the 1850-1860 and 1900-1910. In order to escape obvious absurdities, the figures for the other decades must be supplied by reasoned interpolations. The mere exhibit of the several enumerations by the Census Office will convince the student of their inherent improbability.

NEGRO POPULATION AT EACH CENSUS, AND DECENNIAL INCREASE, 1860-1920

Year.	Number.	Decennial Increase.	Per cent. of Increase
1860	4,441,830	803,022	22.1
1870	4,880,009	438,179	9.9
1880	6,580,793	1,700,784	34.9
1890	7,488,676	907,883	13.8
1900	8,833,994	1,345,318	18.0
1910	9,827,763	993,769	11.2
1920	10,463,013	635,250	6.5

The irregularities of these figures are as whimsical as if produced by the sport of the gods. The normal growth of population uninfluenced by immigration or emigration shows a gradual increase in decennial increment and a gradual decline in the rate of increase. Wherever there is found to be a wide divergence from this law, it must be accounted for by special contributory influences. The column giving the decennial increments, instead of showing a gradual behavior, jumps back and forth with unaccountable capriciousness. A sudden drop from 803,022 to 438,179 is offset by an alarming rise to 1,700,784 for the next decade, when, lo and behold, there is a swift decline to 907,883 for the following ten years. We look aghast at the upward bound to 1,345,318, thence a downward drop to 993,769, followed by a still further startling decline to 635,250. It makes the head swim to try to keep track of such whimsical variations. The decadal increase per cent. shows similar irregularities. The rhythmical rise and fall of these figures impresses one as the alternate up and down motion of boys playing at see-saw. Why should the ordinates of a curve, which should move smoothly downward, drop suddenly from 22.3 to 9.9, then rise to 34.9 and drop again to 13.9, then rise to 18.0 and decline again to 11.2 with a final slump of 6.5? Such variability has perhaps never been experienced by any human population. The internal evidence of error is overwhelming. The Census Bureau has sought to make corrections for the evidently erroneous enumerations of 1870 and 1890. But the equally discrepant figures of 1920 remain so far indisputed.

The census of 1870 has been universally discredited. The greatest error of enumeration falls, naturally enough, on the negro race. This race had just been set free, and had not reestablished itself in definite domiciles. Political conditions in the South were in the flux and flow of readjustment. The machinery of the Census Bureau was not sufficiently efficient to cope with so complicated a situation. Statisticians, recognizing the evident error, have tried to correct the mistake by statistical computation. The Census Bureau estimates the error in the negro population for the decade to be 512,163. An acknowledged error of a half million, it would seem, would put this bureau on the lookout for similar errors in the future. But the census of 1890 was notoriously faulty. Here again the undercount, it is obvious, fell mainly in the South, and largely among the negro population.

The Census Bureau, in commenting upon the apparent irregularities of returns for 1890, states: "According to the returns, the rate from 1880 to 1890 was very much lower than even the last rate, that of 1870-1880, and the rate for 1890-1900 was much higher than during the preceding or succeeding decade. Such abrupt changes in a class of the population which is not affected by immigration seem very improbable and almost force the conclusion that the enumeration of the negroes in 1890 was deficient. In the special volume on "Negro Population of the United States 1790-1915," the director further declares:

> The presumption of an undercount at the census of 1890, therefore, rests upon the improbability of the decennial rates of increase themselves as developed from the census returns; the inconsistency of the indicated changes in the rates from decade to decade with the changes in the proportion of children in the negro population, and upon the improbability of the decennial mortality indicated for the decades 1880-1890 and 1890-1900. . . . . The number of omissions at the census of 1890 cannot be accurately determined, but it would seem to be a fair assumption that the decline in the rate of increase from

decade to decade was constant, and that the rate fell off in each of the two decades 1880-1890, 1890-1900 by approximately the same amount. On this assumption, the probable rates of increase for the four decades, 1870-1910, are 22.0, 17.9, 13.8, 11.2. . . . A rate of 17.9 per cent. for the decade 1880-1890 would give a negro population in 1890 of nearly 7,760,000, which, in round numbers, exceeds the population as enumerated at the census of 1890 by 270,000. This is probably the number of omissions of negroes at the census of 1890, on the assumption that the retardation in the rate of growth in the 20 years 1880-1900 was constant.

By making the estimated corrections for acknowledged error in the counts of 1870 and 1890, decadal growth from 1880 to 1890 would be reduced and from 1890 to 1900 increased, so as to produce reasonable conformity with the laws of normal growth. A gradual decline in the rate of growth from 22.3 per cent. to 11.2 per cent. in 60 years will prove that the negro element conforms to the regular law of human population. This decline would appear even more gradual if we consider that the rate of 22.1 from 1850 to 1860 was contributed, in considerable measure, by African importation. The Census Bureau offers the following table with corrected numbers for 1870 and 1890:

NEGRO POPULATION: DECENNIAL INCREASES, WITH ESTIMATED ALLOWANCES FOR 1870 AND 1890

Year.	Number.	Decennial Increase.	Per cent. of Increase.
1910	9,827,763	993,769	11.2
1900	8,833,994	1,073,994	13.8
1890	7,760,000	1,179,207	17.6
1880	6,580,793	1,188,621	22.0
1870	5,392,172	950,342	21.4
1860	4,441,830	803,022	22.1

According to the recent bulletin issued by the Bureau of the Census, the negro population showed a surprising and unexpected decline during the last decade. In 1910 there were 9,827,763 negroes, and in 1920 10,463,013, giving a decadal increase of 635,250 or 6.5 per cent. If these figures were added to the table corrected to 1910, the disparity would be as glaring as any which has yet come from the Census Bureau. The sudden drop in decadal increase from 993,769 to 635,250, or from 11.2 per cent. to 6.5 per cent., is so strikingly out of harmony with the more or less regular movement of the table as to call loudly for correction or explanation. The table shows a gradual decrease in the decennial increment from 1880 to 1910, a decline of 194,852 in three decades. But now we are called upon to accept a sudden decline of 358,519 in a single decade.

The decennial rate of increase dropped from 11.2 per cent. between 1900 and 1910 to 6.5 per cent. between 1910 and 1920, whereas we should have expected a gradual decline of not more than 1 or 2 points. On the face of the figures it seems probable that the Census Bureau has again committed an error in the enumeration of the negro population. As this bureau has admittedly committed grave errors in enumeration of the negro population in two preceding censuses, it is but reasonable that the obvious discrepancy can be most reasonably accounted for by an error in the present count.

Aside from the internal evidence itself, there is sufficient reason to suppose that this count might have been erroneous. The mobile negro population has been greatly upset by the world war. There was a mad rush of negroes from the South to fill the vacuum in the labor market caused by unsettled conditions. Thousands of negro homes were broken up and their members scattered without definite residential identity. In the cities especially, it seems probable that the count was greatly underestimated. The negro migrants lived for the most part in improvised lodgings and boarding houses whose proprietors had little knowledge and less interest in the identity of the boarders. The census official, visiting such boarding houses with a large number of negro boarders would, in all probability, receive an inaccurate underestimate by the ignorant and uncaring proprietors. As an illustration of such inaccuracy, I cite a quotation from an editorial of the *Dispatch* of Oklahoma City:

> If the census enumerators over the United States were as careless in the count as they were shown to be by this publication during the poll of the population last year, the general charge is right that the black man has made a much larger numerical advance than the official, yet faulty, records show. It will be remembered that the *Dispatch* made the charge during the enumeration that there was a laxness and really seeming desire to overlook the black man in this city. Our charge was printed in the daily papers. To cap it all off, the irate enumerator in the section of the city where the *Dispatch* is located, appeared on the evening that the charge was published, and demanded of the editor the basis of the charge. We took him out into the 300 block on East 2nd Street and found 33 black men whom he had not counted, folk who told him so, and whose names he did not have on his lists.

If a presumption of undercount was justified by the statistical indication for 1870 and 1890, surely a like presumption would obtain for the census of 1920. There are but three methods of accounting for this sudden slump in the growth of the negro population. First, an undercount of the Census Bureau, second, a sudden increase in the death rate, and third, a decrease in the birth rate of the negro population.

It is known that the death rate of the negro is decreasing rather than increasing under improving sanitary conditions and general social environment. The Director of the Census states that "the death rate has not changed greatly." Instead of adhering to the "fair assumption" of a steadily declining rate of increase, as was done for the faulty enumerations of 1870 and 1890, the Director of the Fourteenth Census accepts the violent leap from 11.2 to 6.5 and endeavors to vindicate the count of 1920, by assuming a sudden decrease in negro birth rate.

On this point the Census Bureau explains:

> The rate of increase in the negro population, which is not perceptibly increased by immigration or emigration, is by far the lowest on record. This element of the population has been growing at a rapidly diminishing rate during the past 30 years, its percentage of increase having declined from 18 per cent. between 1890 and 1900 to 11.2 per cent. during the following decade and to 6.5 per cent. during the 10 years ended January 1, 1920. Such data as are available as to birth and death rates among the negroes indicate that the birth rate has decreased considerably since 1900, while the death rate has not changed greatly.

The statement, "this element of the population has been growing at a rapidly diminishing rate during the past 30 years," that is, since 1890, presupposes the accuracy of the census of 1870, which presumption the census office itself discredits in a previous statement. It entirely overlooks the fact that the rate rose suddenly from 13.8 for 1880-1890 to 18.0 for 1890-1900. With the indicated corrections the rate of increase has declined within the expected limits of fluctuation from 22 per cent. for the decade 1850-1860 to 11.2 per cent. for the decade 1900-1910, making a drop of 10.8 points in 6 decades. The sudden downward drop by 4.6 points in a single decade certainly calls for a more satisfactory explanation than a sudden and unaccounted for decrease in birth rate. The only statement which the Census Bureau vouchsafes to account for this rather startling conclusion is a very hesitant and uncertain one:

> Such data as are available with regard to birth and death rate among negroes indicates that the birth rate has decreased considerably since 1910, but the death rate has not changed greatly.

On examining the data on which this conclusion is based, we find that they are wholly insufficient to justify the sweeping conclusion imposed upon it. The mortality statistics are based upon returns from the registration area. Only five southern states are now included in the area, namely, Maryland, Virginia, North Carolina, South Carolina and Kentucky, from which birth and death rates are collected annually, and even these states were not admitted to the birth registration area in 1900. So that the computation of birth and death rates for the colored population of these states is neither adequate nor convincing.

BIRTH RATE OF NEGRO POPULATION IN SPECIFIED REGISTRATION STATES, 1900 AND 1919 (COMPARATIVE)

STATES AND COLOR	BIRTH RATE 1900	BIRTH RATE 1919
Maryland:		
White	25.7	19.0
Colored	27.9	26.7
Virginia:		
White	31.5	25.9
Colored	33.1	27.8
North Carolina:		
White	34.3	29.3
Colored	36.5	28.5
South Carolina:		
White	32.3	27.1
Colored	38.2	26.2
Kentucky:		
White	31.2	24.7
Colored	25.2	17.7

Those are the only heavy negro states within the registration area.

These states were not all included in the registration area for 1900. Mortality statistics in the non-registration area are notoriously inaccurate and unreliable. Birth registration is especially unsatisfactory even in the registration area.

Return of negro births would naturally be most inaccurate. Negro births, especially in rural and small urban communities are not always attended by regular physicians or certified health officials. The midwife still plies her trade. There is a relatively large number of illegitimate births among negroes. Official returns in such cases would not be apt to be rendered fully for prudential reasons. It is therefore evident that the rapidly declining birth rate revealed by the census is based upon noncomparable and inadequate data.

Even the apparent rapid increase in the white death rate awaits fuller explanation before the figures can be relied upon with assurance. It is curious to note that the birth rate among the whites in South Carolina fell from 32.3 in 1900 to 27.1 in 1919, the death rate rising but slightly from 10.4 to 10.6 during the same interval. And yet the white population of that state increased from 557,807 in 1900 to 818,538 in 1920. There was a vigesimal increment of 250,731 with little or no reinforcement from immigration. This unexplained increment in the white population seems also to discredit the reliability of the recorded mortality statistics within the states so recently added to the registration area.

It is well understood that these states, except South Carolina, have shown a comparatively slow rate of increase in negro population for 30 years preceding the census in question. The facts are indicated in the following table:

DECENNIAL RATE OF INCREASE OF THE NEGRO POPULATION IN CERTAIN REGISTRATION STATES: 1880 TO 1910

NAME	RATE OF INCREASE		
	1890	1900	1910
*United States	13.5	18.0	11.2
Maryland	2.6	9.0	—1.2
Virginia	.6	4.0	1.6
North Carolina	5.6	11.3	11.7
South Carolina	14.0	13.6	6.8
Kentucky	—1.2	6.2	—8.1

From the table it will be seen that the increase in negro population in the southern states within the registration area has been considerably lower than that for the country at large. In Maryland, there is an actual decline in the negro population of 1.2 per cent, from 1900-1910 and the small gain of 2.6 from 1880-1890. In Virginia the highest rate of increase during the past 30 years was 4 per cent. In Kentucky there was an actual decline for two of the three decades. The low rate of increase in the border states is due to the large emigration of the negro from these states to the nearby northern states and cities. It is well known that the negro who migrates to the North and the large cities is made up of younger people of both sexes who, if they had remained at home, would naturally tend to increase the birth rate.

The low birth rate revealed by the census in these states is due to the migration of the negro population of reproductive age from those states within the registration area. This, of course, does not affect necessarily the birth rate of negro population as a whole. A better view of the birth rate of the negro population may be secured by considering the growth of this population in the more typical southern states not so much affected by migration during the same period.

DECENNIAL RATE OF INCREASE OF THE NEGRO POPULATION IN CERTAIN NON-REGISTRATION STATES: 1880-1910

NAME	1890	1900	1910
United States	13.5	18.0	11.2
Georgia	18.4	20.5	13.7
Alabama	13.1	21.9	9.8
Mississippi	14.2	22.2	11.2
Louisiana	15.6	16.4	9.7

Thus it will be seen that four heavy negro states, with an aggregate negro population of nearly four million, shows a rate of increase far greater than those in the registration area. The in-

*Footnote: Exclusive of population especially enumerated in 1890.

crease in those states was due wholly to the excess of births over deaths. But this does not tell the whole story. While the stream of migration was not so pronounced from these states as from the northern tier of southern states, still there has been a considerable northern movement for the past three or four decades.

From a comprehensive view of the whole situation, it seems perfectly clear that the sudden decline of the negro population as revealed by the census of 1920 is due to miscount rather than to the declining birth rate. If we should estimate an error in count of 300,000, scarcely greater than that conceded by the Census Bureau itself for the count of 1890, the negro population during the past 60 years would have followed more or less consistently the ordinary laws of growth. Let us accept the substantial accuracy of the census of 1860, 1880, 1900 and 1910 and estimate the error for 1870 at 512,163, for 1890 at 270,000, as conceded by the Census Bureau, and let us still further allow an error in the count, 300,000 for 1920, as here suggested. The growth of the negro population since 1850 will be as follows:

NEGRO POPULATION

	Number.	Decennial Increase.	Per cent. of Increase.
1920	10,763,013	935,250	9.6
1910	9,827,763	993,769	11.2
1900	8,833,994	1,073,994	13.8
1890	7,760,000	1,179,207	17.6
1880	6,580,793	1,188,621	22.0
1870	5,392,172	950,342	21.4
1860	4,441,830	803,022	22.1

The table makes the negro population behave more or less normally, and is certainly more reasonable than the startling deviation revealed by the face of returns, and the explanation is more acceptable to reason than that urged by the Census Bureau, of a sudden and unexplainable decline in the negro birth rate.

It is a source of surprise to note that the American mind seems to expect that any fact which affects the negro will deviate from the normal course of human values. It is prone to accept with satisfaction wild assertions and unsupported theories, without subjecting them to the test of logic and reason. If it is seen in the Census, it is so. Any statement issued upon the authority of the government which seems to be belittling to the negro will be seized upon by would-be social philosophers and exploited throughout the nation to the disadvantage of the race.

De Bow, relying upon the low rate of increase in the negro population, revealed by the census of 1870, proved to the entire satisfaction of those who were satisfied with this type of proof that the negro could not withstand the competition of freedom and would, forthwith, fall out of the equation as an affected factor. The census of 1880, showing the unheard of increase of 34 per cent., set all of De Bow's philosophy at naught. But thence arose another school of philosophers which declared that this unheard of increase in the negro population threatened the numerical ascendancy of the white race, and, therefore, the black man should be returned to Africa from whence his ancestors came. The census of 1890 refuted this conclusion by showing only an increase of 13.8 per cent., but, no whit abashed, another type of anti-negro propagandism arose, declaring that the rapid decline in the race indicated inherent, degenerative physical tendencies threatening to the health and stamina of the American people. The census of 1900, showing a rise of decadal growth to 18.0 per cent., produced a calm in the domain of social speculation. But the preceding prophecies of evil are still of record. It seems to be the nature of the prophet to ignore the failure of the fulfillment of his prophecies.

It is particularly unfortunate that such loose and unscientific propaganda can be bolstered up by data from governmental documents which the uninquiring mind is disposed to accept with the authority of holy writ. The calamity philosophers have already dipped their pens in ink to damn the negro race to degeneration and death by reason of the latest census figures. The thought, and perhaps the conduct, of the nation may be misled on the basis of erroneous data, backed up by governmental authority.

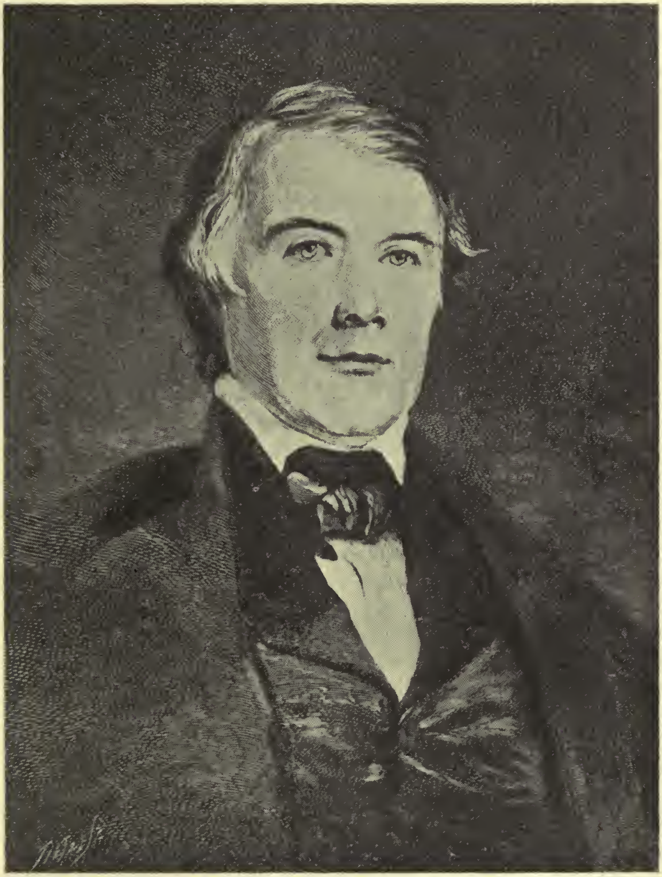
The broader question arises in the scientific mind. If the data on negro population furnished by the census can not be relied on, as is clearly shown by past enumerations, what assurance is there that collateral information, such as death rate, birth rate, occupation, illiteracy, etc., are to be given full credit and confidence. The negro problem is the most complicated issue with which we have to deal. Straight thinking and sound opinion based upon accurate data are absolutely necessary to enable us to reach any conclusion of value. The Census Office has now become a permanent bureau, which, it is hoped, will take rank with other scientific departments of the government.

Statesmen and publicists should have serious concern about the accuracy of negro statistics in view of the importance of the political and sociological conclusions based upon and derived from them.

WEATHER CONTROL

By Professor D. W. HERING
NEW YORK UNIVERSITY

IT is not in human nature to suffer from a prolonged or repeated evil without seeking for a remedy. Severe weather of any kind—heat, cold, rain or drought—if long continued causes distress and the only way to escape the ill effects of such extremes is to control the weather, either to mitigate it when it is becoming too severe or to take proper measures in advance to secure the kind of weather that is wanted. Savages and unenlightened peoples have resorted to all sorts of charms and incantations; to medicine-men, rainmakers, rain-gods, etc. These mummeries have been the subject of many articles and some elaborate treatises. The ceremonies are often curious and ingenious; some are grossly superstitious and others are mere chicanery, but usually the method of the rainmaker among primitive folk is based on homeopathy or imitative magic—for instance, he will attempt to produce a noise like thunder with the idea that this will result in the bursting forth of the genuine article and its attendant rain; or he will subject puss to an enforced bath in spite of her repugnance to it to bring about a rain, inasmuch as when she washes her face it is a sign that rain is coming. These practices have been common also with pagan nations of the highest civilization. Jupiter Pluvius was one of the most potent of the Roman Deities, and of course when the gods controlling the elements are angry they must be propitiated by suitable ceremonies. For excessive cold we provide extra means of heating, for tornadoes cyclone cellars, excessive rainfall and floods present problems for the engineer if he would ward off the destruction they would cause; these measures have reference to individuals or to isolated places, but the actual control—the production, prevention, or moderation of any special kind of weather over large districts—has not been accomplished or even attempted in the case of heat, frost or winds, though it has been undertaken with regard to the production of rain, and, according to Professor McAdie, of the U. S. Weather Bureau, meteorologists are of the opinion that "rain-control is a scientific possibility. Successful rain engineers will come, in time, from the ranks of those who study and clearly understand the physical



(*Courtesy of D. Appleton and Co.*)

PORTRAIT OF JAMES POLLARD ESPY ("OLD STORM KING") process of cloud formation.'' The modern rainmaker therefore can be nothing if he is not scientific. He must have a scientific ground for his process however fallacious it may be.

If any one can be called the Father of the United States Weather Service, it is James Pollard Espy (1785-1860). From his meteorological studies he evolved a theory of the manner in which clouds are formed in high regions of the atmosphere and produce rain. This was to the effect, essentially, that heated air at any locality rises into rarer regions and expands; this expansion is accompanied by fall of temperature which condenses the vapor in the immediately contiguous air as well as within the ascending column; this condensation liberates sufficient heat to stimulate the further rise of the central column of air, with continuous expansion, cooling, and condensation of vapor into clouds, until they are eventually precipitated as rain.

He thought that this natural process could be accomplished artificially by maintaining large fires over extensive areas, and sought governmental aid to undertake experiments for that purpose. He cited the practice of American Indians in burning the prairies to produce rain, and his agitation of the subject attracted so much attention that numerous instances were reported which seemed to confirm his theories, but his petitions to the legislature of Pennsylvania and to Congress were humorously refused. He acquired high repute as a meteorologist in Europe as well as at home, and in 1841 he published his *Philosophy of Storms* which included his proposed method of producing rain artificially. In 1843 he was placed in charge of the meteorological work of the U. S. Signal Service, his division being known as the Meteorological Bureau of the War Department, in the conduct of which he became familiarly known as ''Old Storm King''—a sobriquet which meant that if the public regarded his theories as vagaries, they thought none the less kindly of him on that account. His branch of service was afterwards transferred to the Department of Agriculture, and continued as the U. S. Weather Bureau.

Although Espy's theories are now know to be not wholly sound, their promulgation was a great incentive to further work along their line. The many instances of rain occurring either during or immediately after a severe battle or heavy cannonading had been often commented upon, and in 1871 Mr. Edward Powers published a book on ''War and the Weather'' containing a large collection of data to show that heavy cannonading was followed even in very dry regions by copious rainfall. He developed a theory that although concussion did not cause the formation of clouds in the surface atmosphere, which was lacking in moisture, in some way it did cause precipitation from the higher strata of air which carried moisture. His contention all turned upon the question whether, in the United States, in times of drouth at the surface of the earth, the upper air has a considerable supply of moisture derived not from surface evaporation, but brought from the Pacific ocean; that "it is not the moisture of the surface air east of the mountains that causes the rain; it is the rain that causes the moisture." The idea that at a great height there is a generally prevalent flow of air eastward and above that a stratum flowing westward is still entertained, and aviators are seeking to determine whether it is correct.

As might have been expected, Mr. Powers' theory too was pooh-poohed, but his arguments and illustrations were too cogent to be ignored, and the prospect of large financial benefit that might be obtained from a successful application of these ideas in the production of rain was alluring enough to induce capitalists to finance an attempt on a large scale. The national government went so far in its sanction of the enterprise as to authorize an expedition for the purpose of conducting experiments under the direction of General R. G. Dyrenforth. The Midland Ranch, in the northwestern part of Texas, was selected for the place to conduct the experiments, which were frequent and varied, during the period from the ninth to the twenty-fifth of August, 1891. Both the place and the season were thought to be above rather than below average dryness. The affair attracted much attention, and reports of the experiments were read eagerly throughout the whole country. Various forms of bombs and balloons were used to produce explosions and concussions at different altitudes. General Dyrenforth's report to Congress, (Senate: *Ex. Doc. No.* 45, February 25, 1892), was to the effect that the experiments were not extensive enough or sufficiently long continued to make safe deductions; and Mr. George E. Curtis, who was meteorologist for the expedition, concluded that "these experiments have not afforded any scientific standing to the theory that rain-storms can be produced by concussions." At the same time, the leaders and participants in this expedition did not think the theory was disproved, and its advocates regarded the tests as insufficient. Much discussion followed. Professor Alexander McFarlane, of the University of Texas, in a letter to the San Antonio Daily Express, of December 4, 1891, said "The trial of Friday, August 25, was a crucial test, and resulted not only in demonstrating what every person who has any sound knowledge of physics knows that it is impossible to produce rain by making a great noise, but also that even the explosion of a twelve-foot balloon inside a black rain cloud does not bring down a shower.'' This ''crucial test,'' however, was followed next day by a precipitation that was characterized by different persons as anything from a mere sprinkle to a heavy rainfall, two or three miles to the northwest of the place where the experiment was made, but in a direction in which the wind would have carried the clouds. It was not certain that the rain was due to the explosions, and it was unfortunate that the experiments resulted in this negative fashion and were inconclusive. One consequence of these efforts, especially to be noted, is related by Mr. Curtis. He calls attention to the rash conclusions that were drawn from the telegraphic and incomplete reports of the effect even of preliminary experiments and trying out of the apparatus, and adds ''charlatans and sharpers have not been slow to seize the opportunity thus afforded. Artificial rain companies have sprung up and are now (1892) busily engaged in defrauding the farmers of the semi-arid States by contracting to produce rain, and by selling rights to use their various methods.''

Thirty years have elapsed since the Dyrenforth experiments—what has become of the weather mongers' pseudo-scientific pretensions and practices? As lately as February 1, 1921, the public press reported from *Medicine Hat, Alberta,* the announcement by the United Agricultural Association that ''Rainmaker'' Hatfield *had been engaged to increase precipitation* during the dry season at the rate (*sic*) of $4,000 an inch. The ''Rainmaker'' says he can produce rainfall by chemical and other scientific methods, and is to operate over a section of about one hundred miles radius. That last is a very clever stipulation. It greatly increases his chance of success and makes it much safer for him to guarantee it, for a circle of one hundred miles radius covers just a hundred times as large an area as one of ten miles radius and gives him one hundred times as great likelihood of apparent success *somewhere,* as if the region of his efforts were the smaller district.

A sequel to this appears in later dispatches from Milwaukee, in which Wisconsin farmers are said to offer ''Rainmaker'' Hatfield $3,000 an inch for producing rain. The item states further that ''Hatfield has made rain for the farmers in three counties in Washington State, where he was paid $3,000 an inch. His rainmaking equipment consists of a huge tank 20 feet high in which Hatfield brews a mystic chemical mixture which, he says, opens up the clouds.'' (New York Times, July 27, 1921.)

There is here the same difficulty in tracing any connection between supposed cause and effect—the same kind of difficulty, that is present in the pretensions of the dowser. The operator goes through his performance, (so does the Indian medicine-man);

somewhere in some measure, rain falls; and the blunder, as old as man, of counfounding *post quod* with *propter quod,* continues.

The process of passing from aqueous vapor through clouds to rain is not yet well determined and the rainmaker, who must perforce be scientific, is obliged to proceed in a manner that he can show conforms to "theory." Unfortunately there is a superabundance of theories—at least five, and all have good scientific support, while not one is conclusively established to the exclusion of the others. The rainmaker favors a combination of two; (a), that dust nuclei should be in the air, about which water vapor can gather, (smoke, either from surface fires or exploded bombs will meet this need); and (b), that jars or concussions will so jostle or disturb the air that the water particles will attach themselves to these nuclei. The process of coalescence begun, it will continue of itself although the exact reasons for so doing are not altogether understood; or at least physicists are not agreed upon them. This, however, is not the rainmaker's concern so long as they do act. Mr. McAdie flouts the concussion idea. He says "Rainmakers of our time bang and thrash the air, hoping to cause rain by concussion. They may well be compared to impatient children hammering on reservoirs in a vain endeavor to make water flow."

That was written in 1895, but in 1918, nearly a quarter of a century later, a popular old English almanac, *Raphael's Almanac or the prophetic Messenger and Weather Guide,* gives this caution to its readers:

> No reliance should be placed on weather predictions during the war, as the terrific bombardments cause violent concussions in the atmosphere, producing clouds and rain, particularly in the southeast and east of England.

Weather control by artificial means, however, is not regarded as unscientific, and meteorologists are not hopeless of ultimate success in accomplishing it, at least in producing rain. At the time of the Dyrenforth experiments the psychologist, Elmer Gates, was demonstrating in his laboratory at Chevy Chase, Maryland, the production of rain electrically. Electrifying the air at one spot, (like a limited area of the earth's surface), causes expansion by the mutual repulsion of air particles; the air becomes less dense and rises, currents thus set up encounter colder air in the upper regions, and moisture is precipitated.

Various processes for rain-making have been patented, and the business is carried on with a good deal of financial success by the dowsers of the clouds. They succeed in getting testimonials apparently with little difficulty, in which the witnesses testify to things as of their own knowledge, which occur simultaneously in places twenty miles or more apart, and similar inconsistencies.

(Courtesy of Everybody's Magazine, and the Artist, Jules Guerin)

ILLUSTRATION OF SHOOTING AWAY HAIL STORMS

When clouds take on a sinister aspect it behooves man to do what he can to fend off the injury which they threaten. A hailstorm may work havoc, and in a few minutes may wreck all the hopes which the agriculturist has erected upon the labors of an entire season. It means disaster. Especially has this been the case in the rich wine-growing districts of France, Italy and Austria. Hailstorms are not uncommon there, but familiarity does not breed contempt. The growers have learned to recognize pretty readily the signs of such storms, which cover usually a small area; and the clouds from which the hail falls are massed in a limited region or pass over a narrow strip of territory.

After various haphazard experiences of viticulturists, one of them, an Austrian, Albert Stiger, invented a form of cannon in 1896 which could be readily and effectively used for the purpose of repelling and breaking up such storms. This cannon somewhat resembles the old bell-mouthed blunderbuss in form, with a chamber at the breach for a cartridge containing only powder, and a funnel shaped tube like the cone of a megaphone. Housed in little shacks on the hillsides, these are ready for use at short notice, and since they are distributed among the many adjoining vineyards, a whole battery of them can be brought into action promptly. The grapes are maturing and the vineyards are in their most vigorous growth from July to September, just at the time of year when hailstorms are most frequent, and the workmen accordingly are alert in watching for signs of danger. When the storm is seen to be gathering, the cannons are brought out and directed against the threatening cloud. Signals are sent from vineyard to vineyard and upon the first appearance of the destructive hailstone the counter bombardment begins. From the mouth of the cannon issues a mass of heated gas, smoke and smoke rings, propelled violently against the lowering cloud. The smoke rings are like those discharged from the smoke stack by the puffs of a locomotive, but with far greater energy of propulsion. In a sense this was anticipating the war, for it was a veritable gas attack in the realm of the aeronaut. The theory of the action is not very definite or well assured. Whether the rings of smoke disrupt the clouds, or whether sufficient local heating of the air causes warm air to rise and intercept the hail, converting it into rain or preventing the congealing of water vapor into hail, is uncertain; but there seems sufficient evidence of the efficacy of the plan in dispersing the clouds and checking the storm of hail. The cannons literally *shoot it away.*

LAKE Pepin is caused by the delta of the Chippewa River, which dams up the Mississippi. It is thirty miles long and has an average depth of about twenty-five feet. Its waters support many fishes and clams which are of commercial value. In order to give a picture of the life of the fishermen, the routine of a typical day at the end of June is described.

The wren that lived in the tomato can we had nailed to the tree beside our shack sang at four o'clock, as usual. I lay in my cot and drowsily thought of Chaucer's couplet:

> And small foules, a great hep,
> That had afroyed me out of slepe.

The wren sang again and then I heard the lapping of the river on the sand. The water sounded so near that I peeked over the side

THE MINNESOTA BLUFFS

OUR HOME FOR A MONTH

of the cot to see if it was in the shack, but the floor was dry. With clothes in one hand and boots in the other, I sneaked out on our front porch, which consisted of a barn door that we had salvaged from the river. The mighty provider of porches had risen eight inches during the night and was busily engaged in hurrying trees, logs and all sorts of riff raff toward New Orleans.

The sun touched the Minnesota bluffs. Ghostly clouds of mist crept over Lake Pepin. I pulled on my boots and washed. The wren sang some more. Another day had begun.

I ate my breakfast, then rubbed the spoon and pan in the sand at the margin of the river, rinsed them at the pump, and stood them on the table to dry. We rejoiced in a regular cistern pump, which, driven in the sand, gave us plenty of clear, cool water. The Israelites with Moses were no more appreciative than we!

OUR LABORATORY

I slid the skiff gently into the river and pulled against the current out on Lake Pepin. As I left our cove, I could hear the "put-put" of Earl's engine as he brought his launch around to take out the scow. At night Earl always put the launch in the slough behind the bar, safe from storms. He had a fine start this morning and should, with luck, have his seine out at ten o'clock.

The gill nets did good work. They had been set in the deepest part of the lake (55 feet) and I was rewarded for the long pull with sixteen hacklebacks,[1] two saugers, a channel cat, and two clams. There was a big carp in the two-inch mesh net and I got him to the very surface of the water. But the net was rotten and he was caught only by the saw-spine on his dorsal fin. Just as I was slipping the dip net under him—a mighty flop, and he was gone! The clams were without pearls, too. But we would have hackleback for dinner!

OFF TO SET THE SEINE

As I rowed back to camp, Earl and his crew were loading the big seine into the scow. The lake had been rough the day before, and the seine was badly tangled in the brush. Charley had his waders on and was towing the scow along the shore by hand while the others stowed the seine.

At the shack I found Tasche—wide awake, full of breakfast and ready to go out to the trot-line. Jean was already spearing carp. As soon as my catch was unloaded, Tasche jumped into the skiff and rowed away up the big slough. I had scarcely taken care of

[1] Sand-sturgeon, *Scaphyrhynchus platorhynchus* (Rafinesque).

Published with the permission of the United States Bureau of Fisheries.

HAULING THE SEINE

the fishes from the gill net and straightened up the shack a little, when he was back. I knew by the splash of his oars and the set of his back that he had something. But we went through the regular formula for such occasions. I hailed:

What luck?

Pretty fair.

The skiff dug its nose into the sand and Tasche said,

Got some more channel-cats.

How many?

Three. One of them about five pounds.

Anything else?

Why, yes. I got an eel!

DIPPING THE HAUL INTO THE SKOW

HAULING THE SEINE

With a whoop I ran down the beach. This was the only eel we got all summer! It was a fine old fellow, about three feet long. Tasche held it up, still attached to a leader from the trot-line.

"I was afraid to take him off. He's too slippery to hold!", he said.

It was a strange fish with a strange history—hatched in the Atlantic Ocean and caught a thousand miles up the Mississippi. We made a hasty examination of the eel and put the other fishes in the "live car" for future study. We were anxious to be at the hauling of the big seine.

As it turned out we had plenty of time, for the seine was not quite loaded when we reached the lake. It was soon on board the scow, however, and five minutes later Earl was towing it out into the lake. Earl handled the launch and Floyd, on board the scow, watched the line that was fastened to a tree on shore and "paid out" as they went along. When the line was out, Earl turned his course parallel to the shore to spread the seine. The great net was 2,000 feet long and 28 feet deep. The mesh was two and a half inches, bar measure; except a hundred and fifty feet in the center, which was two inches. After the net was out, Earl turned directly toward the shore while Floyd paid out another hauling line.

Floyd waded ashore with the end of the line, slipped it through a pulley which was lashed to a sturdy stump, and then handed it to Charley. That worthy took a couple of turns around the wheel of his hoisting engine—already popping away at a good rate.

The hauling of the seine took about two hours. First a long line came ashore and was neatly coiled. Then the wooden brail at one end of the net appeared above the water. Two of the boys pulled a hauling line down the beach to where the line from the other end of the net was fastened. They rigged another pulley and, without moving the hoisting engine, began hauling again. Another line was coiled down and finally the brail at the other end of the net crawled slowly up the beach.

When the brail got almost to the pulley, George threw the line off the engine and the hauling stopped. Earl took the end of the line out into the lake until the water was above his waist, stuck his toe under the bottom of the net and raised it so that he could grasp it with his hands. The hauling line was made fast to the lead line. Earl signaled to George and the net began to come on shore. Floyd and Charley took stations about thirty feet away from the water on either side of the net, which they stretched and piled down neatly on the sand to dry. Every time the knot on the lead line came up to the pulley, Earl waded out and fastened the hauling line further along the net.

Earl was ''boss'' because he was, physically and mentally, the best man of the crew. He had travelled all over the United States and served in France during the war. At thirty-three he had come back to his old home on the Mississippi and settled down to spend his life as a seiner—because he loved the outdoors and fishing, and rejoiced in hard work as a strong man should. He always took the hardest tasks; and indeed no other in the crew could do them as well. Altogether Earl was as honorable and rough and fair and profane and instinctively courteous as one could wish—a real man who asked no favors and expected to give none, but would when you least expected it.

When nearly half the net was in, the hauling line was changed

DIPPING THE HAUL INTO THE SKOW

DRYING THE NET

to the other end and another period of stretching and piling ensued. At ten o'clock there were only a few hundred feet of the seine left in the lake. Earl waved his arms and George stopped the engine. All the crew then began pulling in the "center" by hand. As the space between the seine and the shore grew narrower, the fish began to flop. A twenty-pound carp flipped over the top of the seine and Earl yell to old Charley,

"Hold up that cork line! G——! They'll go like a flock of sheep." And Charley "held up."

"There's a big spoonbill!" said George. "They've been awful scarce this year. Twenty years ago we used to get a thousand pounds a day."

"Shut up," said Earl. This was no time to spin yarns.

Finally the net was in and the crew gathered around in a little circle, holding the edges of the net well above the water so that no

LOADING THE NET ON TO THE SKOW

high jumper could escape. Tasche and I lent a hand while Floyd brought up the scow. Then Earl took a dip net, stepped among the flopping fishes, and "ladled" the catch into the scow.

There were many carp weighing from fifteen to twenty pounds —great, glittering, golden fellows that taxed even Earl's sturdy muscles. There was also a good number of sheepshead, river carp (which the Lake Pepin fishermen call "white carp"), red horses, and a mud cat—all marketable fishes. The prize of the day was a forty-two pound spoonbill. At the tail of the catch were about sixty mooneyes—beautiful, silvery fishes—which Earl saved. Mooneyes are not fit for human food, but are ground up and used as an ingredient of chicken feed.

THE HAUL

The game fishes were all put back into the water as soon as possible. It fills an unsuccessful fisherman with regret to see ten-pound pickerel and wall-eyed pike cast back into the lake. George also threw back about fifty black bass, white bass, blue-gills, and crappies.

As soon as the catch was all on board the scow, Floyd jumped into the flopping mass and began putting the small carp and buffalo back into the lake. He also recovered a few game fishes that had not been previously thrown out. Earl meanwhile was bringing up the launch and before Floyd had all the "culls" overboard he was on the way to Pepin. In half an hour after the catch left the net it was on ice in Jim Broatch's fish house, and that evening some of

THE NET IS IN

the fishes were on sale in Minneapolis and Chicago. The best part of the catch, however, was sold in St. Louis and New York two or three days later.

After the "haul" had gone to town, Charley and George pulled in the center of the net and spread it neatly on the sand. A big pike had turned belly up and was floating along the beach.

"He'll never live," said Charley. "I believe I'll cook him for dinner."

"What sort of fish do you fellows usually eat?" I asked. Charley evidently thought I was too curious on short acquaintance and did not answer. George, however, who could not forego an opportunity to say something, after pondering a moment said,

"Well, we mostly eat carp and sucker."

Tasche and I went back to the shack. As we came down the shore a big softshell turtle ran from a sand bar where she had been digging a nest. She scuttled awkwardly but swiftly down to the water, leaving a trail like a caravan.

We dined on fried sturgeon at our table under a willow tree. For dinner, sturgeon is the king of all fresh-water fishes. After the skin is off and the "chord" has been pulled out, there are no bones. The flavor is delicious and, when well cooked, a sturgeon "melts in the mouth."

The softshell climbed out on the bar again while we ate. She found a spot that suited her and began to throw spurts of sand out behind. We tried to slip away from the table without being noticed, but she gave us one neck-stretching look, then tore down the beach and disappeared into the water with a grand splash. We saw her no more.

After dinner we went up to the seiners' shack and talked a while. Sitting on the sand we had a magnificent view across the river to the tree-covered Minnesota bluffs, which tower four hundred feet above the water. As we talked scores of swallows hunted over the bars. Floyd spent all his leisure whittling. Today he was working on an American eagle perched on a ball. He finally cut a great gash in his finger and Earl tied it up. Talk drifted on from women to high prices, and from high prices to war, and finally to fishing. I asked the boys concerning the number and variety of fishes they caught in the big seine. After some debate Earl made the following estimate of the average catch per day during the season (June 15 to November 15), and the others agreed that it was "about right:"

Carp, both "German" and "river"	500 lbs.
Dogfish (1,000 lbs. on some days in autumn)	400 lbs.
Sheepshead	350 lbs.
Suckers and redhorses	200 lbs.
Wall-eyed pike	200 lbs.
Mooneye	100 lbs.
Pickerel	50 lbs.
Buffalo	25 lbs.
Spoonbill	25 lbs.
Catfishes and bullheads	25 lbs.
White bass	10 lbs.

LOADING THE NET ON THE SKOW

THE SEINING CREW

Black bass (two species)	10 lbs.
Bluegill	1 lb.
Crappies	1 lb.

At three o'clock the crew started loading the seine into the scow. Tasche and I got out the minnow seine and dragged along the shore to catch bait for the trot line. We caught a lot of shiners, a few little suckers, about two hundred log-perch, and a tadpole cat. While we were seining Jean came back from the sloughs with

CHARLEY

thirty-two carp that he had speared. Once he had lunged too far and slid over the bow of his boat. His clothes were still wet—and his language scandalous! Jean cleaned his catch and left for Pepin, where his carp would soak in brine overnight and be ready for smoking the next morning.

A fly fisherman tried his luck past our shack. He was an aristocrat among fishermen, with a man to row for him and a beau-

TASCHE WITH HIS CATFISHES

tiful outfit, and he knew his business. Drifting along near shore, his fly fell forty feet away in the exact spot that he chose and it flickered over the water in a way to make any bass long for it. We did not begrudge this fisherman the two fine bass that came into his landing net. He deserved them!

After supper Tasche rowed up into the slough and set the trot line. I sat by the fire, cooking rice and dried apples for breakfast. Before nine o'clock we had our cots set up and were spreading

TASCHE "RUNNING" THE LINE

our soggy garments out for the night. As I dozed off the hoot owl started his nightly refrain.

> And smale foules maken melodie
> That slepen alle night with open eye.

The United States has resources of great commercial value in its larger lakes and rivers. Though there are many fishes in swamps, creeks and ponds, such small bodies of water can never furnish great enough numbers to be of value to commerce. Their resources should be conserved, however, for the sportsman and small boy. Every fish caught on a hook and line probably costs dollars in tackle and time, but it is worth what it costs in health and the wealth of spirit which accrues to those who live outdoors.

There has always been some conflict of interests between those who fish for the market and those who fish for sport or to get a fresh dinner. The one wants a continued supply of large fishes; the other is after a few fine specimens that he can show his neighbor with pride—caught by himself! There will always be these two classes of fishermen and civilization must keep a place for them.

The citizens of the United States have already committed some errors in the administration of the fisheries resources in the Mississippi River. Aggressive and interested sportsmen have secured the passage of certain laws; those concerned in making money have fathered concessions which helped their business. There has been a deal of prejudice, misunderstanding, and thoughtlessness. To a scientist, such conflict seems unnecessary.

The "ultimate" food resources for the animals in the Mississippi are in the aquatic vegetation. Water plants, given solar energy, can make living substance from minerals, water, and carbon dioxide. As animals cannot do this, they depend on plants for food, directly or indirectly. The Mississippi River itself does not contain many plants. Its bottom shifts too rapidly and its water is usually too turbid to permit the passage of solar energy to any except very shallow depths. Its chief value for fishes is as a highway through which passage is permitted to the great stores of food in tributary swamps, ponds, and other situations where plants flourish.

What are the foods of the chief commercial fishes? The carp is omnivorous, but its food is chiefly vegetation. It does great damage to aquatic plants, grubbing up wild celery and other plants which might afford food and shelter for ducks and game. Its best feeding grounds are in swamps. The dogfish feeds largely on crawfishes and minnows. The sheepshead eats snails, clams, and mud. The suckers and red horses feed chiefly on mud and the small organisms associated with it. All these fishes of commercial importance as food do injury to man. The carp destroys vegetation; the dogfish eats game fishes; the sheepshead, and to some extent the carp, devour many young clams which might otherwise grow large enough to be made into buttons. Suckers and carp follow other fishes when spawning and eat their eggs. In all respects it is desirable that the resources represented by these four

TASCHE AND THE EEL

food fishes be conserved, by preserving swamp areas and sloughs, and it is also desirable to keep catching the larger fishes continually in order to check the injury they may do. The sportsman who talks of prohibiting seining, while fishing by "sportsman's" methods continues, is advocating the unchecked increase of "rough" fishes which will compete with the game fishes in aquatic habitats. Wise, supervised seining is one of the best means of increasing game fishes.

The fishes the sportsman most loves are insect and fish eaters. Both the favorite foods of these fishes are usually associated with aquatic plants. The bass hunt among aquatic vegetation for immature insects and skim the surface for adults; the pickerel and pike lurk along the margins of water gardens, ready to snap up any small fish that passes. These fishes are most often found where water plants grow abundantly.

There have been marked changes in Lake Pepin during the past decade. Time was when a seiner caught a thousand pounds of spoonbills every day and when buffaloes were second in commercial importance only to spoonbills. Big sturgeon were also common. Now these fishes are scarce; the carp, sheepshead and, once despised, dogfish have taken their places in the markets. Fish epicures have been obliged to lower their standards. The causes of the decrease of the more desirable food fishes is uncertain. Perhaps overfishing, the introduction of the carp, the pollution of the river by industrial wastes, and the construction of dams have contributed, but there is no satisfactory scientific explanation.

A great natural asset like Lake Pepin should be appreciated—natural reservoir, source of free food for the poor man, livelihood for the fisherman, recreation for rich and poor. It is worth much to the nation. The Mississippi is an opportunity—for science to gain a knowledge of causes, for the government to conserve and improve valuable resources.

FLOWER SEASONS

By CHARLES ROBERTSON
CARLINVILLE, ILLINOIS

THE statements made here are based upon observations made from 1884 to 1913, at Carlinville, Illinois, regarding the blooming seasons of 470 indigenous and 54 introduced entomophilous (insect pollinated) flowers. Twenty-three native and seven introduced species, with an average of five days, are excluded as fragmentary. The blooming time of each flower includes early dates for early seasons and late dates for late ones, and is therefore, when correct, longer than the time for a single season. Unless otherwise specified the statements relate to indigenous species.

March—The season opens on the 15th and shows only 21 plants in bloom for the month. Nevertheless, March shows the highest percentages of trees, 19.0; shrubs, 14.3; woody plants in general, 33.3; acaulescent herbs, 23.8; and white flowers, 57.1; Salicaceæ, 9.5; Parietales, 23.8; Ranales, 19.0; Caryophyllales, 14.2;, and Polemoniales, 9.5; Thalamifloræ, 61.9, and Archiclamydeæ, 85.7—all of the characteristic early groups, except Monocotyledons and woody climbers.

April—This month shows the highest percentages of flowers coming in bloom, 78.6; greenish-yellow flowers, 17.4, and non-social flowers, 75.7; Coronarieæ, 9.7; Ranunculaceæ, 11.6; Cruciferæ, 8.7; Rosaceæ, 8.7; Liliaceæ, 8.7, and Violaceæ, 7. 7. The Parietales and Salicaceæ show April maxima.

May—The following show May maxima: Monocotyledons, Thalamifloræ and Archiclymydeæ; Ranales, Coronarieæ and Umbellales; Orchidaceæ, Caryophyllaceæ, Rosaceæ, Ranunculaceæ, Cruciferæ, Liliaceæ and Umbelliferæ; trees, woody plants in general, pendulous flowers and greenish-yellow flowers. May shows the highest percentages of Calycifloræ, 29.1; Monocotyledons, 14.0, and Umbelliferæ, 6.0. Half the families with more than six species have May maxima. May shows more suborders, families and genera than August, and more families at the maximum, but the groups are represented by fewer species. Therefore, if the fourteen families with more than six species are thrown together, August will show the maximum of species. Only 16.5 per cent. of May flowers bloom through the month, while 58.6 per cent. of August flowers are continuous. The Inferæ begin to form a marked element of the flora.

June—No dominant groups, except Polemoniales, show a maximum in June. They have less influence in the composition of the June flora than in that of any other month. All are declining from an early maximum or rising to a late one. June shows a maximum of woody climbers, all of the species blooming in the month, and of shrubs, but fewer species than in May. It is the most heterogeneous, having the most orders and the most families, and more genera than any other month except July, which has the same number.

June has the most discontinuous blooming seasons. The Scrophulariaceæ, Rosales, Parietales and Thalamifloræ show depressions. June 2 has fewer flowers in bloom than any other day from May 10 to September 24. More species, and a higher percentage of species, go out of bloom than in any other month except September and October, which close the season. In number beginning to bloom it is exceeded only by July. Uniting those beginning and ending gives the highest number for any month. The difference between the percentage of flowers and the percentage in bloom together is greatest for June. The Personales, Lamiales, Compositæ and Papilionaceæ enter as important elements of the flora.

July—The Calycifloræ, Bicarpellatæ, Rosales, Gentianales, Asclepiadaceæ, Papilionaceæ, white flowers, and introduced plants show July maxima. It has the highest percentages of perennial herbs, 72.0, Rosales, 16.4, and Papilionaceæ, 10.0. The Bicarpellatæ for the first time surpass the Calycifloræ. The dark colors begin to preponderate over yellow, including greenish-yellow. Woody plants form only 8.0 per cent. of the July flora. It shows the most flowers beginning to bloom, and more genera than any other month except June, which has the same number.

Comparing July and August gives the following percentages: Of the flora, 53.1, 51.4; of flowers of the month blooming through the month, 37.6, 58.6; of flora in bloom at maximum, 41.7, 42.7. July has the most flowers in bloom, but fails to show the maximum on account of less continuous blooming.

August—This month shows maxima for Inferæ, Asterales, Compositæ, Alismaceæ, the general entomophilous flora, zygomorphous, dark colored, yellow flowers and perennial herbs. The most remarkable thing about August is that 142 of its species, 58,6 per cent., bloom through the month. The nearest approach to this is July with only 94 species, 37.6 per cent. continuous. This is directly connected with the long blooming seasons of the later flowers. The effect of this is that July, while it has eight more species in bloom in the month, shows five less in bloom simultaneously and that only on the last day. In the case of the Asterales, also, there are three more species in bloom in September, but one less at the highest point of those in bloom together. The position of the principal groups of Dicotyledons is just the reverse of what is found in May. August differs from May in having fewer dominant maxima, but in having more species in each. Only 16.5 per cent. of May flowers are continuous, while 58.6 per cent. of August flowers are so. August has the highest percentage of Personales, 7.4.

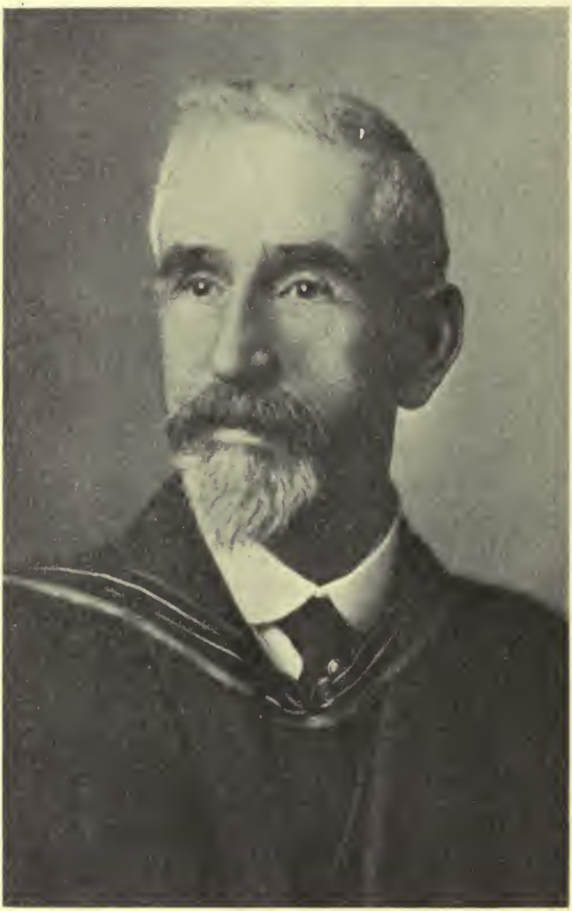
September—The characteristic of September is the decline of general flora. While in August only 51 plants, 21.0 per cent., go out of bloom, in September 115, 57.2 per cent., do so. September shows the highest percentages of dark flowers, 32.3, yellow, 29.3, Lamiales, 11.4, and Labiatæ, 8.9. It shows a maximum for Convolvulaceæ.

October—The flora is 24.7 per cent. less than in August and 3.9 less than April. It has the highest percentages of social flowers, 60.4; annuals and biennials, 42.3; Asterales, 47.0; Polygonaceæ, 9.4; Inferæ, 50.6, and Sympetalæ, 70.5.

A peculiarity of October is connected with the differences in the blooming habits of indigenous and introduced plants. The indigenous ones bloom a shorter time and have become adjusted to the climate so that they decline in anticipation of the approaching cold. The introduced plants average twice as long and often quit blooming only when they are frozen. In October 18.0 per cent. of the indigenous and 64.1 per cent. of the introduced plants are in bloom. While the introduced plants are only 10.1 per cent. of the total flora, they are 28.5 per cent. of the flowers in bloom in October, 39.1 per cent. of the flowers blooming after October 16th.

Another peculiarity of October is that the Thalamifloræ predominate over the Calycifloræ for the first time since April. This helps to explain the higher percentage of white flowers in October over September.

November—This is altogether fragmentary and shows only in unusually late seasons. There are eight indigenous, 57.1 per cent., and six introduced species, 42.8 per cent.



DR. J. PLAYFAIR McMURRICH
Professor of Anatomy in the University of Toronto, President of the American Association for the Advancement of Science.

THE PROGRESS OF SCIENCE[1]

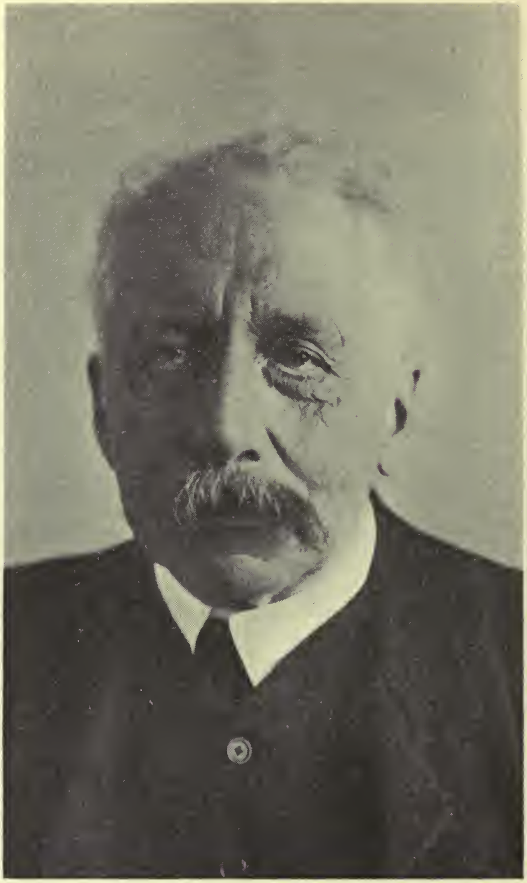
THE TORONTO MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

At the meeting of the American Association for the Advancement of Science and of the associated scientific societies held at Toronto during Christmas week, the total registration was 1,832, and the number of papers and addresses presented before forty sections of the association and associated societies numbered about 900. The meeting was much larger than had been anticipated, partly through the participation of the citizens of Toronto and Ontario in accordance with the precedent set by the British Association. The number in attendance from the United States was 867. The arrangements made by the University of Toronto and the Royal Canadian Institute for scientific sessions and for the enjoyment of the visiting members were unusually complete. About 800 were provided with rooms and meals in the dormitories and halls of the university, and many of the dinners and social events were held on the university grounds.

The meeting of the scientific men of North America was both pleasant and useful and will lead to their closer cooperation for the advancement of science. Both this year and last a number of leading Canadian men of science were elected chairmen of the sections, and this year, for the first time since Sir William Dawson held the office in 1882, a Canadian was elected to the presidency. In accordance with the usual sequence of alternating between the exact and natural sciences, and from a number of distinguished men who were proposed, Dr. J. Playfair McMurrich, professor of anatomy in the University of Toronto, was elected. Dr. McMurrich's scientific research and publications have not been confined to human anatomy, but include comparative morphology, the factors of evolution and the history of science. Born and educated at Toronto, he has had wide experience in the universities of the United States, having received his doctorate of philosophy and taught at the Johns Hopkins University, and having held chairs successively at Clark, Haverford, Cincinnati and Michigan, before accepting the professorship of anatomy at Toronto in 1907. Dr. McMurrich will preside at the meeting to be held next year at Boston, and will give his address at the meeting to be held the following year at Cincinnati.

The American Association holds its larger convocation week meetings once in four years, successively in New York, Chicago and Washington. It is planned that all the scientific workers of the country shall unite in these meetings and it is hoped that they will ultimately be joined by scholars who carry forward research in subjects not usually included under the natural and exact sciences. The meetings at the intervening two-year periods, as the one next year at Boston, are intended to bring together most of the associated societies. On the intervening alternate years, many of the special societies find it an advantage to meet separately in smaller university towns, where the personal contacts are closer. Thus this year the important groups of sciences devoted to anatomy, physiology, biological chemistry,

[1] Edited by Watson Davis, Science Service.



DR. WILLIAM BATESON, F.R.S.
Director of the John Innes Horticultural Institution, Merton, London

pharmacology and experimental pathology met at Yale University. The geologists, including the paleontologists and meteorologists, met at Amherst, an early center of geological science in America, whose traditions have for fifty years been carried forward by Professor B. K. Emerson, to whom a presentation was made. The geographers met at Washington, the astronomers at Swarthmore College, the anthropologists at the Brooklyn Institute and the psychologists at Princeton.

This somewhat wide scattering of the societies associated with the association made the success of the Toronto meeting the more notable. It has indeed often been the case that meetings more remote from the familiar centers have been especially enjoyable. Toronto is near the

SIR ROBERT FALCONER
President of the University of Toronto

northern limit of scientific activity, but it is convenient of access from the east and west. The University of Toronto and the city unite some of the characteristics of older and newer civilizations, and the meeting had features of the British Association.

Among them was the conferring of honorary degrees at a special convocation of the University of Toronto by Sir Robert Falconer, president of the university, on the presidents of the association for last year and this and on the guest from England, whose official appearances added much to the interest of the meeting. The address by the retiring president, Dr. L. O. Howard, chief of the Bureau of Entomology of the United States Department of Agriculture, reviewed the war on insects, in which he himself has been a field marshal. Dr. Howard also reviewed preceding presidential addresses before the British and American Associations, with which he has had opportunity to become especially familiar in the course of the eighteen years during which he has been associated with a long line of distinguished men in his service as permanent secretary of the association.

Preceding Dr. Howard's address,

Sir Robert Falconer welcomed the association in admirable terms, and Professor E. H. Moore, of the University of Chicago, responded with felicity for the association. At the second general meeting, Dr. William Bateson, director of the John Innes Horticultural Institution at Merton, London, and present as the guest of the American Association and of the American Society of Zoologists, gave an address on "Evolutionary Faith and Modern Doubt," in which he argued that while the fact of evolution is not in question, the problems of the origin of species are still unsolved. Dr. Bateson paid a tribute to the "Stars that have arisen in the West," by whose work solutions have been found for many of the difficult problems of genetics, including the direct association of the chromosomes with the developing organism.

RESOLUTIONS OF THE AMERICAN ASSOCIATION CONCERNING THE PUBLIC WELFARE

The National Academy of Sciences is by law the scientific adviser of the government, but the American Association and the associated scientific societies have equal responsibility, representing as they do the consensus of opinion of scientific men. It may be hoped that in the future the council of the association, composed largely of delegates from the associated national societies, may take an active part in enlightening public opinion and in guiding legislation on problems concerned with the advancement of science and its applications to the public welfare. At Toronto several resolutions looking in this direction were adopted by the council.

It put on record its opposition to any action by which the Forest Service or the National Forests of the United States or of Alaska would be removed from the jurisdiction of the U. S. Department of Agriculture. The suspension of scientific periodicals issued by the government, such as the *Journal of Agricultural Research*, the *Experiment Station Record* and the *Monthly Weather Review*, was condemned. The introduction of non-native plants and animals into the national parks and all other unessential interference with natural conditions was opposed. A resolution declared that the American Association "recognizes the need and timeliness of fundamental research on the scientific principles which must underlie the formation, standardization and introduction of an international auxiliary language."

Noting that it had already affirmed its belief in the desirability of the adoption of the metric system by the United States, the council urged consideration by Congress of the metric bills before it.

The United States Commissioner of Fisheries having presented his resignation, the council went on record as emphasizing the prime importance of securing a man who possesses the special experience and scientific knowledge of the field, combined with the necessary administrative ability for discharging the duties of the position.

SCIENTIFIC ITEMS

We record with regret the death of Henry Turner Eddy, professor emeritus of mathematics and mechanics in the University of Minnesota and dean emeritus of the graduate school; of Dr. Howard B. Cross, of the Rockefeller Institute for Medical Research, of yellow fever while studying that disease at Vera Cruz; of Henrietta Swan Jewett, of the Harvard College Observatory; of Earl Jerome Grimes, associate professor of biology at the College of William and Mary, and of Max Verworn, professor of physiology at the University of Bonn.

THE SCIENTIFIC MONTHLY

MARCH, 1922

THE PROBLEMS OF THE TIDE

By H. A. MARMER
COAST AND GEODETIC SURVEY, DEPARTMENT OF COMMERCE

AS a phenomenon of every-day occurrence the regular rise and fall of the tide must have been noted early in the history of mankind. It so happens, however, that the maritime people of antiquity whose history has come down to us lived close to the shores of the Mediterranean Sea where the tide is very small. As a consequence, the tide received scant attention from these people, since it was of little importance in their every-day affairs, and the tidal knowledge possessed by them was not very extensive.

Not only did the maritime people of antiquity disregard the tide for practical purposes, but even as a subject of study and speculation tidal phenomena received little attention. In consequence of the small range of the tide in the Mediterranean the tidal phenomena were not very impressive, and the regularity of their occurrence was frequently masked by the disturbing effects of wind and atmospheric pressure. So far as biblical literature is concerned, there appears no direct reference to the tide either in the Old or New Testaments. And even in classical literature the passages dealing with tides are relatively few in number.

In common with the early explanations advanced for other physical phenomena, the earlier attempts at explaining the tides were based largely on fanciful notions. Some of the ancient philosophers believed the earth to be an animal; it therefore appeared entirely logical to ascribe the rise and fall of the tide to the breathing of this animal or to its drinking in and spouting out a certain portion of the water. Another explanation based on the same belief regarded the water as constituting the blood of the earth and the tide as the beating of its pulse.

With the growth of a more critical spirit more rational theories were advanced, and we find the tide ascribed to differences in the level of the sea, to the discharge of rivers into the sea, to whirlpools and eddies, and finally to sun and moon. Just how early the connection between moon and tide had been recognized we do not know; we do however have record of the fact that Pytheas of Massilia who lived about 325 B. C., and who navigated the ocean from the Strait of Gibralter to the British Isles, noted a relationship existing between moon and tide.

When we come toward the end of the first century of the Christian era, we find the tides ascribed definitely to the action of sun and moon. In his Historia Naturalis, which appeared in the year 77 A. D., Pliny, the Elder, speaks of the tides in the following words:

> Much has been said about the nature of waters; but the most wonderful circumstance is the alternate flowing and ebbing of the tides, which exists, indeed, under various forms, but is caused by the sun and moon.

In succeeding passages, Pliny describes some of the principal phenomena of the tides. He is aware that there are two high and two low waters in a day; that the tides at any given place follow the moon's meridian passage by an approximately constant interval; that the extent of rise and fall varies with the changing phases of the moon, and that the tides are higher at the times of the sun's equinoxes than at the solstices. He does not however advance any explanation for the relationship of moon and tide except that in the concluding passage of the section devoted to tides he says:

> Hence we may certainly conjecture, that the moon is not unjustly regarded as the star of our life. This it is that replenishes the earth; when she approaches it, she fills all bodies, while when she recedes, she empties them. From this cause it is that shell-fish grow with her increase, and that those animals which are without blood more particularly experience her influence; also, that the blood of man is increased or diminished in proportion to the quantity of her light; also, that the leaves and vegetables generally, as I shall describe in the proper place, feel her influence, her power penetrating all things.

That the tide is brought about by the combined action of sun and moon, Pliny definitely states; but he likewise definitely ascribes the leading rôle to the moon. The early formulation of the problem of the tide may therefore be stated as follows: The moon governs the rising and falling of the surface of the sea; how does the moon do this?

Progress to the Time of Newton

This problem of the agency by means of which the moon exerts its influence on the waters of the earth appears to have engaged the attention of many of the leading philosophers in the centuries following Pliny. Thus at the beginning of the eighth century, some six hundred years after Pliny, we find the noted English scholar, the Venerable Bede, devoting to the tides a chapter in his De Temporum Ratione. And while on the English coast the tide is a much more impressive phenomenon than on the shores of the

Mediterranean, there appears no progress in Bede's remarks toward a solution of the problem of the tide.

Indeed, virtually no progress can be recorded for sixteen hundred years following the time of Pliny. While we find Kepler and others attributing the tides to an attractive force of the moon analogous to magnetic attraction, there were not wanting others, among whom must be mentioned Gallileo, who contended that the idea of the moon being the principal cause of the tides was preposterous. The state of knowledge regarding the tide about the middle of the seventeenth century is well summarized in the Geographia Generalis of Bernhardus Varenius which appeared in 1650. The following quotation is from an English translation by Dugdale in 1733:

> There is no Phænomenon in Nature that has so much exercised and puzzled the Wits of Philosophers and learned Men as this. Some have thought the Earth and Sea to be a living Creature, which, by its Respiration, causeth this ebbing and flowing. Others imagined that it proceeds, and is provoked, from a great Whirlpool near Norway, which, for Six Hours, absorbs the Water, and afterwards, disgorges it in the same space of Time. Scaliger, and others, supposed that it is caused by the opposite Shores, especially of America, whereby the general Motion of the Sea is obstructed and reverberated. But most Philosophers, who have observed the Harmony that these Tides have with the Moon, have given their Opinion, that they are entirely owing to the Influence of that Luminary. But the Question is, what is this Influence? To which they only answer, that it is an occult Quality, or Sympathy, whereby the Moon attracts all moist Bodies. But these are only Words, and signify no more than that the Moon does it by some means or other, but they do not know how: Which is the Thing we want.

Newton's Contribution

With the discovery of the law of gravitation by Newton, the connection between moon and tide received a rational explanation. In his Principia, which appeared in 1687, Newton proved that the tides were a necessary consequence of the law of gravitation. The sun and moon in their varying positions relative to the earth bring about attractive forces which, with regard to the solid earth and the overlying waters, are unequal. And it is these differences of attraction which give rise to the tides.

Newton treated the problem as a static one. Simplifying matters by supposing the sea to cover the whole earth and to assume at each instant a surface of equilibrium, he was able to deduce the principal phenomena of the tides in terms of the theory of gravitation. Thus, from this method of treatment it followed that two high and two low waters should occur each day and that the range of the tide should be greatest about the times of new and full moon and least when the moon was in quadrature. Furthermore, morning and afternoon tides should be unequal except when the sun and moon are in the plane of the equator.

Having shown the adequacy of the theory of gravitation to account for the principal phenomena of the tides, Newton did not push his investigations further, but left the development of the theory of the tides to subsequent investigators. And it appeared, at first, as if the problem of the tide were nearing a complete solution.

But it soon became evident that Newton's theory of the tide could not be made to explain a number of important features. On the assumption of the surface of the sea being a surface of equilibrium in response to the tide-producing forces of sun and moon, the range of the tide should not be over three feet, and should vary from the equator to the poles. As we actually find the tide in nature, however, the rise and fall varies from less than a foot to more than forty feet, but without the slightest relation to latitude. Furthermore, according to this theory, the daily inequality in the tides, that is, the inequality in the two high or two low waters of a day, should be zero at the equator and very considerable in the higher latitudes. Yet we find this inequality quite negligible on the coasts of Europe and very marked in the equatorial regions of the Pacific.

There are other features of the tide which this theory leaves unexplained. In fact, the basis of this static theory is in one respect completely at variance with the actual condition of things, for the surface of the sea in response to the tide-producing forces does not even approximate toward a surface of equilibrium. Nevertheless, this theory of the tide, as formulated by Newton, furnished the foundation on which all subsequent work was based; and in the hands of Daniel Bernoulli (1700-1782) this static theory, known as the Equilibrium Theory, was developed sufficiently to give it practical value in the prediction of tides for any particular port when based on tidal observations made at that port.

It may be of interest to note here that in 1738—some fifty years after Newton's formulation of the law of gravitation—the Académie des Sciences at Paris proposed the problem of the tides as the subject of a prize essay. Two years later this prize was divided among four contestants: Daniel Bernoulli, professor of anatomy and botany at Basel; Colin Maclaurin, professor of mathematics at Edinburgh; Leonard Euler, professor of mathematics at St. Petersburg and the Jesuit Antoine Cavalleri. The three first mentioned based their essays on the principle of gravitation and on Newton's theory of the tide, but Cavalleri based his on Descartes' theory of vortices. This appears to have been the last honor paid to Descartes' theory which had already been abandoned by most philosophers in favor of Newton's more rational theory.

With the discovery of the law of gravitation, the formulation of the problem of the tide became somewhat changed, for it was now no longer a question as to the agency by means of which the moon controlled the tide. The problem now resolved itself to deriving a formula which would express completely the relation between the rise and fall of the sea and the tide-producing forces brought about by the gravitational attraction of moon and sun. This, as we found, Newton's static theory of the tide did not accomplish.

The Dynamic Theory

Toward the close of his prize essay on the tides, Euler attempted to treat the problem as one of fluid motion. However, the equation he derived to express the tidal conditions is regarded as not expressing the true tidal conditions, but merely somewhat analogous ones. And it is to Laplace that we must credit the first attempt at a solution of the tidal problem as one of fluid motion. In other words, he approached the problem from the standpoint of dynamics and his theory is known as the dynamic theory of the tides.

Laplace's theory of the tides is contained in his Mécanique Céleste, and his contribution has been of profound importance in the development of the subject. He determined the fundamental tidal equations and expressed the tide-producing forces in the form of the potential, from which the actual forces upon any point of the ocean can readily be obtained. He showed further that these forces could be put in the form of a trigonometric series in which the angle varied with the time. But the solution of the equations resulting from the dynamic theory, after introducing the complex conditions of the existing oceans, either surpasses the power of analysis or entails such enormous labors as to be practically impossible. So that Laplace's theory, although very profound, does not succeed in expressing by means of a formula the rise and fall of the tide as we actually find it in nature.

A different approach to the dynamic solution of the problem was made by Airy, who treated the rise and fall of the tide as the movement of waves in canals. While expressly stating that this theory was imperfect, since this mode of treatment would not apply to every part of the ocean, he nevertheless derived a number of important results which serve to explain many of the observed phenomena of the tides in rivers and channels to which none of Laplace's results is strictly applicable.

Following Airy, a number of eminent mathematicians—Ferrel and Harris in America; Stokes, Kelvin, Darwin, Rayleigh, Lamb and Hough in Great Britain; Lévy and Poincaré in France; Börgen in Germany—have added to the further development of the theory of the tides, either by dealing with the matter directly or by investigating some of the mathematical and physical questions involved. In the meantime there had also occurred a very notable increase in our knowledge of the geographical distribution of the tides brought about, in part, by the use of the automatic tide gauge for securing continuous observations over a considerable period of time.

SUBSTITUTION OF "PROBLEMS" FOR "THE PROBLEM"

With the extension of our knowledge of the rise and fall of the tide as it actually takes place in the various oceans, it became evident that the use of a simple mathematical formula to express the phenomenon was becoming increasingly difficult. For the coordination of the material at hand necessitated such an overloading with corrections of the simpler formulæ previously in use that the unity and simplicity assumed became altogether fictitious.

There thus came to be a tacit recognition of the fact that instead of being confronted with a problem of the tide, the phenomenon involves a number of problems. In other words, the tides as they manifest themselves in the various oceans constitute, not a single phenomenon, but a number of phenomena united only by the bond of a common sustaining force in the gravitational action of sun and moon.

The earliest formulation of the problem of the tide involved the determination of the agency whereby the moon controlled the tide. With the announcement of the law of gravitation, the problem shifted to deriving a mathematical formula to express completely the rise and fall of the tide at any point in response to the tide-producing forces of sun and moon, this involving the assumption that the tide represents a world phenomenon. Now we come to a further shift in the recognition that the phenomena of the tides as we find them in nature involve a number of problems. As matters stand now we may formulate the problems of the tide as follows: Given the tide-producing forces of sun and moon and the form, size, depth and location of an ocean basin or other body of water; required the resulting tidal phenomena.

It is to be noted that in the present formulation of the old "problem of the tide" there is a tacit recognition of the fact that the tide may not constitute a single world phenomenon, and that the tides in any given ocean basin may be independent, to a very large extent, of the tides in the other oceans. This change of view resulted directly from the increased knowledge of the behavior of the tides at various places. The tides of the north Atlantic were the ones with which the first investigators were familiar, and the ones with which they compared their theories. The tides of the

Pacific were found to be considerably different, and the tides in the Gulf of Mexico differed still further. And as accurate observations for the lesser known regions increased, further differences in the tides were brought to light.

This increase in the store of accurate information regarding the tides of the seven seas, while disastrous to the elegance of the solution of the problem of the tide, permitted a mechanical conception of the movement of the tide. By a synthesis of the results of these widely scattered tidal observations it had become possible to construct a theory, based on the observed times and heights of the tide, as to the mechanism whereby the tides along the various coasts are brought about by the tide-producing forces of sun and moon.

Whewell's Progressive Wave Theory

In 1833 William Whewell presented before the Royal Society of London a memoir entitled "Essay Towards a First Approximation to a Map of Cotidal Lines." Included in this memoir was a map of the world on which were drawn so-called cotidal lines, that is, lines joining points at which high water occurs at the same time. On this cotidal map, the tide is shown progressing from south to north in the Atlantic, Pacific and Indian Oceans, while in the Southern Ocean, the belt of water that completely encircles the globe southward of the great land masses, the tide is shown as progressing westward.

It is to be remembered that tidal observations have been confined almost without exception to the immediate vicinity of the coast, and that over the wide expanses of the open ocean the time of high water is not known from direct observations. The joining by a cotidal line of two points separated by a wide expanse of water, can only be made in accordance with certain assumptions, and the entire character of a cotidal map depends on these assumptions. Whewell expressly emphasized this by stating in his conclusion to the memoir "I shall be neither surprised nor mortified if the lines which I have drawn shall turn out to be in many instances widely erroneous: I offer them only as the simplest mode which I can now discover of grouping the facts which we possess."

The name of Whewell and also that of Sir John Lubbock (1803-1865) should have been included in the list of those whose work contributed considerably to the advancement of our tidal knowledge. Dealing largely with observational results these two investigators analyzed and coordinated enormous masses of tidal data at various ports. And it was at Whewell's suggestion that in 1835 the United States and several European countries cooperated in securing simultaneous tidal observations covering a period of about three weeks at a number of points.

As represented by Whewell the tide has its origin in the Southern Ocean. Here, it was argued, the tidal forces have almost uninterrupted sway and the moon in its journey around the earth compels the tide in this ocean to keep time with its own motion. And it is from this tide wave, which is constrained to keep step with the moon, that tides are propagated to the north through the three great channels of the Atlantic, Pacific and Indian Oceans.

Whewell's progressive wave theory, or, as it is frequently called, the Southern Ocean theory, therefore sets up the forced tide wave in the Southern Ocean as dominating the tides of the world. From this primary forced tide wave, progressive waves set northward through the various oceans at a rate dependent on the depth of the tidal waterway. And the differences in the times, ranges and types of the tide are accounted for as being due to differences in depth and width of channel, to changes in the configuration of the shore line and to interferences of tide waves coming from different directions.

This progressive wave theory has many things in its favor: it is very plausible and explains certain features of the tides as they are found in nature. And it has had many distinguished proponents, notably Sir George Darwin, son of the great Darwin and himself a mathematician of the highest rank. To quote Darwin, "It is interesting to reflect that our tides to-day depend even more on what occurred yesterday or the day before in the Southern Pacific and Indian Oceans than on the direct action of the moon to-day."

Too many of the characteristics of the tides however, are left by the progressive wave theory to be explained by changes in cross section of channel, configuration of coast line and by interferences of tide waves coming from different directions. Moreover, a number of investigators had from time to time suggested stationary waves or oceanic oscillation as a probable explanation of the very considerable rise and fall of the tide at many places on the open coast. And at the beginning of the present century the stationary wave was made the basis of a new theory of the tide.

Harris' Stationary Wave Theory

This newer theory is diametrically opposed to the ideas advanced by the Southern Ocean theory of the making of the tide. It does away with the conception of a single world phenomenon and substitutes regional oscillating areas as the origin of the dominant tides of the various oceans. It may be of interest to note here that the older theory is due to European mathematicians and tidal workers, while the newer theory is the outgrowth of American genius. Almost entirely, the stationary wave theory is the work of one man, the late R. A. Harris of the United States Coast and Geodetic Survey. Before taking up this newer theory, it will be of advantage to digress for a moment to a consideration of progressive and stationary waves.

Along the coast we are familiar with the waves that come in from the ocean, the crests of which progress uniformly from point to point. If for the moment we call the crest of such a wave high water and its trough low water, it is evident that when this wave travels over a body of water, the times of high and low water will progress uniformly from one end to the other of the body of water. This kind of wave is known as a progressive wave, and such a wave travels with a speed depending on the depth of water.

A wave of a totally different kind may also be made to travel through a body of water. Suppose we have a vessel, say a rectangular tank, partly filled with water. If we raise and then immediately lower one end, a wave will be started which puts into oscillation the whole body of water. But it will be noticed that high water will occur at one end when it is low water at the other end, and that for the body of water as a whole, high water will occur simultaneously for one half at the same instant that it is low water for the other half. This type of wave is known as a stationary wave.

If we start stationary waves in tanks of various lengths filled with water to different depths, we will find that the time taken for a wave to travel from one end to the other and back, or the period of the wave, depends only on the length of the tank and the depth of the water. And if it is desired to maintain a wave of this kind in a tank, it is only necessary to apply a slight force to the tank at regular intervals; but it will be found that if this force is applied at intervals that coincide with the period of the wave we will have the maximum results.

Now to come back to the tides, the Stationary Wave theory states that the dominant tides of the world are caused by stationary waves which are set up and maintained in various portions of the oceans by the periodic tidal forces of sun and moon. According to this theory therefore, the tides do not constitute a general world phenomenon, but are local phenomena, the tides of any given region being due primarily to the stationary wave oscillation of that region.

The principal tidal forces of sun and moon have a period of about half a day. A stationary wave of the same period, in the deep waters of the ocean, has a length of approximately five thousand miles. On a map of the world that shows soundings we can therefore locate regions which have the requisite lengths and depths to support a stationary wave having the same period as the principal tidal forces. Dr. Harris has done this and has outlined the systems of oscillating areas for the various oceans; and furthermore, by theoretical considerations, he has connected the phases of oscillation of these systems with the phases of the tide-producing forces.

The stationary wave theory thus makes of the tides of any given body of water a separate and distinct problem. If the body of water is small and sufficiently deep, we shall have equilibrium tides, that is, the surface will arrange itself normal to the direction of terrestrial gravity as disturbed by moon and sun. If the body of water is situated along the coast, the tide may be due either to a progressive wave from an oscillating system of the open sea or to a dependent stationary wave excited in the body of water itself. But in the open ocean the dominant tide is due to a stationary wave oscillation brought about by the tide-producing forces of sun and moon acting upon such portions of the ocean basin as are susceptible of sustaining stationary waves having the same period as the tide-producing forces.

It was unfortunate for the stationary wave theory that at its birth it met with adverse criticism at the hands of Sir George Darwin, who dissented absolutely from the views advanced by Harris. In his well known book on The Tides and Kindred Phenomena in the Solar System, Darwin further disparaged this feature of Harris's work by stating that "One cannot but admire his courage in attacking so formidable a problem; but I do not propose to explain his conclusions because I cannot bring myself to believe in the trustworthiness of the principles on which he relies."

Darwin's adverse criticism, in view of his well-deserved reputation as an authority on tidal matters, together with the weight carried by the name of Darwin, resulted in bringing Harris' theory into disfavor in Europe for some time. But in 1910 there appeared the third volume of Poincaré's Leçons de Mécanique Céleste in which after subjecting the various tidal theories to searching analysis, the great master states "Il est vraisemblable que la théorie définitive devra emprunter à celle de Harris, une part notable de ses grandes lignes." Due to Poincaré's exposition of Harris' work and also to the ease with which a number of otherwise baffling questions can be answered by the aid of the stationary wave theory, recent tidal researches have come more and more to be based on this newer theory of the tide.

The Prediction of Tides

In the development of the theory of tides, a number of interesting collateral problems have been brought to light. As examples we may mention the determination of the mass of the moon from the observed heights of the tide; the prediction of the times and heights of high and low water; the determination of the rigidity of the earth from tidal observations; the effects of tidal friction; the variations in mean sea level. Even the briefest discussion of these collateral problems would not be possible in the present paper and we shall therefore limit ourselves to summarizing the work on two of these problems, namely, the prediction of tides and the effects of tidal friction.

An advance knowledge of the times and heights of high and low water is obviously of considerable importance to the mariner in entering or leaving a harbor; and the practical value of such knowledge led, early, to the prediction of tides for the construction of tide tables. It may perhaps be of interest to note here that the oldest tide table of which there is record is one now in the library of the British Museum. It is a manuscript table that appears to have been written in the thirteenth century, and gives the time of "flod at london brigge," that is, the time of high water at London Bridge. The time of high water as shown in this old tide table is made to increase by a constant difference of 48 minutes from day to day and is given not for calendar days of the month, but only with reference to the age of the moon.

To predict the tides two different methods have been employed. The older one, technically known as the nonharmonic method, is based on the close relationship existing between the time of high or low water at any given place and the moon's meridian passage. It begins by determining, from tidal observations made at the port for which predictions are desired, the time intervals elapsing between the moon's meridian passage and the occurrence of high and low water. These time intervals, known respectively as the high-water and low-water lunitidal intervals, have an approximately constant value for any given place and after having been once determined from a month or more of observations, may be used for making a rough tide table for that place by adding to the times of the moon's meridian passage as given in a nautical almanac.

As stated above, the lunitidal intervals for any given place are only approximately constant. During a lunar month they undergo periodic changes, depending principally on the variations in phase and declination of the moon. From long series of tidal observations these periodic changes may be determined, and by using these as corrections to the lunitidal intervals, satisfactory predictions of the times of high and low water may be secured. And for many years the tide tables issued in the various countries were constructed substantially as here outlined.

The height of the tide was predicted in a similar manner. The average heights of high and low water at the port for which predictions were desired were determined from observations. To these average heights there were then applied corrections for changes in the phase and parallax of the moon, these corrections likewise being derived from observations. And the tide tables produced by this method worked quite satisfactorily for Europe and for the Atlantic coast of the United States, where the tide is of a simple type. But when the nonharmonic method is used for the prediction of tides of a more complex type, such as found on the shores washed by the Pacific and Indian Oceans, it necessitates so many corrections as to become prohibitive. Before the need for accurate tide tables covering the whole maritime world became pressing, the mathematician had introduced a more powerful method for the prediction of tides, known as the harmonic method.

In the harmonic method the tide is conceived as being made up of a number of simple harmonic waves, each of which may be referred to some motion of sun or moon. In other words for sun and moon as tide-producing agencies this method substitutes a number of hypothetical tide-producing bodies which, with respect to the earth, have circular orbits in the plane of the equator. Each of these simple tide-producing bodies is assumed to give rise to a tide of its own kind, and the tide as it actually occurs in nature is thus considered as being made up of a number of simple harmonic tide waves each of which has a period corresponding to the period of its particular hypothetical tidal body.

The periods of revolution of the assumed tidal bodies and hence the periods of the simple constituent tides, are determined once for all from the known motions of sun and moon. These periods being independent of local conditions are therefore the same all over the earth; what remains to be determined for the various simple constituent tides is their phases and amplitudes which vary from place to place and which can be determined accurately only from observations. The mathematical process by which these phases and amplitudes are disentangled from the tidal observations at any place is a very ingenious one known as the harmonic analysis and is due to that versatile British mathematician, William Thomson, better known as Lord Kelvin, who first proposed it in 1867. Since that time the harmonic analysis has been extended and perfected chiefly by Darwin, Ferrel and Harris.

Now it is obvious that when the period, phase and amplitude of a simple harmonic constituent tide is known, it is not a difficult matter to find the height of the tide due to that constituent at any given future time. To predict, therefore, the tide that will actually occur at some future time, it is only necessary to add together the heights of the constituent tides at that time. The labor involved in doing this by ordinary methods of computation, however, is so great as to be prohibitive, and it was only after Lord Kelvin had devised a machine which mechanically effects the summation of all the various tidal components, that the prediction of tides by the harmonic method was put on a practical basis.

Since Kelvin's first tide predictor, made in 1872, there have been introduced improved mechanical tide predictors, notably two devised in the U. S. Coast and Geodetic Survey, the earlier one in 1883 and the later one in 1910. In the tide tables for our own country, issued annually in advance by the Coast and Geodetic Survey, all the predictions are made by means of the mechanical tide predictor and this is also true to a large extent of the tide tables published by the other leading maritime nations. And the accuracy of these predictions as determined by comparison with the actual times and heights of the tide is all that one can expect in view of the disturbing influences of wind and weather. The problem of the prediction of tides, in so far as this is based on previous observations made at any given port, may therefore be considered as completely solved.

The Effects of Tidal Friction

In the motion of the waters brought about by the tides, friction is produced by the movements of the water particles against each other, by the movement of the water over the beds of seas and rivers and by the movement of the water on the shelving shores along the coast. There is, furthermore, friction produced in the yielding of the solid earth to the tide-producing forces of sun and moon. This tidal friction consumes energy which can come only from the rotational energy of the earth. In other words, tidal friction acts as a sort of brake on the rotating earth, tending to reduce its rotational velocity and as a consequence tending to make the day longer. The stock of energy possessed by the earth, however, is so enormously great as compared with the friction produced by the tides that it is only by a minute quantity that the day is lengthened by tidal friction even over a period of years. And while attempts at an accurate numerical estimate of the amount of this lengthening of the day has thus far been unsuccessful it appears probable that it is of the order of something like the thousandth part of a second in a century.

The effect of tidal friction is not confined to the earth alone, but makes itself felt on the moon. A mathematical investigation proves that besides decreasing the rotational velocity of the earth, tidal friction also tends to increase the period of revolution of the moon and to increase the distance between earth and moon. All these effects of tidal friction are exceedingly small now, but they have been operating for untold ages, so that by this time the cumulative effect must be considerable.

With these conclusions as to the effects of tidal friction, suppose we go backward in time and attempt to trace the early history of the earth and moon. Let us go so far back that the whole life of man on this earth is but a day in the reckoning, back to the time when according to the nebular hypothesis our earth was a molten mass. As we travel backward through time we are undoing the effects of tidal friction and the day is becoming shorter, the moon is approaching nearer the earth and the month is becoming shorter.

But it is to be noted that when the moon was nearer the earth the tides raised were much greater than now, for the tide-producing power of a heavenly body varies inversely as the cube of its distance from the earth. And aside from the increased friction due to the greater tides, the tidal friction varies inversely as the cube of the moon's distance from the earth. Hence the efficiency of tidal friction in increasing the length of day and month and the distance between earth and moon varies inversely as the sixth power of that distance. So that when the moon was one tenth her present distance from the earth, the effects of tidal friction were one million times as great as they are now. It follows therefore that although the effects of tidal friction now are excessively small, they were enormously greater in the remote past when the moon was nearer the earth.

Based on considerations as outlined above, Sir George Darwin has investigated the subject mathematically and developed an exceedingly interesting and very plausible theory as to the early history of earth and moon, from which it appears probable that the moon was at one time part of our earth.

The effect of tidal friction is to make both the day and month longer, but the increase in the length of the day is greater than the increase in the length of the month. It follows therefore, disregarding any counteracting influences that may intervene, that a time will come in the distant future when the day and the month will be of the same length. At this time moon and earth will be presenting the same faces to each other all the time and the moon will have ceased producing any tides on the earth, although the sun will still bring about a rise and fall of the surface of the sea.

The above is but a very meagre outline of this exceedingly interesting problem. But taken with what precedes it is probably sufficient to indicate the nature of some of the problems of the tide. Prior to the formulation of the law of gravitation, the study of the tide had engaged the attention of the leading philosophers; and since Newton's time many distinguished mathematicians have contributed to its development. It still constitutes a fertile field for research, offering to the investigator a number of interesting problems.

THE ORGANISM AND ITS ENVIRONMENT

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THERE are times when we need to remind ourselves that the organism—the real organism, which lives and grows, and functions and acts, and in some cases thinks—is not an isolated phenomenon in nature, but is part of a complex system of interacting forces. It is utterly unintelligible, indeed we shall see presently that it does not even exist, except in organic relation to the outer world. Nevertheless, various trends in present-day biological discovery and speculation have confirmed us in the habit of viewing the living being as a distinct and independent entity, and of underrating the importance of a thorough knowledge of its environmental relations. Add to this the inevitable increase of specialization in all fields of science, which has tended to separate and to keep apart those whose studies relate chiefly to the isolated organism from those who are concerned primarily with its conditions of life and occurrence in nature. It is possible that these tendencies have already passed their zenith, and that the movement toward a greater measure of integration in biology is making satisfactory headway. But a perusal of the writings of those who form the dominant groups at the present time does not furnish much ground for this belief.

Let me be somewhat more concrete in regard to the causes which have led to this relative neglect of the environment by modern biologists. Morphology has for years, and perhaps unavoidably, confined itself to the study of preserved organisms, or more frequently of the excised organs or tissues of organisms.

Physiology—when it has broken away from medical bondage and asserted its rights as an independent science—has commonly studied the activities of animals or plants, or isolated parts thereof, under strictly "controlled," *i. e.,* highly unnatural conditions. Taxonomy has dealt with collections of stuffed, pickled, pressed or otherwise preserved material. There has frequently been a rigid division of labor between the collector, who gathers and preserves the specimens, and observes them in nature, and the systematist, who studies and classifies them in his laboratory or museum, without such clues as are afforded by a knowledge of their local distribution, seasonal occurrence, life history, etc.

When we come to my own special field of genetics, this apotheosis of the organism and relative neglect of environmental factors is particularly evident. Strictly speaking, it is not even the organism here which is exalted into this position of well-nigh exclusive interest. It is that more or less imaginary entity, the "germ-plasm," which is conceived to flow on through the ages as an uninterrupted "stream," giving rise, at intervals, to ephemeral and relatively unimportant objects, the bodies of the individual organisms. Within broad limits, this "germ-plasm" is not supposed to be affected by the environment at all. It may, it is true, be killed by lack of food, extremes of temperature, or the like, or a particular "stream" of germ-plasm may at any time be brought to an untimely end by its failure to produce individuals which are adapted to their special conditions of life. But, aside from this process of selective elimination, the environment is not credited with the power of calling forth adaptive changes of a hereditary nature. Furthermore, many biologists are at present dubious as to whether environmental influences are capable of producing germinal changes of any sort, even those which result in the "mutations" upon which selection is supposed to act.

The great volume and the high importance of researches in Mendelian heredity during the past two decades have lead to a virtual identification of genetics with Mendelism. This statement applies not only to the rather confused notions of the layman, but to the deliberate utterances of the expert, who sometimes explicitly defines the word genetics in this restricted sense. Now Mendelism, as we all know, is concerned with the mode of transmission of certain more or less distinguishable "unit-characters" of the organism. These last, in turn, are supposed to be the visible manifestations of independent, indivisible, and in a high degree unalterable "factors" in the germinal substance. Occasional instances are cited, to be sure, in which particular unit characters depend for their manifestation upon particular conditions of the environment, and certain geneticists believe—usually as an article of faith—that unit factors may undergo "mutation" as the result of sufficiently potent changes in the external conditions. But, on the whole, the general effect of Mendelian studies has been to emphasize the isolation and independence of the organism—or at least, of its unit factors—and to minimize the importance of the environment, except as imposing limiting conditions to existence or growth.

After more than a generation of stalwart drubbing, Lamarckism is believed by most biologists to have yielded to the inevitable and to have gone to its last repose in an unhallowed grave. Not only are individual acquirements believed to be incapable of hereditary transmission, but for man, at least, the rôle of external circumstances in the development of both body and mind, during the single lifetime, is frequently denied any very high importance. Environment—the "culture medium"—must furnish a certain low minimum of requirements for normal development. Beyond that, it is impotent to alter the preordained course of the individual life history.

The foregoing picture is not intended primarily as an indictment of recent biological philosophy. My chief object has been to point out some of the reasons for the relative neglect of the natural environment as an object of biological research. That the prevailing viewpoint which I have outlined above, is largely founded upon exact knowledge must, I believe, be admitted. That it represents an extreme position, and overlooks important lines of evidence, is to some of us equally clear. While I can not here enter into an extended justification of this last contention, I feel bound to indicate rather briefly the sort of facts upon which it is based.

In the first place, one can not overlook the utter bankruptcy of the Mendelian-Mutation scheme of things to account for evolution, and particularly to account for the origin of adaptive structures and functions.[1] Hereditary differences among organisms, according to this theory, depend upon the presence, in their respective "germ-plasms," of somewhat different unit factors. Every natural species and most artificial races are known to be far from homogeneous in their hereditary make-up. As the result of selection—natural or artificial—individuals carrying certain favorable factor combinations may be perpetuated to the exclusion of others. As long as this process of sorting out is possible, the average character of the race may be altered in one direction or another. Sooner or later, however, we reach a condition in which all members of our selected strain possess the particular factor combination that insures the highest possible manifestation of the character for which we are selecting. In respect to these particular factors, our material has become homogeneous, and further progress along this line must cease.

Now, as a matter of fact, we all know that in some cases such progress has been continued indefinitely. We may point to abundant instances from nature, in which a tendency, once started, has been continued throughout ages of geologic time. The reduction

[1] One prominent geneticist, Heribert-Nilsson, when confronted with the contradiction between the "facts" of Mendelism and the "theory" of evolution, escapes from his dilemma by casting the latter overboard! (Festkrift Lunds Universitet, 1918).

of the lateral toes of the horse's foot is an often cited example, which is as good as any. Certain breeding experiments, likewise, have shown the possibility of continuous modification throughout many generations. In some instances, this has occurred among the cultures of those who insist most strongly upon the truth of the "sorting out" conception of selection. Occasionally, too, there seems to be a sudden revival of the efficacy of the selective process, some generations after stability seemed to have been reached.

We are all familiar with the current explanation of these phenomena. Effective selection, in a race which has become homogeneous in respect to the factors concerned, is only possible through the occurrence of "mutations" or spontaneous changes in these factors. If such changes chance to occur in the same direction as the changes which were initiated by our selective process, the latter is given a new lease of life, until a condition of racial uniformity is once more established.

It is well to consider for a moment where such a conception leads us. There would seem to be nothing particularly mysterious in the fact that a race of organisms should undergo continuous changes in a given direction, as the result of "mutations," arising without any reference to environmental needs. Progressive changes are going on all about us in the inorganic world, some of these continuing for untold periods of time. What does need explaining is the fact that these changes, in the organic world, are so often in the direction of increasing adjustment to the conditions of life. Darwin's explanation of this fact—one which he felt obliged to supplement by another quite different explanation—is known to us as the theory of natural selection.

At the present day, there are probably as many estimates of the effectiveness of natural selection as there are biologists who are competent to express an opinion on the subject. All are probably agreed that it must be regarded as one of the factors of evolution. But most recent biologists are strongly impressed by various considerations which were either unknown to Darwin or were probably not sufficiently recognized by him. In the time allotted I can speak of only one of these. This is the inadequate supply of variations which are actually available as material for selection. At a time when most individual differences were believed to be more or less hereditary, and when practically no bounds had been set to the efficacy of the selection, it was much easier to assert the "all sufficiency" of this principle as the cause of progressive evolution. Even then, it must be remembered, there were many who denied the possibility that wholly random variations could furnish an adequate basis for evolution through natural selection.

In recent years, this difficulty has been magnified many fold. A large part of the variability of organisms, including many differences of survival value in the struggle for existence, are believed to be "somatic" or "phenotypic"—that is to say, non-hereditary. In respect to any given character, so much of the variability as is found to be inheritable is attributed to the action of relatively small numbers of unit-factors, which can be readily, and rather speedily, segregated in particular descent lines, if the degree of selection is rigid enough. Thus a very limited amount of permanent modification may be brought about fairly promptly. After that, we are forced to wait for the decidedly capricious process of mutation to help us further along the road.

One having a limited acquaintance with the discoveries of Morgan and his co-workers might be disposed to exclaim at this point: That is easy! New mutations are coming to light every day in the case of *Drosophila*. Would not this prove to be true with every race of organisms, if studied intensively?

I fear that such persons are leaning on a very frail reed. When we examine into the nature of these mutations of the fruit-fly, we find very little promising material for a theory of progressive evolution. Many of them are obvious deformities and abnormalities, not only in the sense of being departures from the typical condition, but in the sense of rendering the insects unfitted for life in nature. The body may be warped, the wings so abbreviated as to be useless, the legs duplicated or greatly shortened, the eyes reduced in size or suppressed altogether. Many of the mutant factors described by these authors belong to the class known as "lethals." That is to say, their presence in a homozygous condition results in the death—or failure to appear—of all the organisms so affected. Indeed, most of the mutant strains are distinctly less hardy, or more difficult to raise, than are flies of the wild type. The best that can be said for any of the modifications thus far appearing is that they are harmless to the organism. Those which are not positively deleterious consist in changes in the color of the body or eyes, in the number or form of bristles on the thorax, and other trivial departures from the normal condition. So far as I know, not a single one of these mutations—and there are some two hundred of them described—can be said to represent a better adapted type of organism. With a very few exceptions, they consist in obvious losses of structures or materials previously present.

We are not, of course, warranted in concluding from this that mutations of evolutionary value never occur. It is quite possible that they do. But what we actually know at present regarding such mutations as occur in our breeding cultures affords no safe ground for the belief that evolution has come about through the accumulation of these by natural selection.[2] This belief seems particularly difficult in the case of very slow breeding animals, such as the elephant, which have none the less undergone enormous structural modifications during relatively brief periods in the earth's history.

Here then is one difficult situation in which we find ourselves, if we follow the lead of the majority group of biologists in questioning the positive effectiveness of the environment as an agency in evolution. Are we not brought back to a viewpoint similar to that of Naegeli, who held "that animals and plants would have developed about as they have even had no struggle for existence taken place, and the climate and geologic conditions . . . . . been quite different from what they actually have been?"[3] According to Naegeli, the environment has had merely a pruning effect upon the tree of life, eliminating certain branches and permitting certain other others to grow. If this be the truth, we must, of course, accept it. But we should accept it on evidence, and not on authority.

That the environment may have had a far more positive influence upon evolution than is admitted by the Mendelian-Mutationist school of biology is further rendered probable by certain recent experiments. I refer particularly to the remarkable work of Guyer and Smith upon the inheritance of artificially induced eye defects in rabbits. The studies of these authors seem to prove conclusively that one particular class, at least, of "acquired characters" may be transmitted indefinitely from one generation to the next. And the mechanism by which these acquired characters seem to have been registered in the germ-cells is of a type which is conceivably operative on a large scale throughout the living world. I am waiting with interest to see whether the results of these remarkable experiments are to be explained away or robbed of their significance for biological theory.[4]

Another field in which this depreciative attitude toward the power of environment is at present conspicuous is that of eugenics and the study of character formation in man. Since I have recently

[2] Professor Bateson, who is usually regarded as a pioneer "mutationist," has recently declared (SCIENCE, January 20, 1922) that "we have no reason to suppose that any accumulations of characters of the same order" [*i. e.,* "transferable" or segregating ones] "would culminate in the production of distinct species."

[3] Kellogg (Darwinism Today, p. 278).

[4] For present purposes it is immaterial whether these phenomena be attributed to "parallel induction" or to "somatic induction."

published a special article on this subject,[5] I shall take the liberty of quoting rather extensively from this. My first object in the article referred to was to point out the very general confusion which exists regarding the relations between heredity and environment in human development.

"'Every 'character' (whether we mean by this word a bodily part or organ, or a trait or mental disposition) has a hereditary basis. Likewise, every character is due, in its final state, to the interaction of this hereditary basis with other parts of the developing body, and with the sum-total of external conditions, physical and biological, which we call the 'environment' of the organism.

"However, it seems quite proper to speak of *differences* between two organisms as due solely to heredity or solely to environment. Thus plants of different stock, reared under identical environments, might differ greatly in size or in other respects. These differences would be of purely germinal origin. On the other hand, two plants of identical heredity might be reared in different soils and come to differ widely in size or otherwise. Such differences would be purely environmental.

" . . . . The familiar question, Which is the more important, heredity or environment? is not capable of answer when stated in that form. One might as well ask, Which are the more important in the construction of a house, the building materials or the carpenters? We may, however, as just indicated, frame the question in another way: Are the *differences* which we observe among our fellow men due chiefly to *differences* of heredity or to *differences* of environment, using the last term in its broadest sense?[6] Even here, we must be more explicit. Do we refer to the differences between the white man, the Chinaman, and the negro, or do we refer to the differences which we observe among individuals of the same race? The differences between the various races would be granted by most persons to be hereditary. But the differences within a given race are regarded by many as being due, in large degree, to the circumstances of life—to feeding, home surroundings and 'bringing up.' This is claimed particularly for the mental and moral characteristics."

"Francis Galton, after reviewing the evidence derived from the study of identical twins, thus expresses his belief regarding the relative potency of heredity and environment in determining human differences: 'There is no escape from the conclusion that nature prevails enormously over nurture, when the differences of nurture do not exceed what is commonly to be found among persons of the same rank in society and in the same country.'

"And truly, I do not see how we can escape this conclusion, if we bear in mind Galton's reservation. . . . .

"I think it likely, however, that many recent geneticists, especially some of those who are active in the eugenics movement, would throw out Galton's reservation and insist that 'nature prevails enormously over nurture' in determining the mental and moral differences among an entire population, regardless of its social strata.

"The opposite, or 'environmentalist' philosophy, in its extreme form,

[5] Heredity, environment and responsibility. Bulletin of the Scripps Institution, No. 10, July 2, 1921.

[6] See Popenoe and Johnson, "Applied Eugenics," p. 3.

would assert that almost any individual may be given almost any type of physique, intellect, or moral character, if taken sufficiently early and subjected to a proper regimen during the period of growth and character formation. . . . .

"It is my own belief that the scientific geneticists and eugenicists are much nearer the truth than the mere undisciplined lovers of mankind, but that they have been led into a somewhat extreme position by their efforts to square the facts of life with certain biological theories. Now there are various considerations of a strictly scientific nature which would seem to establish the presumption that non-inherited factors in the formation of human character should be given more weight than is frequently accorded them by biologists."

The time at my disposal does not permit of an adequate discussion of these considerations. I shall restrict myself to a brief mention of one of them. This is the probability, admitted by most biologists, that civilized man has undergone little if any improvement in his inherent mental make-up since the dawn of history.

While it is not necessary to admit such extreme claims as have been made by some biologists, I think there is no escape from the conclusion that mankind, or the civilized part of it, has made *little* advance in potential brain power during the entire period of history—little in comparison with his racial achievements in science, philosophy, art, invention, morals, etc. In other words, human progress has been extrinsic rather than intrinsic. We have built up an enormously complex world of racial acquirements, consisting of customs, laws, and knowledge, as well as all the physical paraphernalia of civilization.

Thus, if it is really true that the innate brain power of mankind has undergone little or no increase since paleolithic times, the higher mental status of the modern man is due almost wholly to a fuller development in each of our lives of potentialities which were present in the man of the Old Stone Age. This, of course, is but another way of saying that even such enormous differences as distinguish a Cro-Magnon cave-dweller from a modern European are chiefly, if not wholly, environmental.

It may be worth while, in the interests of clear thinking, to undertake an analysis of this distinction which we are so prone to draw between organism and environment. How far is this antithesis a real one, and how far is it a mere matter of convenience? Let us consider this question, first of all, in its bearing upon the science of genetics.

The sum-total of causal agencies which result in the production of a complete organism from a fertilized ovum are commonly grouped under two heads: (a) the material constitution of the fertilized ovum itself, particularly of its chromosomes; and (b) external influences which act upon the developing organism, from the moment of fertilization to the close of the life cycle. This classification corresponds in the main to the familiar antithesis between heredity and environment, nature and nurture. As a matter of fact, the distinction thus drawn is largely a chronological one, the influences acting before fertilization being lumped together along with "nature," those acting after that event being assigned to "nurture." If we insist that heredity relates only to the "intrinsic" factors in the situation—to the material constitution of the "germ-plasm" independent of environmental influence at *any* period—it seems to me that we are dealing with something purely imaginary. There never is a period in the history of the germ-cells or their forerunners when they are not vitally dependent upon their living environment. Every step in their history involves an interaction between certain factors which may be called "intrinsic" and other factors which are external to these. What is "intrinsic" at one moment may have been "extrinsic" the moment before. Whether this relation is of a type which makes possible the form of inheritance assumed by Lamarck is a question which we need not consider here. I merely wish to point out that no hard and fast distinction can be drawn between heredity and environment as conditioning the life of an organism. The distinction is largely one of chronology, and the moment of demarcation between the two must be chosen rather arbitrarily. In practice, to be sure, the distinction implied by these words is in the highest degree useful. But we should not imagine that it is an absolute one.

It may be of interest to carry this analysis a step further. I am prepared to defend the somewhat paradoxical thesis that the organism and its environment constitute an inseparable whole; that if we could detach all environmental elements from this complex there would be no organism left. Nor do I intend this as a mere bit of Hegelian dialectic. A moment's reflection serves to show that we can draw no sharp line of division, not even a theoretical one, between the two.

If I should ask you whether the nest of a bird constituted a part of the organism or a part of its environment, I presume that every one present would resent the question as an insult to his intelligence. Nor would there probably be any hesitation if the question related to the patch-work dwelling of a caddis-worm, even though this dwelling is carried around by the larval insect, as if it were an integral part of its body.

The situation becomes somewhat less clear, perhaps, when we consider the calcareous tube of a marine annelid. Here is something which is definitely secreted by the epidermal cells of the organism, and which forms a sort of permanent integument. It does not, however, in this case, retain any organic connection with the body of the worm. But when we pass to the shell of a mollusk we find that there is such an organic connection with the body, so that the animal cannot be dislodged without extensive injury to its living tissues. Moreover, the purely mineral ingredients of the shell are sandwiched in between layers of a substance which we commonly speak of as "organic," though not in this case as living. Does such a shell belong to the organism or to its environment?

If there be any doubt in the case of the mollusk, let us consider the bony carapace of the tortoise. This, likewise, is composed in part of mineral salts, in part of equally lifeless "organic" materials, produced through the metabolism of living matter. But in addition to these lifeless elements, we here encounter a multitude of living cells contained in minute spaces scattered throughout the bony substance; and even blood-vessels and nerves, which provide for the nutrition and growth of these cells. All persons would probably agree that such an exoskeleton belongs to the creature's body.

Let us pass next to a consideration of the internal fluids which are concerned with distributing food and oxygen to the living tissues and with carrying away their waste products. Perhaps a reversal of the order previously followed would here be instructive. In the case of vertebrates, the blood is itself commonly classed among the tissues of the body. Cells of several kinds are present, along with a fluid, intercellular matrix consisting, in large part, of proteid substances, approaching in complexity those which compose the "protoplasm" of the living cells.

Among the mammals, the blood maintains a high degree of constancy in its composition, regardless of changes in the external medium. A seal or a porpoise may pass from fresh to salt water, or vice-versa, without undergoing any change in the concentration of the blood. This is not true, however, of the fishes. Those which are capable of living equally well in fresh and salt water show a higher salt content in the latter than in the former.

Now among fishes—or at least the bony fishes—this concentration of salts in the blood is not proportional to that of the water in which they happen to be. But the case is quite different with many marine invertebrates. As a result of osmosis and diffusion both the concentration and composition of the salts in the body fluids of such animals is rapidly brought into conformity with that of the water in which they are placed.

In the coelenterates, it is well known that the gastrovascular cavities and their contained fluids are in direct connection with the surrounding ocean, while in the sponges the only circulating medium is the sea-water itself, which is propelled through multitudinous canals by the motion of the flagella. Once more, is it not obvious that the distinction between organism and environment is a conventional and arbitrary one?

This line of argument would be quite incomplete without reference to the transformations which constitute that most characteristic process of living matter, metabolism. Unfortunately, my limited knowledge of biochemistry would not make it possible for me to discuss the subject adequately even if my allotment of time permitted. But even such slight knowledge as I do possess enables me to assert with confidence that there is no definite point in the process at which we can say for the first time: This is no longer food; it has become living matter. Nor, on the descending phase of the metabolic cycle, is it possible to distinguish the moment at which the living passes over into the non-living. But food and waste matters belong to environment. They can hardly be regarded as parts of the organism.

In short, the organism and the environment interpenetrate one another through and through. The distinction between them—let me repeat—is only a matter of practical convenience. Should not such considerations affect our attitude toward the propriety of neglecting the environment as an object of biological research? I make no pretense, of course, that such neglect is universal. An active and important group of present-day biologists is giving its chief attention to the organism-environment complex. My criticisms—so far as I have made any—relate to general tendencies and average conditions, and these have not, I believe, been unfairly portrayed.

CONTROL OF PROPAGANDA AS A PSYCHOLOGICAL PROBLEM[1]

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AN interesting phenomenon of the last few years has been the unanimity with which millions of men and women have conformed in their thinking and in their actions to what certain leaders wanted. Vast sums of money have been raised for liberty and victory loans, for the Red Cross and for many other agencies. Citizens of the United States consented to universal conscription, cut down their daily use of sugar, closed down their factories on certain days, and went without gasoline for their autos voluntarily and enthusiastically. To an extraordinary degree men and women in nearly all the countries of the world have cooperated in carrying out programs necessitating radical changes in their every-day life; and they have done so not because they were ordered to do so, and so were forced to it, but because they freely responded to suggestions presented in skillfully conducted propaganda.

Because of the surprising success of all this propaganda, the innumerable times it has been employed and the ease with which it has been carried out, people generally have become conscious of propaganda as a great tool or method for influencing others. Propaganda has, of course, existed for ages. But it has not been comprehended so clearly by the mass of people as it is to-day. And certainly it has never before been employed on such great numbers of men and women. To-day it is a clearly recognized method of social control.

If propaganda were a means of influencing others along lines only of benefit to society, it could be hailed with great acclaim. But unfortunately it can also be employed for dishonest and socially vicious programs, just as well as for honest and worthwhile movements. At the present time the advertising of patent medicines that can not possibly cure, and of stock in companies formed for no other purpose than to defraud the public, appears

[1] Retiring vice-presidential address before Section I, Psychology, American Association for the Advancement of Science, at Toronto, December 30, 1921.

in altogether too many of our publications. Federal authorities estimated that in five years, 1910-15, the 2,861 swindlers that were arrested had defrauded the public of $351,000,000, averaging a dishonest gain of $123,000. All authorities are agreed that such swindling increased very greatly during the war, and possibly reached its climax some time after the armistice. If so, it is now on the decline. Let us hope so!

The drive, a new form of propaganda, has now become a regular business. According to James H. Collins, somewhere between a billion and a billion-and-a-half dollars have been raised in one year for various causes other than governmental. Many of these have been worthwhile, but unfortunately many have been the reverse. A bureau that makes a business of investigating national and interstate money-raising activities, reported that by April, 1920, the number of drives had risen to 1,021, of which the bureau approved only 124. The district attorney of New York County investigated 534 money-raising activities in 1918 and put 384 of them out of business. One gang of ex-convicts had obtained $500,000 in eight months.

But we are less concerned here with swindling propaganda than with those forms not so palpably dishonest. It is important that our citizens be protected from pecuniary loss, but it is far more important that the United States, for example, deals with Russia, Mexico and the Irish question in the right way. And it is just such problems that furnish us with propaganda very difficult to handle.

As a case in point, consider the Russian situation. Those opposed to the Bolsheviki have attempted to destroy the movement by linking it up in our minds with the fact that the Bolsheviki were under German influence, that they were anarchists, that they were guilty of murder and atrocities, that they persecuted the Church, that they had nationalized women and were deliberately corrupting the morals of children, and now, recently, that their government is so unstable that we can not do business with them. The friends of this political and social revolution have told us entirely different stories. And so-called unbiased persons have often made statements which do not agree with what any one else has set forth.

Consequently to-day the average citizen confesses he really does not know what the facts are in this and many other important issues. He has been deluged with facts, near-facts and falsifications put forth by interested parties, so that he has a mass of undigested and conflicting ideas on these subjects, or else has become frankly partisan to one view.

President Butler, of Columbia University, recently called attention to the dangers to society of this sort of thing. "Liberty," he said, "which once was endangered by monarchs and by ruling classes, has long since ceased to fear either of these; it is now chiefly endangered by tyrannous and fanatical minorities which seize control for a longer or shorter time of the agencies and instruments of government through ability and skill in playing upon the fears, the credulity and the selfishness of men."

The question naturally arises, is there no way of controlling propaganda? Certainly there are ways and they are enforced more or less in the case of certain types of propaganda. But there are other types which are not so easily evaluated and consequently not so easily handled.

A perusal of literature on this subject gives one the impression that very few to-day are sincerely interested in the matter, except those apparently who desire to control or eliminate propaganda directed at their own. It is still viewed as highly ethical for us to sort and reject and trim in the name of our own view of truth, justice, democracy and loyalty to our group. But it is anti-social for the other fellow to do so. If we are Republicans we want the editor of our newspaper to give us good Republican views and to damn the Democrats. If we are Democrats, we want the reverse. We really want "facts" that support our views. It is too uncomfortable to be confronted with many counter "facts."

Naturally as a psychologist, I view this matter as an interesting psychological problem. It is my purpose in this place to discuss certain psychological aspects of the subject and to point out some of the ways in which propaganda may be controlled. It is also my purpose to call attention to certain types of propaganda which at present I see no way of controlling, in the hope that others may become interested in the subject and labor to work out some adequate methods.

First of all let us clarify the use of certain terms which are employed in discussing the subject and at the same time come to an understanding of the psychological elements which are involved.

The word "propaganda" means essentially the spread of a particular doctrine or a system of principles, especially when there is an organization or general plan back of the movement. Propaganda differs from "education" with which it is purposely confused, in that in the case of the former the aim is to spread one doctrine, whereas in the case of the latter the aim is to extend a knowledge of the facts as far as known. Advertising men have never been able to agree on a definition of "advertising" and I should not want to attempt here what they have failed to do. But

I think we can distinguish between advertising and propaganda by saying that advertising is usually concerned with making known and desirable a definite commodity or service with the definite aim of leading many individuals, as such, to acquire the commodity or service. Propaganda includes many types of advertising, but it is mainly concerned with the subtle presentation to the public of information so chosen and so focussed that among many individuals there develops a general "point of view" which is favorable to the aim of the propagandist and leads to action in that general direction. A further distinction between these two methods of influencing people pertains to the *methods* employed rather than the *object*. The advertiser buys space upon which appears his message, and the reader knows it a paid advertisement. The propagandist may advertise, but he especially aims to employ space he did not buy, at least directly, and not to permit the reader to know that the material is propaganda. He believes his material will have greater effect when its source is unknown.

It is clear that both advertising and propaganda make use of argument and suggestion. And much has been written and said as to these two methods of influencing others. We have no quarrel in this paper with argumentative or "reason-why" appeals to the public. But we are very much concerned with appeals involving suggestion.

The term "suggestion" has been employed in a great variety of ways, sometimes in a narrow sense, but usually in a rather broad and indefinite way. Frequently it is used to cover all the means of imparting information and exerting influence other than through reasoning. Without going into the subject here, let us recognize three phases of non-rational influencing of others. In the simplest form one or more ideas are presented which are known to be associated in the minds of the audience with another idea not mentioned. The audience thinks the non-mentioned idea because of their established habits of thought. In this way a speaker may denounce most viciously and unfairly a prominent man without giving his name, by skillfully referring to one or more of his known characteristics. The desired effect is accomplished and without making it possible for the prominent man to reply. Then there is the more complicated phase of suggestion where an *action* is brought into the mind of the audience—the action being a familiar one and also one that will be desired as soon as mentioned. Thus a school boy at recess says, "Let's get a drink." The other boys might not have gotten a drink if they had not been reminded of the action. But as soon as it is called to mind, they feel the desire and so go. So also a nation like Germany, all primed for war, as in 1914—I don't refer here to her military preparations, but to the state of mind of her citizens—was ready to act immediately when her leaders said "Let's fight." It was the absence of just such a mental state in the United States that kept us out of war. Later on the attitude was developed—almost over-developed before it had a chance to function—and we were eager to act when the word was given.

In both these phases of suggestion the effect is produced because there exists within the mind of the person being influenced certain habits of thinking and action and when the proper stimulus or cue is given the associated thinking and acting immediately follow. There is still a third phase of suggestion, which I prefer to call motivation, in which a person is led to do something which is unfamiliar or which he would not do if it were merely mentioned. It is because of this third method of influencing others that the control of propaganda is so difficult. Let us see what this process of motivation is.

Consider an example: An electric light and power company launched a newspaper campaign some time ago in order to sell vacuum cleaners. The appeals were made to women to buy the cleaners in order to save labor and to make their homes cleaner and healthier. Many cleaners were sold. But the stock on hand was far from exhausted. Some time later the company launched another campaign, in which they directed their appeals to husbands, not wives. In these advertisements they depicted, for example, a successful business man in his office surrounded with filing cases, typewriters, dictaphones, and the like, and in another cut, showed the wife at home with a dust-cap on her head, sweeping the dining room, with the dust flying all about. The caption underneath read something like this: "Why not equip your wife's office like your own?" This second campaign sold more vacuum cleaners than the first one. Why? Because the man's love for his wife was aroused and this strong force was coupled to the idea of vacuum cleaners. Buying a vacuum cleaner then became a most satisfactory manner of expressing love. In advertising to the wives, on the other hand, no such fundamental motive was aroused. The vacuum cleaner would save labor, it is true, but it would not give to the wife as much satisfaction for the money as a new rug to be seen by every one coming into the home, or as new clothes for the children.

In this case we have men led into doing something they had no intention of doing, of buying something that little concerned them, and that they probably knew very little about. They were so led because love for their wives was aroused and they were shown how this love could be very adequately expressed. With minor changes, the advertisement could have sold them an electric washing machine, or any useful household device. They were not sold, then vacuum cleaners so much as they were the satisfaction of pleasing their wives.

Motivation involves two elements—first, the arousal of a strong desire, and, second, the presentation of a certain action which appears to be a satisfactory way of expressing the aroused desire. Moreover the action in such cases is not one that the individual would perform if it were merely suggested.

The question has often been discussed: Could the United States have declared war in 1914? I think there is no doubt that there was insufficient war sentiment at that time to have permitted mere suggestions from the President to be effective. But I think there is also equally no doubt that proper propaganda would have motivated the country into war. The years 1914 to 1917 may be looked upon as a period in which such sentiment developed and was finally put into action in a calmer and far less emotional manner than usually prevails at such a time.

Recent work in psychology has emphasized the distinction between an "idea" and a "sentiment." The sentiment, according to Rivers, is an idea emotionally toned. "House" is thus an idea, whereas "home" is a sentiment, for home always includes an emotional consciousness of mother and father, brothers and sisters, old familiar associations and the like. When the sentiment becomes suppressed and lost to consciousness it is called a "complex." Sentiments and complexes, we are coming to see more and more are extremely important in explaining behavior; much of abnormal conduct being traceable to the existence of complexes.

Motivation is thus the process of deliberately developing a sentiment, of deliberately associating an idea with an emotion, of tying together in the mind of another the love for wife and the idea of buying a vacuum cleaner, or of sympathy for the Belgians and hatred of the Germans, and the idea of war.

The aim of propaganda is to develop sentiment and then precipitate action through mere suggestion. Let us consider some implications which are involved in all this.

First of all let us note that theoretically any emotional element can be associated with any specific line of action. Practically, certain combinations are difficult to accomplish, but theoretically they are possible. Thus, the correspondence school arouses the boy's love for his mother and challenges him to make her proud of him and "funnels" the aroused emotional desire into taking a correspondence course. The same appeal could be utilized to get young men to go to church, to quit gambling, to work harder for their employer, to enlist when war is declared, to do anything the boy could be made to believe his mother would approve of.

In the last political campaign for President of the United States, the maternal instinct was appealed to by both sides. A Democratic editorial appealed as follows:

"Mother of America! Mother of Pennsylvania! Mother of Pittsburgh! Do you want your boy to go to war? Is the roll of battle drums sweeter in your ears than the song of his voice in the home? Would you rather have his hands in fierce grip on gun in battle's rack than have his arms in love about your neck? That is the question you must answer to your God and your fellow-man when you go into the voting booth on November 2. Do not let demagogs confuse you. The issue is plain: A vote for the league is a vote for peace; a vote against the league is a vote for war. . . . Mother of an American boy! The munition makers of the world are arrayed against American participation in the League of Nations. They are snatching at your vote, because with it they may claim the body of your first-born. Mother of a Pittsburgh boy! The question comes home to you! Your boy was not born to be food for guns."

A Republican advertisement stated in part:

"Women! For your own good vote the Republican ticket. . . . The American woman asks of her country: That it be a secure place for her home and for her children and that it be security with honor. That it give her children opportunity to lead their lives even better than she and her husband led theirs. That it be just in its relations with other nations, and merit the pride which the best of its citizens have in it, in its history and its ideals. A policy which has these purposes will have the support of American womanhood and American motherhood. That is the Republican policy and has been Republican policy from the days of Abraham Lincoln. The Republican policy is to protect the security of the United States by preserving its right to make decisions regarding its actions in the future as events in the future demand. The Republican party is unwilling to pledge now that it will protect European boundary lines and to deprive Congress of the power to say in each case what the action of the United States will be. . . ."

Here we have the same instinctive emotional element aroused and then associated with two diametrically opposite lines of action. Both of these articles are intended to arouse a mother's love for her boy and consequent horror of war, and then show that her desire could be best obtained by voting the Democratic ticket in one case and the Republican ticket in the other.

A second fact can be considered regarding motivation. It is that no logical connection needs to exist between the emotion which is aroused and the program which is outlined. And further still, there need be no logical establishment of the fact that the program is really the best one to be pursued or even that it is honestly conceived.

Consider the propaganda for the Red Cross, an organization for which we are all enthusiastic. The Red Cross has rendered inestimable service. And because its work has touched our hearts a real sentiment has been built up about its name. So strong is this sentiment that one now finds himself unable to resist the request for annual dues. But my friends—I have asked several—and I do not know whether all the money that is now raised is really needed, nor how it is spent, nor whether the organization is efficiently administered or not. I am not saying this in the way of criticism: I am only pointing out that when one's emotions have been properly aroused one acts as directed and without intellectually considering the matter.

Take the recent "Clean-up and paint-up" campaign as another illustration of what most would call a worthy propaganda. A trade journal, The American Paint and Oil Dealer, started it off with an editorial in May, 1912, in which it was pointed out that for many years there had been special campaigns inciting people to clean-up their towns and their neighborhoods for some specific gala occasion. It was now time "to back the idea that you clean up and paint up and keep cleaned and painted up, not just once a year, but the whole year through." "The idea was to inculcate into the minds of people pride in home and city, and in thrift and cleanliness, and to appeal to that pride to the end that it might be organized and wisely directed for the benefit not only of the paint industry, but of the whole United States of America. Enlisted in this campaign were various types of people. Material was prepared that appealed to every one of these types in a most specific manner."

R. F. Soule writing in Associated Advertising tells us how Chambers of Commerce were the principal bodies that helped put the campaign over. He describes how fire departments were aroused to the need to prevent fires as well as to put them out; how police departments became much more interested in enforcing sanitary ordinances along with the street-cleaning departments; how women's clubs helped the good work along; etc. In 1920 there were 7,000 towns and cities engaged in this campaign. And illustrative of the work accomplished it is reported that in Cincinnati 384 buildings were torn down that were a fire menace and the city so cleaned up as to lessen the annual premiums for fire protection by $850,000.

According to Soule not over $25,000 was spent in any one year by the organization back of this campaign, although a great deal of publicity was given in newspaper editorials and in the advertising of many companies in connection with their own products.

Now note: This campaign is characterized as having been unselfish. The big idea was not to sell merchandise, it is claimed, but "to sell the people of this country citizenship, pride of home and ownership, and a desire to be of greater service to the community of which they were a part."

These were the motives, desires or wants that were aroused and then hundreds of business men saw to it that they were expressed by way of buying their goods, whether it was paint, oil, lawn mowers, flower seeds, or even safety razors. Clearly any emotional desire can be coupled up with any line of action and there needs to be no real logical connection between them.

Propaganda depends upon this psychological process of motivation for its success. And motivation, as we have seen, is the deliberate process of arousing one's emotions and desires and then suggesting a line of action by which these desires may be expressed. And we have seen further that any emotional element can be associated with any specific action; and that when one is well motivated he ignores intellectual considerations touching upon the honesty of the statements or the efficacy of the program.

So much for our analysis of motivation—the principal psychological process in propaganda. Now let us consider how propaganda may be controlled by society so that dishonest and pernicious campaigns may be prevented without interference to worth while propaganda.

The most convenient method of considering the many angles of the subject will be through discussing propaganda in terms of the following three aspects: First, propaganda considered with regard to the truth or falsity of the statements in which it is presented; second, with regard to the action suggested as the means of satisfying the aroused desire; and third, with regard to the emotional element, the desire that is aroused. The matter of control can accordingly be discussed in terms of these three question: First, how far can propaganda be controlled in terms of the validity of the statements which are made? Second, to what extent can propaganda be controlled in terms of the action which is proposed? And third, to what extent can propaganda be controlled in terms of the emotional elements that are involved?

First of all, then, how far can propaganda be controlled in terms of the validity of the statements which are made?

Society has long dealt with false statements and already has postal regulations, laws against slander, libel and the like. To protect politicians the English law provides a fine not to exceed £100 if the name and address of the printer and publisher is omitted from a poster relating to the candidature of any person for Parliament and other offices. The Association of Advertising Clubs of the World carries on a steady campaign against dishonest advertising and has accomplished a great deal of good against this type of propaganda. At this time, thirty-six states have passed the Printers' Ink Statute or a modification of it, thereby facilitating convictions in such cases. And the Association of Advertising Clubs of the World is spending money and effort in enforcing it. Control of propaganda publicly making dishonest statements can clearly be taken care of.

But unfortunately many undesirable propaganda will not fall under the class of propaganda publicly making dishonest statements. One very undesirable sort is spread by word of mouth. No one knows from whence it comes, and exactly what is back of it. We had many stories thus circulated against the Germans during the war, and we have the same sort of thing carried on against prominent men almost all the time. Stories of Roosevelt's excessive drinking were thus circulated. And it was not until they were publicly expressed that he had an opportunity of disposing of them through law suit. Such word of mouth propaganda is fostered in times of emotional stress and particularly wherever people believe they are not being told all the facts. The best possible cure for it is publicity of the sort that makes people *believe* they are getting all sides to the question.

But in addition to this sneaking underhand propaganda there are all sorts of campaigns which are very undesirable, but which adhere technically to the truth. They cannot accordingly be prosecuted for dishonesty. Some of them, however, give false impressions just the same. This is so because the human brain does not necessarily think in a logical manner. For example, the statement, "No watchman here between 6 P. M. and 6 A. M." means just that and no more, but actually the effect is as though the statement had gone on to say that a watchman was on duty in the day time. For a distributor of a food product to advertise that his goods contain no arsenic is to give the impression that the goods of at least one of his competitors do contain that poison. And the lurid page description of two successful gushers between which the advertising company's property is located gives the impression one is surely buying stock in a gusher-to-be, even though the company's property may be several miles from either of the described oil wells.

Then there are other kinds of propaganda which deal with this subject in such a general way that no one can challenge their statement. One of the packing companies ran an advertisement some time ago which came no nearer to stating facts than this: "Possibly, we are partially to blame for the lack of understanding which exists in regard to our business. In the past, knowing that attacks upon us have been based on tissues of half-truths, adroitly handled inuendo and misinformation, we may have forgotten that the public were not in full possession of the facts." The statement is a very clever one, undermining criticism without giving a single fact in reply except the company's own belief that all attacks have been based on half-truths.

To require that propaganda contain truths and not falsehoods is a desirable regulation, but it will not stop undesirable campaigns.

Let us consider second to what extent propaganda can be controlled in terms of the action which is proposed.

If the proposed action is that of buying, it is not difficult to evaluate the propaganda, or advertising as it would usually be in this case, upon the grounds that the individual did or did not get value received. But if the proposed action is that of giving money for some cause or charity, justification upon such grounds is far more difficult. If a woman, very fond of cats, wants to endow a hospital for them, run by thoroughly incompetent people whom she likes, isn't that sufficient to justify her action and the propaganda, as far as she is concerned? It is hard to attack such action in terms of the rights of individuals, but it is being more and more attacked upon the grounds of social welfare. Business men through their Chambers of Commerce in sheer defense are increasingly investigating such propositions and in many places list the charities that they will countenance. Out of the war has come the Community Chest movement whereby all social agencies in a district make up their budgets in advance and after they have been gone over by both disinterested and interested parties, a single united effort is made to raise the total amount in one campaign for the year. Such plans help the worthy cause and interfere with the unworthy one. But they do not eliminate the unworthy campaigns.

The establishment of bureaus, whose business it is to investigate all organizations asking for funds—organizations like the National Information Bureau—renders it easier to determine whether any organization is desirable or not. Can society go farther here? Can society not only positively help the worthy cause, but put the unworthy, inefficient or unnecessarily duplicating agency out of business? There is no question but that many individuals are being fooled every year and much money squandered through such non-worthwhile causes. But at the same time, we must remember that most new uplift movements have encountered great opposition at the start, and to increase this opposition still more through the establishment of legal regulations may do society in the long run more harm than good.

In addition to campaigns to sell a commodity or service or to obtain gifts, there are other campaigns devoted to accomplishing specific actions of a sort much more difficult to estimate fairly. Political campaigns aim to secure votes for certain men; propaganda appears from time to time to influence citizens to vote for or against certain measures; propaganda appeared in many forms a short time ago, appealing to citizens of the United States to intervene in Mexico; lobbies are familiar accompaniments to our legislatures, each one aiming to accomplish a specific program; unions appeal to public opinion to aid them in winning a strike and companies appeal to the same public to help them prevent or break the strike, etc. We are so accustomed to our political machinery that we do not often stop and ask ourselves whether it is geared up so as to serve society in the best way. Only when some enthusiastic social uplifter boasts that she and four others alone put a measure through a state legislature by the use of skillful lobbying, or a secretary of a business man's organization calmly announces months in advance that Congress will do away with a bureau because his organization is demanding such action, and his prophecy comes true, does one wonder whether some sort of control of propaganda would not be worthwhile even here. And one waxes quite indignant, as did a former Secretary of War, when he comes to realize that much of the propaganda for bringing back the bodies of our dead soldiers was instigated by the journal of the undertakers and casket makers.

To control such propaganda we must have facts and we must have a body to review the facts. This we do not have in many cases. A political campaign on a clean-cut issue is supposed to be a trial as to the merits of the two sides before all the citizens who through their votes decide the issue. This is the theory of democracy. It works pretty well in many cases, surprisingly well in some. But in most campaigns the issue is not clean-cut and in nearly all campaigns the political strategist endeavors to confuse the issue, so that many a time a citizen votes against what he really wants. And then there are many measures coming up in our fearfully complex life of to-day upon which the average man is not at all competent to pass judgment. Except in a few instances, society has not yet organized itself so as properly to handle such matters. In the case of struggles between capital and labor, we are steadily advancing toward the insistence upon both sides that they shall present the facts as they see them and also toward the establishment of tribunals which shall weigh all the facts and decide the issue. The impartial chairmanship program maintained by the clothing industry in Chicago and other cities has worked very satisfactorily and seems to be the ideal machinery for controlling propaganda in that field. Its greatest merit lies, it seems to me, in the fact that complaints are studied and evaluated very shortly after they arise, thus eliminating the getting under headway of extensive propaganda with all the arousal of emotions that propaganda assures.

But there are many issues to-day, strongly supported by a minority, regarding which it is difficult to obtain facts. And as long as one side is insistent and the other side largely indifferent, society cannot expect that the minority will present facts regarding their claims. For it is not facts that will sell the program, but emotion and the emotion which is aroused needs not be logically connected with the issue. So a few harrowing tales of deserted mothers and their poverty stricken children bring us a mother's pension program because a few people believe this is the best solution. Possibly it is. I am not here arguing the case. But how much real thinking has entered into the matter by disinterested parties before a legislature has voted!

We have briefly considered the possibilities of controlling propaganda in terms of the action which is proposed—when the action is that of buying, giving money, or gaining support for *definite* political or other issues. But there is an entirely different type of response which some propaganda aims to accomplish. It is that where no definite act is suggested, at least directly, but where public opinion is to be changed. Pro-German propaganda before and during the war, or pro-Irish propaganda to-day, or the New Era Movement of the Presbyterian Church, or the International Typographical Union advertising in the newspapers do not aim at getting any one to do a specific act. What is aimed at is the development of a broad sentiment with the perfectly clear understanding that when this sentiment is established the individual will do something to forward the cause. To evaluate the propaganda in such cases, the entire program must be considered. And as individual members of a big movement emphasize different aspects it is very difficult to determine just what the movement stands for. For example, legal action was instigated some time ago against a union because in its constitution, if I remember correctly, it stood for a soviet type of government. But no progress could be made because no specific action had been taken by the union, openly against the laws of the United States. Now possibly the constitution as far as this point was concerned was and had always been a dead letter. But possibly the point was the very heart and center of the union's life. Still, how can its propaganda be limited until it has resulted in definite action? But if it cannot be controlled until anti-legal action commences, then there can be no control of such situations until most of the harm (or good) has been accomplished. For if the propaganda has accomplished the establishment of a certain sentiment without interference and then specific action has been suddenly advocated, no legal machinery in existence can stop the action. The existence of a sentiment in Great Britain, that treaties to which they were a party must be observed, was one of the factors that forced that nation into war with Germany when the latter violated the neutrality of Belgium. As Sir Edward Gray said, "My God, what else could we do!"

There is another very vexatious phase of this point. When a sentiment has been established the individual may do almost anything which he feels will advance the cause in which he is interested. Can a propagandist be held responsible for the actions of his followers because he stirred them up originally. A newspaper publisher's propaganda against McKinley may have caused that president's assassination, as some have felt. But is the publisher responsible for an act he did not specifically advocate, even though, for the sake of argument here let us say, he did stir the assassin emotionally and against the President? The newspapers report the non-cooperation propaganda of Mahatma Gandhi of India and how this leader is fasting one day a week in protest against the rioting which his followers are indulging in. To maintain that the publicist is responsible for what his followers do seems very unfair: to hold that he is entirely unaccountable opens the way for most subtle and dangerous attacks on society.

This leads us squarely up to the issue: shall propaganda be evaluated only on the basis of the actions that result or on the basis of the motives back of the propaganda?

Our law basically concerns itself with man's behavior and takes little account of motives. But a distinction is made between wilful murder and unintentional manslaughter. And a man can be convicted of murder if a person's death results within a year from his shooting at a chicken with intent to steal it. The intention to steal makes the accidental death murder. Here man is held responsible for the final results of his criminal intention in just about as far reaching a manner as if he had inflamed another who then went out and murdered a complete stranger. Responsibility for the actions of another under certain circumstances, has been established. The Court of Appeals of New York State has recently awarded damages to an employee who when reprimanded by his foreman for negligence called the foreman a liar, and was struck and knocked down by the foreman. His glasses were shattered and vision in one eye destroyed. It was held that the employer should be held responsible for an excitable and violent foreman in the prosecution of his duties as such, at least until there is sufficient interruption in the performance of such duties as to justify the conclusion that the foreman had abandoned his employment and that the assault was an independent and individual act, as distinguished from acts within the terms of his employment.

In connection with the Espionage Act the Attorney General's Department opposed the proviso that "anti-war utterances or propaganda would not be punishable if made with good motives and for justifiable ends" on the grounds that it would make it difficult to prosecute and convict. Regulation according to this view must be in terms of actions, and motives can not be considered. Twenty-two states have adopted the Printers' Ink Statute regulating dishonest advertising in which no reference to motive or intention is made. Sixteen other states have, however, inserted the word "knowingly" or its equivalent, thus making it necessary to prove that the dishonest advertising was intentional. Legal action in these sixteen states is based primarily then upon the motive, not the act.

The 1918 Report of the Attorney General states the policy of that department regarding the enforcement of the Espionage Act. It is of significance here. One paragraph reads as follows:

"The Department throughout the war has proceeded upon the general principle that the constitutional rights of free speech, free assembly and petition exist in war time or in peace time, and that the right of discussion of governmental policy and the right of political agitation are most fundamental rights in a democracy. It has endeavored to adhere to the principle that neither the Government nor any group or class of citizens should be permitted to take advantage of the war situation to suppress discussion and agitation of domestic problems, whether political, social, economic, or moral. At the same time, however, it has held to the view that neither under the guise of political theory, social conviction, or religious creed should any man or group of men be permitted to indulge in propaganda which has the deliberate purpose of disintegrating our strength in the war or which is of an essential nature necessarily producing that effect."

In other words, the policy outlined here maintains that the welfare of the nation is paramount and that any propaganda which can be classified as injuring the national war program will be condemned regardless as to how this propaganda could be classified in terms of rights of free speech, free assembly and the like. And further that motive is of little consideration in comparison with an overt act.

So far we have considered the possibilities of controlling propaganda from the two aspects: first, as to whether the statements in it were true or false; and second, as to whether the proposed action was socially worth while or not. This discussion has seemingly emphasized the necessity of taking motives into account. Now let us consider the third aspect of the subject—the element of aroused desire, the emotional background and psychologically true cause of the action.

We have seen that theoretically any emotion may be aroused as the basis for stirring one to act and that there needs be little or no rational connection between the two. The detailed suffering of a little girl and her kitten can motivate our hatred against the Germans, arouse our sympathy for the Armenians, make us enthusiastic for the Red Cross, or lead us to give money for support of a home for cats. The story may be true or concocted for the purpose; the inferences against the Germans or for the home for cats may be also true or false; the organization carrying on the propaganda may be efficiently administered or not—all these considerations little concern us. We feel the emotion, we want to do something because by acting we will feel better, and away we go regardless of mere intellectual considerations.

Here is the real psychological problem concerning propaganda. Take away the emotional element and society need have no fear of propaganda. For man is always very slow to act in terms of ideas alone. Witness his indifference when he really knows the political organization in control of his municipality is flagrantly dishonest. He does nothing until his emotions are aroused by a whirlwind speaker, or by personal injury. So long as a radical writes or speaks in a philosophical manner society can rightly be indifferent. But when he discards the intellectual aspects of his views, seizes upon some slogan and fills his writings or speeches with concrete tales of human suffering and the arrogance of the rich, society rightly becomes alarmed. For now the radical is setting fire to dynamite and neither he nor any one else can tell what may result.

At the present time the prospects do not appear over bright of controlling propaganda through regulation. There is, however, a method of weakening its influence, and that is by fighting one propaganda by another, or by general publicity. The trouble, however, with fighting bad propaganda by good propaganda, aside from the very practical consideration that the former is usually better equipped financially, is that seldom is the public supplied with facts upon which a real conclusion can be thought out. Instead it is inflamed to take sides and a deadlock results, or the matter is settled by some sort of resort to force. Just in this way arose the turmoil about the League of Nations program. Instead of thinking it through and arriving rationally at a real conclusion, Wilsonites and anti-Wilsonites became emotionally aroused and it was voted down because the latter group had the greater force measured in votes. Both sides know the real issue is not dead, and the Republicans who defeated Wilson's program are now attempting at Washington to find the conclusions we should have reached months ago. Fighting propaganda with propaganda is not likely, then, to give us satisfactory results.

Can propaganda be controlled through publicity? Yes, if we had perfect publicity. But that, apparently, we cannot have. Hence, we can only hope to have partial control by this means.

It has been suggested that propaganda could be controlled by national control of all publicity. Would such regulated and censored publicity help here?

The two extremes of publicity are no freedom of speech and complete freedom to say whatever one wants to. The Anglo-Saxons have decided that freedom is better than no freedom. The French lean quite strongly to centralized control of all publicity. Observers both from within and without that country testify that such censorship deadens public interest in the news of the world. And it certainly makes possible all manner of mouth-to-mouth whisperings—the most insidious and undermining of all propaganda. An editorial in the New York Times only the other day called attention to the marked difference in behavior of radicals in this country and abroad concerning Sacco and Vanzitti, who have been condemned to the electric chair for murder. Abroad the Reds have inspired the rank and file of their group with rage over the so-called persecution by the American Government of those radical leaders and several assassinations have been attempted as a result. In this country no such disturbance has resulted because, as the Times points out, everyone is familiar with all the facts of the case and so even the Reds can not be stirred up over the affair.

Possibly publicity is the one best cure we have to-day for handling those forms of propaganda which are not readily controlled by other means. But if this is the case it means that more of our newspapers and magazines will have to convince the public that what they print is not controlled by certain interests. At the present time I should judge that great numbers of citizens believe most newspapers, if not their own, distort the facts to fit their purposes. And again, if publicity is to cure the evils of propaganda, it means that society must work out some more satisfactory method than now exists of providing the groups of poor people with adequate publicity to offset the enormous advantage that groups composed of wealthy people have in commanding the printed page. Too few newspapers print to-day, and too few can ever afford to print, the detailed testimony in a labor controversy, yet unless the laboring man feels his side is presented, he will have supplied to him and will read wild denunciations of capital instead of the sworn testimony of his leaders as given before a board of arbitration.

Another means of controlling propaganda lies in educating the public to an understanding of the methods employed in propaganda. It is thought that man likes to feel he is being appealed to on logical grounds: that he resents being "soft-soaped." And that he does not want to be "worked," or to have something "put over on him." Possibly, it is contended, articles such as have appeared recently in our magazines recounting the methods by which propagandists have fooled men and women may educate the public to see through a publicity campaign. Personally, I do not believe that very much can be accomplished in this way, for, as Barnum claimed, the public likes to be fooled; and secondly, clever appeals to the emotions will nearly always win when pitted against intellectually held convictions.

In closing, I want to emphasize one point. It is possible to-day for a group to carry on a very subtle propaganda with the immediate aim of developing some sentiment. There is no machinery to stop them, whether the sentiment is socially good or bad. For sentiment is an emotional state of mind and as long as no action results, society to-day has no way to handle it. So France mourned at the Strasbourg statue in Paris each year and kept alive the sentiment to retake Alsace-Lorraine. Of course, we completely sympathize with her. But it made Germany prepare all the more for war. And the world sat back and looked on while Germany established the sentiment in the minds and hearts of her citizens that they lived only for the fatherland and that war was the truest expression of their country's life. The Grand Army of the Republic and the Confederate Veterans have perpetuated northern and southern antipathies and the American Legion must of necessity keep us antagonistic toward Germany. For these organizations are surcharged with emotion. General O'Ryan is quoted in the papers as follows:

"Ten years from now the battlefields of Europe will not look as they appear to-day. They will bear monuments of men on horseback and the young men will grow up thinking of war in terms of medals, glory and men on horseback rather than in terms used by the young men of to-day who were in the war. Delay in solving this problem will mean that those who profit by war will get control of the kids and that's what they want. The youngsters will be hypnotized to believe anything in the name of patriotism and they will want to get medals and glory of their own."

If war is to be eliminated, it will be necessary to control the sentiments that are developed in each and every country. Similarly if peace is to be attained between capital and labor, the right sentiment will have to be developed. Many an employer has been smarting under conditions now past when labor had the whip hand. He is now getting even, as he says. He is reacting to a sentiment of revenge and at the same time building up a similar one in the minds of his employees. This is the sure road to worse conditions.

As far as I can see, society has reached the point in its development when it must take motives into account, because man has now learned how to arouse motives to action in an economical and wholesale way. And in regulating motives society must come to evaluate the sentiments that propaganda is aimed to create, and to regulate in some way the use of phrases arousing emotions, as distinguished from phrases appealing to rational consideration. Without control in some way of the emotional element in propaganda, legal action will never stop the most dangerous of propaganda which arouses a sentiment first of all and then at the proper moment in one fell swoop precipitates that sentiment into action.

PUBLIC HEALTH AND EXPERIMENTAL BIOLOGY

By Professor HARRY BEAL TORREY

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I

LAST October, in the library of the College of Physicians in Philadelphia, I came upon a letter from Lord Lister to Dr. W. W. Keen. It was dated 4th April, 1898. It began as follows:

12 Park Crescent, Portland Place, London W.
4th April, 1898.

My Dear Sir:

I am grieved to learn that there should be even a remote chance of the legislature of any state in the Union passing a bill for regulating experiments on animals.

It is only comparatively recently in the world's history that the gross darkness of empiricism has given place to more and more scientific practice; and this result has been mainly due to experiment upon living animals. It was to these that Harvey was in a large measure indebted for the fundamental discovery of the circulation of the blood. And the great American triumph of general anæsthesia was greatly promoted by them. Advancing knowledge has shown more and more that the bodies of the lower animals are essentially similar to our own in their intimate structure and function; so that lessons learned from them may be applied to human pathology and treatment. If we refuse to avail ourselves of this means of acquiring increased acquaintance with the working of that marvelously complex machine, the animal body, we must either be content to remain at an absolute standstill or return to the fearful haphazard ways of testing new remedies upon human patients in the first instance, which prevailed in the dark ages. . . .

My own first investigations of any importance were a study of the process of inflammation in the transparent web of the frog's foot. The experiments were very numerous and were performed at all hours of the day in my own house. I was then a young unknown practitioner; and if the present (English) law had been in existence, it might have been difficult for me to obtain the requisite licenses; and even if I had got them, it would have been impossible for me to have gone to a public laboratory to work. Yet without these early researches which the existing law would have prevented, I could not have found my way among the perplexing difficulties which beset me in developing the antiseptic system of treatment in surgery.

In the course of my antiseptic work at a later period I frequently had recourse to experiments on animals. One of these occurs to me which yielded particularly valuable results, but which I certainly should not have done if the present law had been in force. It had reference to the behavior of a thread composed of animal tissue applied antiseptically for tying an arterial trunk. I had prepared a ligature of such material at a house where I was spending a few days at a distance from home; and it occurred to me to test it upon the carotid artery of a calf. Acting on the spur of the moment, I procured the needful animal at a neighboring market; a lay friend gave chloroform and another assisted at the operation. Four weeks later the calf was killed and its neck was sent to me. On my dissecting it, the thread, instead of being thrown off by suppuration, had been replaced under the new septic conditions, by a firm ring of living fibrous tissue, the old dangers of such an operation being completely obviated. . . . .

At the very time that I was reading these words, twenty-two years after they had been written, *The Country Gentleman* for October 16, 1920, was carrying broadcast over the United States an article entitled "Vivisection" by an antivivisectionist, which after exhibiting the grossest ignorance of the purposes and practices of contemporary investigators who use animals in their experiments concludes as follows:

Alienists—Doctor Bishop and various others of high standing—have taken a further step than the mere plea of needless cruelty in their arraignment of vivisection.

They claim that vivisectors are not actuated by any scientific zeal, but are mental degenerates. In other words, that vivisection is a recognized form of mental perversion—a savage mania which is known to the keepers in every mad house. It is of the same order as the spirit which incites murderers of a certain type to rip their human victims' bodies to pieces. ! !

The author is obviously irresponsible, and his work would be negligible were it not for the fact that it receives official endorsement. On the editorial page, under the caption "Vivisection," cognizance is taken of the statement already quoted, in an editorial which is essentially a brief abstract of the article ending with these words:

Other doctors, here and in Europe, go a step further, by declaring that cases of a recognized form of mental perversion are known among vivisectors. The public should understand this vivisection argument from both sides. The accompanying article supplies such needful information in a way to prove antivivisection's case.

My attention had been attracted originally to this number of *The Country Gentleman* by editorials in two eastern newspapers that were disposed to be sharply critical of the appearance of this propaganda on the eve of the November election in California where an antivivisection measure was on the ballot.

The motive prompting the appearance of the article at that time need not concern us. The charges implied in the editorials to which I refer have been officially denied, and I am glad to accept the denial. Indeed, it should be said that on February 12 *The Country Gentleman* printed a very able defense by Dr. W. W.

Keen of what he very properly calls experimental research. It even introduced with kind words the widely known and respected author. Its editorial columns are, however, silent. This silence after Dr. Keen's admirable exposition of the facts contrasts significantly with the warm editorial endorsement of the October article, in which one looks in vain for the slightest first hand knowledge of contemporary experimentation.

Yet *The Country Gentleman* is published in Philadelphia. The Saturday Evening Post, published by the same company, was founded by Benjamin Franklin, the same Benjamin Franklin who was one of the founders of the Philadelphia Hospital in which the students of the first school of medicine to be founded in the United States were taught by its first professor of clinical medicine. From that time Philadelphia has been a great seat of medical learning. Two of our best medical schools now flourish there. On the roster of the College of Physicians are many of the most illustrious names in the medical history of the last century and a half. Its wonderful library is said to be surpassed in this country only by that of the Surgeon General's Office in Washington.

II

There is no need to dwell further on this remarkable exhibition of opposition to a principle which has not only been repeatedly established in fact, but has recently been ratified by a decisive majority at the polls. California is free, for the present at least, to safeguard the health of its people by the necessary research.

What part may experimental biology be expected to play in this connection?

An answer to this question will depend first upon what we may consider experimental biology to be. As I think of it, its limits are set by no group of organisms nor by any circumscribed body of facts. The field of experimental biology is the living world. Its materials are omnipresent there. Its problems are general, fundamental problems of organisms, carried to the limits of human interest. Its method is analytical. Its object is the discovery of mechanisms, processes, dynamic relations. I like to think of it as an attitude of mind rather than a department of biological knowledge. For there is no department of biological knowledge that may not reveal this interest in the fundamental problems, dynamic relations, and analytic methods which to my mind characterize experimental biology.

What is the relation between experimental biology, thus conceived, and the public health?

Health is a name we apply to a standard of mental and physical fitness that varies with our enlightenment and our individual necessities. This standard is maintained by both private and public agencies. Private agencies are concerned primarily with individual cases involving some form of treatment. This treatment may be: (1) applied by the individual himself when in control of the necessary means, as provided, for instance, by the rules of personal hygiene or athletic training; or (2) applied by an expert upon whose superior skill or insight he temporarily relies.

These experts form a heterogeneous assemblage, including such different elements as masseurs and physio-therapists, physical directors, physicians and surgeons and all others who may be licensed by law to render professional services under definitely prescribed conditions. This heterogeneity raises many perplexing practical problems, which however, need not detain us here.

While private agencies are concerned primarily with the problems of private individuals, public agencies are concerned primarily with the interests of the public as a whole, especially with those sources of danger whose control demands collective as against individual effort. The general method of the public agencies is *prevention.* This we are accustomed to contrast with *treatment,* the traditional method of the private agencies. These methods in certain respects, do contrast sharply with each other. Where prevention succeeds, treatment becomes superfluous. And in so far as private practice is dependent upon the treatment of preventable disorders, its function is temporary only—of the nature, let us say, of emergency service. But it must be recognized that treatment may be essentially preventive in nature, and is becoming more and more so, as old-fashioned prescription writing is displaced by the instruction of patients in the care of their bodies and the avoidance of disease. The functions of private and public agencies are thus entirely compatible. No reputable physician will prolong treatment for his own profit, nor will he hesitate to make it unnecessary if he can. Though worthy of his hire, he is nevertheless a public servant. Under no other theory can the state appropriate the sums it does for his professional training. It is his duty to destroy disease and develop a sturdy race just as it is the duty of the teacher to dispel ignorance and encourage resourceful, self-reliant minds. His is a double function: to cooperate with public agencies in preventive measures and to care especially for those whom such measures have failed to protect.

So much for the relation of public and private agencies. From whatever angle the problems of health may be contemplated, they are scientific problems. They are also fundamentally biological problems, of a sort to invite an experimental method of attack.

III

The problems of public health center about the control of the causes of disease. Disease may be defined as a more or less radical departure from a standard of bodily or mental health, variously determined, which may be taken as a standard of reference. It is a relative term, in no sense a definite entity. Thus defined, it has a variety of causes. Some of these are well known, and form the basis of the public health work of the present day. Some of them—how many we cannot say—are quite unknown. It is toward the discovery and control of these that experimental biology may be expected to make its chief contributions to the health of the future. Accordingly I shall attempt to gain space for the discussion of these problems of the future by avoiding more than a summary reference to the conquests of the past.

These conquests were largely initiated by Pasteur and a few of his contemporaries. The mysteries of suppuration vanished in the light shed by his experimental studies on fermentation. And contagion received its clear explanation in the demonstration of the transportation of an infecting organism by some appropriate carrier from one host to another. Thence arose a dominant motive in prevention, the discovery and eradication of pathogenic organisms and their means of dispersal—by fumigation, quarantine, sanitation, destruction of breeding places, and carriers and their breeding places, and so on. New organisms are being almost daily discovered—witness the organism of yellow fever recently isolated by Noguchi, and many additions to our knowledge of the intestinal fauna to which Professor Kofoid and his co-workers have made such notable contributions.

When it is not possible to prevent infection, the same result, since Pasteur, may be achieved by immunizing the host with specific antitoxic sera and vaccines of various sorts.

When neither contagion can be prevented nor immunization effected, it is naturally sound practice to discover the infection at the earliest possible moment. This is one reason for such agencies as public health nurses and public dispensaries.

Education in hygiene is another means of prevention—efficacious both against infectious diseases (*e. g.*, tuberculosis) and those lapses from health that are referable to other causes connected with the customary mode of life, such as bad housing, dangers of occupation, unsatisfactory food and clothing, and so on.

With this sketchy summary of public health activities as they are commonly practiced, we may turn to certain aspects of the general problem which have for the most part a future significance. First, let us consider the group of psychopathic disorders. These are due to a variety of causes, among which are defective inheritance, syphilis, alcoholism, accidental injuries, social including occupational maladjustments, sex maladjustments, defects in education, especially early education. The first may be controlled by prevention of propagation, and in severe cases in no other way, as has been established by studies in heredity. The manner of prevention is open to question. Segregation of the sexes is entirely possible, but presents some practical difficulties at the present time. Sterilization laws are in effect in a few states. But the recent experimental results of Steinach throw some doubt upon the all-round efficacy of the usual method of vasectomy. In the tests of rats whose *vasa* had been ligated, the sex cells degenerated; but the interstitial tissue hypertrophied with a corresponding augmentation of the sex impulse. It is obvious that such an operation, effective though it may be as a method of sterilization, is of questionable protection for the public against a potential rapist and carrier of venereal disease. Further experiments are needed.

Spyhilis continues to resist all methods of prevention, but infections are subject to control as a result of the experimental investigation of Schaudinn, Metchnikoff, Ehrlich and others; that complete cures are effected, however, has still to be demonstrated.

Alcoholism is—theoretically—preventable by law. There can be no question of the salutary effect of even our present degree of prohibition upon the prevalence of venereal disease and the milder psychopathic cases, as well as crime and poverty. As a cause of degeneracy Pearson's well-known statistics are supported, on the one hand, by the performances of Pearl's alcoholized fowls, and opposed, on the other, by Stockard's degenerate guinea pigs which continued to reappear for several generations after one ancestor, a male, had become an involuntary victim of alcoholism. Whether the present law in the United States represents a position of biological stability can not be determined until further careful experimentation produces more, and more varied, data on the physiological effects of alcohol on the human mechanism as a whole.

Social and occupational maladjustments, though often apparent to casual inspection, offer to the nerve physiologist and psychologist a multitude of subtle problems in abnormal human reaction that have hardly begun to receive proper attention, important though they appear in the analysis of psychopathic cases.

Sex maladjustments, further potent sources of ill health, present another array of problems to the student of nerve physiology and the endocrine organs and their inter-relations, that have so far been merely reconnoitered.

Finally, the education of early life provides large opportunity for the crossing of reflexes in tangled patterns that exert a warping influence upon normal behavior. Here is a field for both biological experimentation and the prophylaxis of biological instruction. We hold our young too cheap. To develop with careful teaching their natural interest in themselves and the normal processes of organic nature, is to provide insurance toward a normal life.

In a second group of disorders that from the increasing frequency of their incidence and their obscure causation are of distinct public concern, I have placed the malignant tumors and the affection of the endocrine glands.

Time will not permit me to dwell upon the grave seriousness of the problems they present, and the great opportunities they afford for experimental analysis.

Similarly it will not be possible to consider further the subject of eugenics, which has already been touched upon in connection with psychopathic disorders.

The few illustrations that have been cited will suggest something of the place of experimental biology in the medical research of the future.

IV

In closing I would like to tell you of two education experiments that are being made in Oregon bearing on the present subject of discussion. The first is the introduction of elementary biology into the school systems of three cities of the state. The courses are planned for the third to eighth years (inclusive) of school life. They are in charge of specially trained teachers who are undertaking to teach the subject as science and encourage the experimental method. The results for the past year are everything that could be wished. The children are enthusiastic, and have carried the infection of their interest to other classrooms and to their homes. The wide-ranging observation, initiative, inventiveness, keen criticism and clear thinking of these eight-to-ten year olds have astonished and pleased parents and school authorities alike.

The course covers the whole field of biology. One of its objects is to provide a natural, unconscious and authentic approach to the problems of adolescence. To one who has waited many years for the establishment of such instruction, the admirable teachers' reports embodying its first fruits read like fairy tales. I suggest it as a serious experiment in mental and moral prophylaxis.

The second project to which I have invited your attention is a seven year course in medicine. The student who enters the university with the intention of studying medicine enrolls at once as a student of medicine, in a curriculum that extends without break through the seven years of formal instruction preceding the assumption of his professional degree.

The prime object of this curriculum is the fusion of those phases of medical education that are customarily known as the work of the pre-medical, pre-clinical and clinical years into a single organic whole. By this means it is hoped

(1.) To introduce students early to medical problems that they may see the very practical connection between their basic work and ultimate professional success—avoiding, however, the serious error of permitting the substitution of the superficial drama of the clinic for the fundamental scientific knowledge on which their later clinical success must rest.

(2.) To stimulate intensive cultivation of the medical sciences, biology, chemistry, physics and psychology, by means of which to continue indefinitely to live in the present of medical achievement—to quicken especially the spirit of research.

(3.) To indicate that medicine is beyond all things a calling that makes demands on every human resource—on all the fullness of experience, the ripeness of wisdom, the subtle understanding of men.

4.) To make every student of medicine wise and skilful in the technic of his profession.

(5.) To make him a public-minded citizen, thoughtful of his community, jealous for its future.

It may be said further that a department of experimental biology has been added to the traditional subjects provided by law for medical schools, and a directorship of research in fundamental medical science with functions extending throughout the entire seven year course.

These are concrete expressions of the view that has been here supported—that medicine has a biological foundation and with the public health must needs prosper on biological research.

THE CONSERVATION OF THE MAMMALS AND OTHER VANISHING ANIMALS OF THE PACIFIC

By Dr. BARTON WARREN EVERMANN
MUSEUM OF THE CALIFORNIA ACADEMY OF SCIENCES

AT the Pasadena meeting of the Pacific Division of the American Association for the Advancement of Science two years ago, the writer presented a paper on the "Scientific and Economic Problems of the Mammals and Birds of the North Pacific." In that paper attention was called to the inadequacy of our knowledge of the distribution, abundance and habits of even the most common species of marine mammals of the North Pacific. We know only approximately what the species are. There may be 44, as given in the most recent lists, or there may be more or not so many; we do not know with any certainty.

Excepting the fur-seal, our knowledge of the various species is very incomplete. We know the fur-seal fairly well, but not completely in all its aspects by any means. Much has been added in recent years to our knowledge of certain of the whales, through the investigations of Dr. Roy C. Andrews, but of others little or nothing has been learned since Scammon in 1870.

In the paper referred to, attention was called to the richness of the North Pacific as a field for scientific investigation and some of the problems were mentioned. The commercial or economic necessity for an immediate study of some of these problems was urged. At the Pan-Pacific Scientific Conference held at Honolulu in August, 1920, he again called attention to this matter and expressed the hope that some cooperative arrangement might be perfected whereby the various countries bordering on the Pacific might jointly undertake such investigations.

During the last three years, through the cooperation of the California Sea Products Company of San Francisco, a considerable amount of very interesting and useful data has been assembled regarding the whale fishery on the California coast, but we do not yet know even approximately well the life history of a single species of those great animals.

The whales are only one illustration of the incompleteness of our knowledge of the animals of the Pacific. Even our knowledge of the fur-seal, about which more has been written than about any other animal (man excepted) in the world, is still incomplete in several very important respects. We know only a trifle about the sea lions, harbor seals, walrus, elephant seal, the porpoises and the sea otter. Much remains to be learned concerning the life history of the halibut, the herring, the tuna and the sardine, before we can formulate laws for their proper utilization and conservation. We are only now, chiefly through the painstaking investigations of Dr. Charles H. Gilbert, beginning to understand what must be done to save the salmon fishery and make it a going concern.

Most of the animals mentioned, as well as many others about which we know little, are of wide distribution and their effective study and conservation can be brought about only through international cooperation. And this brings us to a consideration of the nature of the cooperation that will be most effective, and the ways and means by which it may be brought about.

It is now desired to offer some suggestions upon this phase of the subject and to call attention to a few of the problems of most pressing moment.

In the first place, it must be realized that these problems, certainly many of them, are international in their scope, and not limited in their relations merely to two or three of the most important countries concerned; that mistake was made by the United States in the fur-seal treaties.

When the Paris Tribunal was formed in 1892, the United States and Great Britain thought they were the only countries seriously concerned. This view was no doubt based upon the fact that only their citizens were, or had been up to that time, engaged in pelagic sealing. The vital mistake made was the assumption that other countries were not likely sooner or later to go into the business.

Up to that time, it is true, no other country had seriously engaged in killing fur seals in the open sea of the North Pacific; even the Japanese had not yet done much, if any, pelagic sealing.

The Japanese government was anxious to join the United States and Great Britain in the treaty of 1892, but her advances were not encouraged. And what was the result? Japan immediately embarked with great vigor in the vastly remunerative and extremely fascinating sport of killing seals in the open sea. Not being bound by the Paris Tribunal regulations, Japan could lawfully kill seals at any time and anywhere in the ocean, even right up to the 3-mile limit around the seal islands and along the American coast. So vigorously did the Japanese carry on this business, and so defective in other respects were the regulation of the Paris

Tribunal, that the Alaska fur-seal herd steadily and rapidly decreased from 402,850 seals in 1897 to 127,745 in 1911.

A new fur-seal treaty was negotiated in 1911, the participating countries being the United States, Great Britain, Russia, and Japan. The United States and Great Britain had at last learned that the problem did not concern them alone, so Japan and Russia were permitted to come in. But who knows how soon some other countries may not be tempted to engage in pelagic sealing? In 1911, our fur-seal herd had become reduced to about 127,000 seals. Under the protection of the present treaty it has increased to more than 550,000. Very soon fur-seals will be so abundant in the North Pacific as to promise great profits to adventurous spirits who may be tempted to engage in pelagic sealing; indeed, it is thought some pelagic sealing has already been going on in the last year or two. What is to prevent them from outfitting in China, Mexico, Peru, Chile, or other countries bordering on the Pacific, sailing under the flags of those countries, and again endangering the existence of the fur-seal herd? Any of those countries has a perfect right to engage in the business if it wishes to do so. The only question they need to consider is whether it can be commercially profitable. And the rapid increase of the herd gives the answer to that question.

The present treaty became effective December 15, 1911, and runs for a period of 15 years. It seems to be fairly well observed, and the herd, although some pelagic sealing has apparently been going on, and in spite of some mismanagement on the islands, has increased rapidly. By 1926, when an opportunity will be afforded to revise the treaty, or even to withdraw from it if any of the signatory powers should wish to do so, the herd will probably contain not fewer than 1,000,000 seals.

It can be assumed, I think, that the treaty will be continued in 1926. The opportunity then afforded should not be neglected to invite all countries bordering on the Pacific and any and all others ever likely to become interested in pelagic sealing, to become parties to the treaty.

The opportunity to correct certain other defects in the present treaty should be taken. For example, under the present treaty, the aborigines on the coasts of the United States, British Columbia, Alaska, Japan and Russia, are permitted to kill seals in the open sea and along their shores. This is a very unwise provision, in that it permits the killing of female seals which has always been regarded as the most objectionable feature of pelagic sealing. The number of seals killed every spring by our Indians on the coasts of Oregon, Washington and Alaska, and by those on the coast of

British Columbia, is already great and is increasing every year. Granting this concession to the Indians or other aborigines is unwise and unnecessary and should be withdrawn.

Cooperation in a Study of the Problems of the Pacific

Steps have already been taken looking toward cooperation among bodies of scientific men of the countries bordering on the Pacific for the purpose of investigation and study of the scientific problems of the Pacific. The Pan-Pacific Scientific Conference which was held at Honolulu in August, 1920, devoted most of its time to discussion of these problems and to consideration of the method of attack.

The National Research Council, established in 1916 under the Congressional Charter of the National Academy of Sciences and organized with the cooperation of the national scientific and technical societies of the United States, has taken cognizance of the matter. In the Council's Division of Foreign Relations has been formed a Committee on Pacific Investigations, which has already begun consideration of the preliminary problems involved. Evidently, one of the first questions to consider is that of the nature of the cooperation that will avoid embarrassing entanglements, and which will bring results.

The National Research Council, through its Division of Foreign Relations, has already addressed letters to similar organizations or bodies of scientific men in several of the countries bordering on the Pacific, inviting them to cooperate with the Committee on Pacific Investigations in a study of the problems of the Pacific of broad or international interest. It is understood that favorable replies have been received from various countries addressed. The exchange of views expressed by the biologists, geologists, meteorologists, oceanographers and others at the Honolulu Conference last year showed clearly that the scientific men of the Pacific area are alive to the importance of the scientific problems of the Pacific and to the necessity of cooperation in their study. The replies received by The National Research Council abundantly bear out the same conclusion. The time, therefore, seems opportune, for consideration of ways and means.

Method of Cooperation

The problems to be studied are so many, so large, and so complex, that their solution can not be brought about in a day. They will require time and money. Whatever may be the character of the organization at the beginning, it is more than probable that the work must sooner or later depend upon government patronage.

It is doubtful if this could be secured until after a campaign of education has been carried on. The holding of the first Pan-Pacific Conference at Honolulu last year, under the patronage of the Pan-Pacific Union, did much to develop public and government interest in the matter. Other similar conferences that may be held perhaps in the near future, in Japan, New Zealand or Australia, and perhaps in America, would prove very effective in increasing this interest. The Pan-Pacific Union would, in all probability, be glad to act as host and provide the funds to meet all necessary expenses. These conferences would almost certainly result in the taking up of certain more or less local investigations by local scientific institutions or bodies of scientific men.

When the governments see what private and institutional agencies are doing, they will begin to realize that some of these investigations can be carried on only with government aid and international cooperation. Then the time would be ripe for effecting an organization for the study of the scientific problems of the Pacific, something like The International Council for the Exploration of the Sea.

In the meantime, it would help greatly if the various scientific agencies on the Pacific Coast of America could unite in some sort of a cooperative organization to study some of the important and pressing problems right at their doors. Among the problems that concern us here on the American coast the following may be mentioned:

(1.) The Gigantic Tortoises of the Galapagos Islands. Fifteen species of these wonderful animals are known from those islands. Some are already extinct; others are certain of very early extinction unless steps be taken very soon to protect them.

(2.) The elephant seal of Guadalupe Island should be looked after at once. It may already be too late.

(3.) The Heermann gull and other sea bird breeding rookeries on islands in the Gulf of California. The California Academy of Sciences expedition to those islands this year found eggers from La Paz, Guaymas and other places at the islands gathering the eggs as fast as they were laid and taking them for food. Only a few years of such practice will prove fatal to the breeding rookeries of these interesting birds.

(4.) The sea turtles of the Gulf of California and the west coast of Lower California are in great danger of extermination.

(5.) The sea lions and harbor seals from the Gulf of California to Bering Straits need careful study. We do not yet know sufficiently well their relation to the fisheries.

(6.) The sea otter, now nearly extinct, should receive immediate attention.

(7.) The whales of the Pacific supply one of the most important and urgent fields for investigation.

(8.) The salmon, halibut and herring of our northern coast present a number of problems of mutual interest to the United States and British Columbia.

(9.) The tuna and other migratory fishes of the southern California coast.

(10.) The walrus of the North Pacific is being rapidly and ruthlessly destroyed.

Each and all of these present problems require for their investigation and solution the cooperation of two or more American countries.

There are on the Pacific Coast of America more than a score of scientific and educational institutions as well as numerous commercial and social organizations, and hundreds of scientific men that should be interested in the study and conservation of these animals.

It ought not to be difficult to bring about some sort of an organization of all, or at least a considerable proportion of these various units to work unitedly for the conservation of these vanishing natural resources. Such an organization, working through committees, would carry great weight with the several governments concerned and should in time be able to accomplish important results.

It would seem that this is an opportune time for taking the initial steps for bringing about the cooperation necessary for a study of these problems. With this object in view the following resolution has been offered:

Whereas, Our knowledge of the habits, distribution, and abundance of the marine mammals, certain species of food fishes and other interesting and important animals occurring on the Pacific Coast of America, is not adequate as a basis for the formulation of laws and regulations for their conservation and proper utilization, and

Whereas, There is reason to believe that several of these species will in the near future become extinct unless measures are promptly taken for their preservation, and

Whereas, The problems involved are such as concern the several countries of America bordering on the Pacific, now therefore be it

Resolved, That a committee of five, representing the Pacific Division, American Association for the Advancement of Science, be appointed by the president to take up with the committee on Pacific investigations of the Division of Foreign Relations of The National Research Council, the question of effecting an organization of the institutions and biologists of the American countries bordering on the Pacific for the purpose of formulating and carrying out a comprehensive plan for the scientific study of the mammals, birds, fishes, reptiles, and other marine animals of the Pacific coast of America now threatened with extinction.

Note.—The above resolution was unanimously adopted by the Pacific Division of the American Association for the Advancement of Science at its meeting at Berkeley, California, August 4, 1921. President George E. Hale at once appointed the following as members of the Committee:

Mr. Norman B. Scofield, of the California Fish and Game Commission;

Professor Edwin C. Starks, of Stanford University;

Captain W. C. Crandall, of the Scripps Institution for Biological Research;

Dr. Walter P. Taylor, of the U. S. Bureau of Biological Survey;

Dr. Barton Warren Evermann, of the California Academy of Sciences, as chairman.

Dr. Hale has recently authorized the enlargement of the committee and the following have been added:

The committee has been organized and is now formulating the problems to be taken up and the method of procedure. It is believed that it will be able to accomplish much for the conservation and proper utilization of the marine life of the Pacific.

Mr. W. E. Allen, Scripps Institution for Biological Research, La Jolla, Calif.;

A. W. Anthony, Museum San Diego Society of Natural History, San Diego, Calif.;

Professor William A. Bryan, Museum of History, Science and Art, Los Angeles, Calif.;

Dr. Harold C. Bryant, Museum of Vertebrate Zoology, Berkeley, Calif.;

Professor John N. Cobb, College of Fisheries, University of Washington, Seattle, Wash.;

Dr. C. McLean Fraser, University of British Columbia, Vancouver, B. C.;

Dr. G. Dallas Hanna, California Academy of Sciences, San Francisco, Calif., Secretary;

Dr. Harold Heath, Stanford University, Calif.;

Dr. William E. Ritter, Scripps Institution for Biological Research, La Jolla, Calif.;

Mr. Alvin Seale, Steinhart Aquarium, California Academy of Sciences, San Francisco, Calif.;

Dr. F. B. Sumner, Scripps Institution for Biological Research, La Jolla, Calif.;

Mr. Will F. Thompson, California State Fish and Game Commission, San Pedro, Calif.

THE DAWN OF THE CELL THEORY

By Professor JOHN H. GEROULD
DARTMOUTH COLLEGE

HOW often it happens that a great discovery, before it finally flashes out upon the world, smoulders for a long time in men's minds, dimly understood, its full significance unfelt! So it was with wireless telegraphy, which by Marconi's great imagination and skill was transformed from a piece of laboratory apparatus, capable of transmitting electric waves across a room, into a great system, flashing messages across oceans and around the world. So it was with each of the three great biological discoveries of the nineteenth century, the cell theory, organic evolution and Mendelism. The last, indeed, as the reader knows, lay dormant during the final third of the century, ready to spring into rapid and luxuriant growth at the opening of the twentieth.

Organic evolution, it is well known, had its birth in the master mind of the great French naturalist, Lamarck, at the very beginning of the nineteenth century, fifty years before the appearance of Darwin's "Origin of Species," but probably few, even among the ranks of professional biologists, are aware that the cell theory owes its conception to the same fertile, comprehensive mind.

Probably no statement in the history of biology is more widely accepted and quoted by biologists today than that the cell-theory, *viz.*, that all plants and animals, as well as their embryonic forms, are composed of similar elementary parts, the cells, founded in 1838 and 1839 by the German botanist Schleiden and his friend, Schwann. So when the present writer first read in Lamarck's "Philosophie Zoologique," published in Paris in 1809, the following statement, he could hardly believe his eyes. "No body can possess life if its containing parts are not a *cellular tissue*,[1] or formed by cellular tissue." And further, "Thus every living body is essentially a *mass of cellular tissue* in which more or less complex fluids move more or less rapidly; so that, if this body is very simple, that is, without special organs, it appears homogeneous, and presents nothing but *cellular tissue* containing fluids which move within it slowly; but, if its organization is complex, all its organs

1 The italics in this translation correspond to those in the original.

without exception, as well as their most minute parts, are enveloped in cellular tissue, and even are essentially formed of it."

In the introduction to the chapter on the "Physical Causes of Life," in which the words just quoted occur, Lamarck calls attention to the phenomena of organization and its development, especially in the lower animals, the consideration of which should convince the reader, he says, that (1) "The entire operation of nature in forming her direct creations [the development of the individual] consists in organizing into *cellular tissue* the little masses of gelatinous or mucilaginous matter that she finds at her disposal and under favorable circumstances; in filling these cellular masses with fluids that they are adapted to contain; in vitalizing them by setting the contained liquids in motion with the aid of subtle exciting fluids that ceaselessly flow into them from the surrounding medium."

How much more modern this sounds than the idea that those of us who are biologists at the beginning of the twentieth century are accustomed to hold regarding the doctrine of those who worked and wrote at the beginning of the nineteenth! We have been wont to think of the conception of the cell in those earlier days as being a cavity surrounded by a cell-wall that was then regarded as all-important, and here we find Lamarck declaring that the "little masses of gelatinous or mucilaginous matter," the protoplasm of later writers, organized into cellular tissue, are the essential vital elements, just as we hold to-day! Of the "subtle exciting fluids that ceaselessly flow into them from the surrounding medium," we are even to-day almost in ignorance. What Lamarck had in mind, as one gathers from reading elsewhere in the same work, was electric action. Lamarck seems to have anticipated by more than a hundred years the application of the electron theory to the cell, a field which to-day is still almost wholly unexplored.

Lamarck's conception of the mechanics of development set forth in his second essential condition of life is as follows:

> *Cellular tissue* is the matrix (literally "gangue," or vein-stone) in which all organization has been established, and through the medium of which the different organs have been successively developed by the movement of the contained fluids, which have gradually modified this cellular tissue.

The comparison of cellular tissue to a matrix or veinstone, in which the fluid living substance, energized and set in motion by forces acting chiefly from without, is gradually moulded into definite organs is not an apt simile, to be sure, from our present point of view, and yet even to-day are we able to replace it by a metaphor that would be more exact? In the conception now in vogue, however, the shaping of organs is attributed especially to the enzyme-like action of the chromosomes, to *internal* physico-chemical phenomena which Lamarck covered under the expression movements of "fluides contenables," acted upon by subtle exciting fluids, "which ceaselessly flow in from the surrounding media." Present conceptions (Weismannism and Mendelism) lay great emphasis upon the rôle in development believed to be played by cell nuclei, which were unknown to Lamarck. Thirty years later, when Schleiden and Schwann approached the subject, cell-nuclei had been discovered.

It is worth a passing notice that in a clear and keen analysis of the differences between organic and inorganic bodies, which Lamarck states had been already discussed by M. Richerand, but to which he adds his own ideas, growth of organisms is described as being by "intus-susception," a notion that the present writer has been accustomed to regard as much more modern.

The statements thus far mentioned were taken from the first volume of the "Philosophie Zoologique." In the second, Lamarck devotes an entire chapter to cellular tissue, in which he says: "It has been recognized for a long time that the membranes that form the envelopes of the brain, of nerves, of vessels of all kinds, of glands, of viscera, of muscles and their fibers, and even the skin of the body, are in general, the productions of *cellular tissue.* However, it does not appear that any one has seen in this multitude of harmonizing facts anything but the facts themselves; and no one so far as I know, has yet perceived that *cellular tissue* is the general matrix of all organization, and that without this tissue no living body would be able to exist nor could have been formed. In a foot-note he adds, "Since the year 1796 I have been accustomed to set forth these principles in the first lessons of my course."

In the same year (1809) that Lamarck published this classic work, another great Frenchman, Mirbel, brought out the second edition of his "Exposition de la Théorie de l'Organisation Végétale." The general conclusion reached in the book was that "The plant is wholly formed of a continuous cellular membranous tissue," or stated as the first of a set of botanical "aphorisms" that he had prepared for the Musée de l'Histoire Naturelle to accompany a large and beautiful plate illustrating the finer structure of plants, "Plants are made up of cells, all parts of which are in continuity and form one and the same membranous tissue."

Mirbel was probably the most distinguished and industrious plant anatomist at the opening of the nineteenth century, and it is interesting to trace in his works the earliest stages of the development of the cell theory. In 1802 appeared his "Traité d' Anatomie et de Physiologie Végétales." Here are only the incoherent elements of a cell theory. He had not yet arrived at the idea that all plants are essentially cellular, and he regarded the cell-wall as of primary importance. Cells he found, in fungi and Fucus, in the epidermis and parenchyma of the higher plants, more abundantly in herbs than in trees, in sprouts than in old wood. The embryo was composed "almost entirely" of cell tissue. But he had not at the time discovered the origin of the *tubes* that are embedded in the deeper tissues of plants, so that this earliest version of the first "Aphorism," quoted above, then read: "Plants appear to be entirely composed of cells and of tubes, all parts of which are continuous." Tubes, however, it will be noted, were omitted from this aphorism when it appeared in 1809.[2]

How much collaboration there may have been between Lamarck and Mirbel, who was thirty-two years his junior, does not appear from evidence now at hand, except that both must have been closely associated in the Musée de l'Histoire Naturelle, but in 1809 both entertained somewhat similar views regarding the structure of plants.

As Mirbel expressed it in his letter to Treviranus included in his "Théorie de l'Organisation végétale," all plants are formed of "one and the same membranous tissue, variously modified," not of distinct and separate elementary organs existing independently and held together by interwoven tubes and fibers; moreover he laid great stress upon his observation that cells freely communicate with one another by pores.

Whether Lamarck based his more extensive generalizations, which included animals as well as plants, upon Mirbel's observations as well as upon his own, it is evident that both held in 1809 the essential features of the cell theory.

As Mirbel's first aphorism stated it, "Les végétaux sont composés de cellules, dont toutes les parties sont continues entre elles, et ne présentent qu'un seul et même tissu membraneux."

It must be recognized, however, that Mirbel laid emphasis upon the membranous cellular tissue as fundamental, rather than upon the cell as a unit. The folding and modification of this tissue during development resulted in the specialized full-grown plant. And, to Lamarck, cellular tissue was the matrix within which the organs, *i. e.*, the blood vessels, nerves, and other "tubes" are moulded by the movements of the contained fluids. The thought of both was centered upon the organism as a whole and

[2] It was not until 1832-33 that his studies on the structure of Marchantia convinced him by direct observation that the tracheæ are formed from cells, and do not constitute an exception to the rule that all plant structures are cellular in origin.

the primacy of cellular tissue. But to Mirbel's mind this tissue was membranous. Bichat had just laid the foundations of animal histology by the classification and description of tissues among which he included membranous cellular tissue, by which he apparently meant undifferentiated connective tissue. Probably this important and remarkable work influenced Mirbel. Neither Mirbel nor Lamarck apparently thought of the individual cell as the elementary unit.

The idea of the individuality of the cell, an important contribution to the cell theory, is due to Dutrochet, 1824, who set the notion forth in a book apparently very little known at present.

This is a fascinating account of his own physiological experiments on the movements of the sensitive plant, on growth movements and heliotropism in plants, and on muscular action in animals. He was also something of a histologist, though his microscopes (simple lenses of high magnification) were undoubtedly poor, and his methods of treating tissues with nitric acid and strong alkalis a bit drastic. After summarizing the then recent (1824) researches of Milne Edwards (Mémoire sur la structure élémentaire des principaux tissus organiques), who had found in the tissues of animals nothing but masses of globules (globules agglomérés) he says, "I have verified the exactness of these observations: everywhere, indeed there is found in the organs of animals only globular corpuscles, sometimes united into longitudinal and linear series, sometimes massed in a confused manner." After numerous details, which we pass over, he states, "From this we may draw the general conclusion that the globular corpuscles, which by their assemblage make up all the organic tissues of animals, are actually globular cells of exceeding smallness, which appear to be united only by a simple adhesive force; thus, all tissues, all animal organs, are actually only a cellular tissue variously modified. This uniformity of finer structure proves that organs actually differ among themselves merely in the nature of the substances contained in the vesicular cells, of which they are entirely composed."

Then, after telling of the wonderful diversity of cell organization in plants, which he believed to be greater than in animals, he exclaims, "One can not conceive how a diversity of products so astonishing can be the work of a single organ, of the cell! This astounding organ, in the comparison that can be made between its extreme simplicity and the extreme diversity of its real nature, is truly the fundamental element (pièce fondamentale) of organization; everything, indeed, in the organic tissue of plants, is evidently derived from the cell, and observation has just proved to us that it is the same with animals." Thereupon he points out that the blood itself is a fluid tissue, capable by coagulation of becoming like other tissues. In it the corpuscles, which he regards as cells, float freely.

But closer examination of Dutrochet's work reveals the fact that the cell theory which he held rested upon an insecure basis of fact. This was due not so much to imperfect observation with imperfect microscopes as to the fact that the ultimate organic unit had not yet been accurately defined. That every bit of living matter has its spherical nucleus was still undiscovered.

It was the aim of the naturalists of that period, however, to resolve all organisms into their ultimate parts. The ultimate parts that they found were minute globules of various sizes, some cells, some nuclei, some nucleoli, some merely granules within the cytoplasm. It was unfortunately upon the observation of these diverse globules that Dutrochet based his excellent conclusions. He undoubtedly saw cells, and his figure of a segment of an arm of Hydra seems to prove that he saw nuclei, but the latter were to him "nervous corpuscles," corresponding to bodies in the cells of the sensitive plant, which, his figures suggest were probably nucleoli or chromosomes. He showed corresponding granules also in the stem of Vorticella, arranged in linear order. Possibly these were cytoplasmic microsomes; certainly they were not cells.

The fundamental ideas of Schleiden and Schwann's cell theory were thus contained in the writing of these and other writers of the previous generation, who have not been recognized as its founders chiefly because the term cell, in their minds, was loosely defined. They had not learned that a typical unit mass of living matter has a single spherical nucleus. The discovery of this fact made the establishment of the cell theory sure, and in the present writer's opinion was even more important than the work of Schleiden.

Although the nucleus had been seen and figured by still earlier writers, its general occurrence in plant cells was first recognized by Robert Brown, 1833, a by-product of his work on fertilization in orchids and milkweeds.[3]

It was this work that furnished Schleiden with his inspiration, and led to his attempt to discover the relation of the nucleus to the development of the cell, to answer the question: "How does this peculiar little organism, the cell, originate?" This question he answered to his own satisfaction, though not to ours, when he described the birth of the young cell by the appearance of a sort

[3] p. 710-713. See *References to Literature.*

of lens-shaped bud upon the surface of the nucleus, or "cytoblast," as he renamed it.

It is difficult in these days to follow Schleiden through the details of his "discovery," but it would appear that by the great solubility of cellular tissue (cell walls), when not too thick, a fact which "some physiologists ——— have felt prepared to deny," the new-born cells first float free, then become massed together and secrete about themselves new walls, in which the nucleus becomes imbedded, if it has not already been absorbed or "cast off as a useless member." This incorrect idea of the general method of formation of new cells overemphasized their freedom, and is reflected in Schleiden's oft-quoted remark of that "Each cell leads a double life: an independent one, pertaining to its own development alone; and another incidental, in so far as it has become an integral part of the plant." It is around this version of the cell theory, further elaborated by Haeckel in his conception of the organism as a cell state or cooperative colony of free citizens, that much discussion and criticism of the cell theory has centered, led particularly in the last decade of the nineteenth century by Sedgwick, 1895, and Bourne, 1896. The outcome of this and still more recent discussions has been to swing the emphasis away from Schleiden's version, founded as it was upon misconceptions of the process of the formation of new cells and ignorance of the universal fact of nuclear and cytoplasmic division, back to the point of view of Lamarck and Mirbel that, in its growth, the cellular organism reacts as a whole.

Although Schleiden did not originate the idea of the cell theory, which, as his "Phytogenesis" shows, he got directly from Mirbel and his own German contemporary, Meyen, he did good service to science by calling attention to Robert Brown's discovery of the universal occurrence of the nucleus in plant cells, and especially by stimulating his friend Schwann in the prosecution of those important and epoch-making studies into the structure of animal cells that we have so long regarded as the foundation of the cell theory.

Schwann, as the preface of his classic work indicates, evidently knew little of the ideas of the French biologists who had drawn the plans and begun to lay the foundations of the cell theory thirty years earlier. The physiologist, Dutrochet, for example (whom Schwann does not mention), while he had held the Lamarck-Mirbel cell theory, having no standard by which to decide what a cell is, had left the notion of the animal cell in that confused, almost chaotic state, in which Schwann says that he found it. Schwann does refer to an isolated observation of Turpin, who compares the cells of the epithelium of the vagina with those of the parenchyma of plants, and of Dumortier, who had drawn the conclusion, from researches into the embryology of the snail, that Mirbel's proof of the development of plants from a single cellular tissue would not apply to animals, but there is probably little doubt that Schwann found in contemporary literature much confusion regarding the cell in animals.

The beautiful plates which Schwann has left us are a perennial memorial to his skill as an investigator and a striking demonstration of the essential features of various types of cells in animal tissues. Schwann, moreover, recognized that the egg is a single cell, though he was unable to decide whether its nucleus (germinal vesicle) is indeed a nucleus or a young cell.

Both Schleiden and Schwann were inquisitive to know how new cells are formed. They knew as little about it as did Lamarck. Schleiden's guess, that a lens-shaped excrescence forms upon the surface of a nucleus and furnishes a sort of intracellular bud from which the new cell develops, has already been mentioned. Schwann thought that their germ is a nucleolus, which, escaping from the nucleus into an intercellular, cell-producing "cytoblastema," grows by a process akin to crystallization, first generating the new nucleus and then the surrounding protoplasm.

But to follow the cell theory further would bring us beyond its dawn and to the break of day, to the time when the question that had perplexed the mind of Schleiden, "How does this peculiar little organism, the cell, originate?", was answered by the discovery of the interesting phenomena presented by the nucleus in cell-division. That discovery brought the cell theory into a new epoch, fraught with new and perplexing questions as to the nature of the forces that divide nucleus and cytoplasm, and shape the growing organism.

As we ponder upon these problems and seek to devise new experiments to solve them, we should do well now and then to turn back to the suggestive thoughts of Lamarck, who, untrammeled by some of the modern working hypotheses that tend to become crystallized in our minds as dogma, approached the great problems of life with the keen mind of a seer.

Résumé: (1) The cell theory was stated originally by Mirbel and Lamarck in 1808 and 1809, thirty years before Schleiden and Schwann. (2) Mirbel, like Schleiden, showed in 1808 that all plants are composed of cells, of cellular tissue, which he regarded as everywhere continuous, primarily membranous, and variously modified into all other plant tissues. He laid especial emphasis in the earlier years of his brilliant investigations upon cell walls, which he believed to be porous, allowing free, though slow, circulation of the contained fluids. (3) Lamarck, a year later, 1809, extended the idea of cellular origin to include both animal and plant structures. To him, cellular tissue was the matrix in which the organs (tubes of various sorts) are shaped by the movements of the contained fluids, which he regarded as essential vital substance. (4) Both Mirbel and Lamarck thought of the organism as a cellular whole, not as an agglomeration of units. (5) Dutrochet in 1824, adopting the Mirbel-Lamarck theory, introduced the idea of cellular units as composing the animal and plant organism, but the idea of the cell-unit had not yet been standardized and made definite by the discovery of the nucleus. (6) Robert Brown in 1833 recognized the universal occurrence of nuclei in all plant cells. The idea of the cell as a unit then became definite. (7) Schleiden in 1838 extended Brown's discovery by his own investigations of plant tissues, and stimulated his friends Schwann to research into the cell structure of animal tissues. He failed to discover how new cells originate, though this was the chief aim of his classic paper on phytogenesis. (8) Schwann in 1839 made a most important contribution to knowledge of animal histology, isolating, and accurately describing and drawing, many different varieties of cells. He added to the cell theory of Lamarck, Mirbel, and Dutrochet, guided by Brown's discovery of the nucleus, a clear-cut conception of the nature and limits of the individual animal cell. His elaborate speculative comparison between the origin and growth of crystals and of cells was founded on an erroneous belief as to the origin and development of new cells out of nucleoli, but, nevertheless, contains suggestions as to the nature of growth that foreshadow some of the more recent ideas of bio-chemistry and bio-physics.

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JAPANESE INFUENCE IN CHINESE MEDICAL EDUCATION[1]

By Dr. E. V. COWDRY

CHINESE STUDENTS IN JAPAN

THE forty-fifth annual report of the Japanese Minister of State for Education, published in 1920, is an imposing volume of about four hundred pages, printed in English. It is an analysis of the activities of the department for the fiscal year 1917-1918, and clearly shows how Chinese students of all kinds come to Japan for their education. They are found from the Kindergartens to the Imperial Universities, in the technical schools, Academy of Music, Fine Art School, in the Schools of Agriculture and Forestry, of Sericulture and Filature, even in the schools for the deaf, in fact almost everywhere. In the public and private special schools 980 are studying law and politics (giving Japanese ideals a strong footing in China) as compared with 66 in medicine. In the Imperial Universities, where it is more difficult to gain admission, there are but 18 in medicine. It is quite clear from the context that the Chinese are often listed simply as "foreigners," though a very small minority of foreigners are probably Europeans. A conservative estimate would place the number of Chinese students at well over 4,500. The report, as far as it concerns us, may be summarized as follows:

Foreigners in elementary schools	71
Foreigners in public and private kindergartens	127
Chinese in Tokyo School for the Deaf	1
Chinese in Tokyo Higher Normal School for Men	79
Chinese in Hiroshima Higher Normal School	6
Chinese in Tokyo Higher Normal School for Women	7
Foreigners in normal schools	1
Foreigners in public and private middle schools	11
Foreigners in public and private higher schools for girls	1
Chinese in higher schools	154
Foreigners in Tokyo Imperial University	52
Chinese in Kyoto Imperial University	29
Foreigners in Tohoku Imperial University	17
Chinese in Kyushu Imperial University	10
Chinese in Kokyo Fine Art School	13

[1] Anatomical Laboratory of the Peking Union Medical College and the Laboratories of the Rockefeller Institute for Medical Research, New York.

Foreigners in public and private special schools	1,188
Foreigners in Tokyo Academy of Music	11
Chinese in Kagoshima Higher School of Agriculture and Forestry	10
Chinese in Tokyo Higher School of Sericulture and Filature	4
Chinese in Tokyo Higher Commercial School	24
Chinese in Kobe Higher Commercial School	14
Chinese in Nagasaki Higher Commercial School	8
Foreigners in Tokyo Higher Technical School	202
Chinese in Osaka Higher Technical School	27
Chinese in Kyoto Higher Technical School	5
Chinese in Nagoya Higher Technical School	10
Chinese in Kumamoto Higher Technical School	1
Foreigners in public and private technical schools	29
Foreigners in public and private miscellaneous schools	3,052
	4,962

Since the elementary schools maintained by the Chinese communities in Yokohama, Osaka and other large commercial centers, and some private schools, are apparently not always included, it is safe to estimate that the number of Chinese students returning home each year to enter professional or business careers is well over a hundred. During the past few years some ill-feeling has developed but there are indications that a few of the more progressive Japanese are alive to the fact that these students may be converted into ambassadors of good will between the nations. It is unlikely that there has been any great falling off in number. Detailed reports subsequent to 1917-1918 are unavailable; but Mr. Shun Ichi Ono has very kindly obtained data from the official records kept in the "Inspection Office for Chinese Students in Japan," maintained in Tokyo by the Chinese Government, showing that 199 Chinese students have registered for courses in medicine (including dentistry) for the academic year 1921-1922 distributed as follows:

Achi Medical School	14
Chiba Medical School for Women	1
Chiba Special Medical School	50
Fuji Pharmaceutical School	1
Jikei Medical School (Tokyo)	6
Keioh University Medical School	1
Kyoto Imperial University	6
Kyoto Medical School	3
Kyoto Prefectural Medical School	2
Kyoto Pharmaceutical School	4
Kyushu Imperial University	17
Mizuhara Midwifery School	1
Nagasaki Midwifery School	5
Nagasaki Special Medical School	9
Nagoya Prefectural Medical School	1

Nippon Medical School (Tokyo)	23
Okayama Special Medical School	6
Osaka Dental School	1
Osaka Prefectural Medical School	5
Tokyo Dental School	4
Tokyo Imperial University	2
Tokyo Medical School	17
Tokyo Medical School for Women	15
Tokyo Midwifery School	3
Tokyo Pharmaceutical School	2
	199

The records show that the expenses of 118 of these students are paid by the Federal or Provincial Chinese governments and that 54 come at their own expense. The means of support of the remaining 27 are not given. It is interesting to note that none of the government students attends the Imperial University Medical Schools, perhaps on account of their insufficient pre-medical training or in view of the relatively high fees. They attend for the most part the special medical schools of which Chiba appears to be the most popular, with an enrollment of 50 students. The Nippon and Tokyo Medical Schools, which also attract a considerable number, are of rather inferior grade.

The fact that 25 out of the total number of 199 students, or a little over 12 per cent. are women, is indicative of the broad-minded policy which the Chinese are adopting toward medical education for women. It is indeed a considerably larger percentage of women medical students than we find, even in the United States, where in the year 1920-1921, they amounted only to 5.9 per cent.[2] It is significant also that 9 of them are maintained by the Chinese government; but why they should be sent to Japan where the opportunities for women medical students are distinctly less favorable than in China[3] it is very difficult to suggest.

The instruction offered is fairly uniform, because, in Japan, government control is far-reaching, and the private schools are usually well-organized and systematic in the enforcement of their requirements. Judged by the "Standards of the Council on Medical Education and Hospitals of the American Medical Association," with liberal allowance for difference in local conditions, very few of the Imperial Universities and special medical schools would fall below "B" grade while quite a number would probably be granted "A" rating. From our point of view there seems to be room for improvement in at least two directions.

[2] *Jour. Amer. Med. Assn.*, Chicago, 1921, lxxvii, 531.

[3] Cowdry (E. V.), *Anat. Record,* Phila., 1920, xx, 52.

The Japanese have outdone the Germans in the domination of the lecture method and have failed to compensate for so doing by giving elective courses and by making the curriculum elastic. For example, in thirteen representative medical colleges, lectures consume on an average of 59.67 per cent. of all the time allotted to the teaching of anatomy.[4] In one case they take up as much as 90 per cent. Since approximately the same proportion of lectures is given in other subjects, it is fairly obvious that the students have but little opportunity to discover things for themselves and to develop originality. The rigidity of the curriculum and the absence of any elective courses worthy of the name tend in the same way to stifle individual initiative. On the other hand, it can not be denied that students do learn the principles of medicine in a thorough if cut-and-dried fashion and that they profit greatly by their experience in other ways.

Only one Japanese instructor has volunteered the information (quite unsolicited) that Chinese students are in some cases unfairly treated. The accusation usually comes from foreigners, who know nothing first-hand, or from Chinese, who have also studied in the United States or in Europe. As a matter of fact, Chinese students are probably treated with indifference, or with a shade of patronage, which they may easily resent when they notice how different it is in the United States, where the instructors are particularly interested in them and vie with each other in their efforts to bring out their best qualities, so that, in effect, they receive preferential treatment. I have received verbal confirmation of the statement made in the report of the China Medical Commission of the Rockefeller Foundation[5] that entrance requirements are reduced in the case of Chinese students. This probably does not apply to the Imperial Universities. Actually, it is an encouragement to Chinese students to take up the study of medicine, though the motive may have been to increase the number of students for political or financial reasons.

It is perhaps safe to assume that these young Chinese, like many of their Japanese teachers, come to believe that Western supremacy depends upon nothing more than skill in mechanical inventions. This interpretation is soothing to their feelings, which are some times ruffled by the apparent crudity of Western customs. The more thoughtful among them may notice how thoroughly the Chinese classics are studied throughout the Empire and what excellent libraries are to be found in Tokyo, almost rivaling those in

[4] Cowdry (E. V.), *Anat Record*, Phila., 1920, xviii, 84.

[5] Rockefeller Foundation, 1914, Report of the China Medical Commission on Medicine in China. University of Chicago Press, 113 pp.

Peking, as compared with the easy way in which the classics are dismissed from consideration in the occident. As they follow the successive steps in Japan's renaissance, they cannot help observing that it is quite possible to take advantage of Western discoveries without jeopardizing the fundamental ideals of oriental civilization. Far from being injured by the new teaching Shinto and Buddhist shrines receive financial support from the Imperial Department of Education and are gradually increasing in number. Whether this increase is commensurate with the increase in population, I am unable to say, but even a casual visitor will notice how carefully the temples are tended in comparison with the dilapidated and neglected appearance of national monuments in China. They note also that the Japanese have overcome their scruples and have organized a system for obtaining bodies for dissection, which is unique in its efficiency. During the year 1914-15 over one thousand bodies were available at the Tokyo Imperial University alone; about ten times the yearly supply for the whole of China.

BODIES DISSECTED IN THE JAPANESE IMPERIAL UNIVERSITIES

YEAR	TOKYO	KYOTO	TOHOKU	KYUSHU
1917-18	781	370	223	378
1916-17	939	416	173	396
1915-16	724	435	93	438
1914-15	1,328	427	94	330
1913-14	888	433	89	329

The atmosphere in which the students live is charged with a strange mixture of liberalism and autocracy. Surprising innovations are being made, some of which are almost without parallel, even in the United States. The real significance of the enforcement of a law, passed some years ago, according to which the Presidents of the Imperial Universities of Tokyo and Kyoto are appointed on the recommendation of a nominating committee elected by the faculty, instead of by the Emperor, probably escapes them; but they do observe that freedom of speech is increasing and that the voting franchise is being extended. Growing confidence in the democratic methods of private schools is exemplified by the President of the Kyoto Imperial University sending his son to the Keioh University in preference to a government institution, an action which caused lively discussion and comment. The liberal and progressive element is certainly gaining strength in all domestic affairs, but unfortunately it is still quite inconspicuous in the foreign policy pursued by the government in Korea and in China. Both at home and abroad these students have had a taste of the shady side of militarism so that many of them become intensely liberal in their sympathies. With their pride of race they feel, and are justified in feeling, that what Japan has done they can also do. As far as they are able, they will try to duplicate her successes and to avoid the painfully mistaken Prussian philosophy of her military leaders. On their return to China, many of them secure positions of responsibility and exercise considerable influence (often political) in the federal and provincial medical schools and hospitals. It is natural for them to send their own students to Japan, to buy their medical supplies in the Japanese markets with which they are familiar, and, in some cases, to appoint skilled Japanese instructors to important posts in which other foreigners would not be tolerated. Only recently, following the Shantung award, has it become necessary to replace these Japanese by Chinese in the medical schools of the capital.

Professor John Dewey[6] sums up the situation as follows: "Although cultivated Japanese as well as politicians like Marquis Okuma have long proclaimed the right and duty of Japan to lead China, to be the mediator in introducing western culture into Asia (including India, where they look upon the English[7] as alien interlopers), few Americans have taken seriously the dependence of China upon Japan in just these ways. I have seen books on the development of modern Chinese education which do not mention Japan, which attribute the renovation of the Chinese system to American influence, and which leave the impression that it is molded upon the American common school system. As a matter of fact, it is molded administratively wholly after the Japanese system, which, so far as Western influence enters in, is based on the German system, with factors borrowed from French centralization. I have visited nine provinces and seen the educational leaders in the capitals where the higher schools are concentrated. There are but two cities, Peking and Nanking, where, in the government schools, direct western influence begins to approach the Japanese, either in methods or personnel. To talk about returned students and fail to discriminate between those from Japan and those from Europe and America is to confuse everything touched by the discussion." He goes on to say that "By far the greater number of the revolutionary leaders who formed the Republic were Japanese or had lived in Japan as refugees and imbibed its culture as they never assimilated that of the West."

Japanese Teaching In China

In addition to training Chinese students at home, the Japanese

[6] *The Asia Magazine*, 1921, xxi, 582.

[7] In this, the Japanese are deceiving themselves, because anthropologists hold that the English are Aryan and consequently more closely related to the Hindus (who are also Aryan) than are the Japanese.

are actively carrying medical education into China. In 1911 the South Manchuria Railway Company established a good hospital and medical school at Mukden. The arrangement of buildings is illustrated on page 290. Visitors are ushered into a reception room and, after a fitting delay, are received by the director who conducts them on a tour of inspection. On entering the wards, which extend out behind the main hospital building and are spotlessly clean, dispensation is courteously granted so that it is not necessary to follow the Japanese custom and remove one's shoes. Any dirt that may have been introduced is quietly wiped away by nurses wearing their black and heavily-oiled hair piled high in pompadour, precisely as in Tokyo. Passing from building to building, along paths bordered with newly planted trees, one is impressed with the completeness of it all. No necessary detail of equipment or administration seems to have been forgotten. The new laboratory building, shown on page 291, would not seem out of place on the campus of one of our best universities. It is semi-fireproof and the rooms are laid out upon the unit system and supplied with moveable furniture so that they may be easily adapted to meet the changing demands of medical science.

Useful information is given in the official announcement, printed in English (for the convenience of foreigners), from which I quote *verbatim* as follows:

Aims of College

The aims of the college lie in training Japanese and Chinese physicians of fine character and competent ability who assume their parts to contribute to the progress of medical science, particularly to study the natures of, and the cures for, endemics peculiar to Manchuria.

Status of College

The college stands on a plane equal to the medical colleges at home under government management. It is organized according to the Imperial College Act. It goes without saying that the graduates of this college are entitled to every privilege and qualification accorded to the graduates of home colleges.

Competitive Entrance Examination

The competitive entrance examination for the first year grade of the principal course is conducted in:

Mathematics (algebra, geometry and trigonometry), physics, chemistry, natural history (zoology, botany, physiology and hygiene), composition, foreign language (either English or German), Japanese (for Chinese applicants only), etc.

The standard of the examination is put on a level similar to that of a graduate of a middle school.

The entrance examination for the first grade of the preparatory course is held in mathematics (arithmetic and algebra), physics, geography, and history, Chinese classics, drawing, etc., on a level with the third year of the middle school.

Curriculum

The new students joining the first year grade of the preparatory course are to take up the study of ethics, Chinese classics, Japanese, mathematics, physics, chemistry, biology, gymnastic exercises, etc., in the course of two years, and then pass into the first grade of the principal course.

The curriculum of the principal course running four years comprises: Physics, chemistry, anatomy, physiology, pathology, pharmacology, interclinique, surgery, kinderclinique, dermatology, the science and treatment of venereal diseases, rhyno-laryngo-otology, opthalmology, gynecology, psychology, hygiene, bacteriology, medical jurisprudence, dentistry and oral surgery, ethics, Chinese or Japanese (Chinese for the Japanese students and Japanese for the Chinese), German, gymnastic exercises, etc.

Monthly Expenses of Students

The monthly expenses of a student inclusive of tuition fee, dormitory expenses, etc., amount about Y 17 each.

I am indebted to Doctor Motoi Yamada, Director of the college at the time of my first visit, for many courtesies and to his successor, Doctor M. Hirano, for the following detailed information which shows a steady increase in the proportion of Chinese students compared with Japanese, and enables us to calculate the cost of the education provided. In 1921 the outlay for current expenses exceeds the income by 394,773 Yen, so that each of the 212 students represents a yearly expenditure of 1,862 Yen or about $931 U. S., which compares favorably with the tuition fee of 17 Yen per month (including dormitory and other expenses). On the basis of ten months' instruction per year, this would amount to 170 Yen, or about $85 U. S.:[8]

Annual Budget of 1921

	(School)	(Hospital)
Buildings, gold yen	186,912	314,348
Instruments	5,400	9,000
Books	8,100	———
Income	6,472	434,574
Current Expenses:		
Outlay	278,703	557,116

Students

	(Japanese)	(Chinese)	(Total)
Final class	18	13	31
Fourth class	25	15	40
Third class	19	17	36
Second class	28	16	44
First class	37	14	61
Total	127	85	212

[8] The Report of the Council on Medical Education and Hospitals (*Jour. Amer. Med. Assn.*, Chicago, 1921, lxxvii, 534) for the year 1920-1921 shows that in 42 American medical schools listed in Class A, the fees for each student range from $175 to $350 per year, which does not include the very large item of living expenses.

Graduates

(No.)	(Year)	(Japanese)	(Chinese)	(Total)
1st	1915	11	0	11
2nd	1916	12	0	12
3rd	1917	17	4	21
4th	1918	24	11	35
5th	1919	24	14	38
6th	1920	25	15	40
Total		113	44	157

Bodies for Anatomical Purposes

(Year)	(Men)	(Women)	(Total)
1911	3	2	5
1912	18	5	23
1913	31	7	38
1914	44	10	54
1915	120	21	141
1916	88	15	103
1917	65	14	79
1918	56	14	70
1919	34	10	44
1920	71	12	83

Patients

(Year)	(Outpatients)	(Inpatients)	(Total)
1911	23,543	13,884	37,427
1912	35,890	20,000	55,890
1913	62,035	34,701	96,736
1914	68,911	49,628	118,539
1915	69,536	67,257	136,793
1916	84,839	70,507	155,346
1917	114,423	75,888	190,311
1918	116,135	74,847	190,982
1919	126,033	83,417	209,450

A beautiful booklet, bound in yellow silk, containing a splendid selection of photographs of the buildings, clinics and points of interest, has been recently published and may be obtained from the director. In the pre-clinical divisions there is an adequate full-time staff, so that the college is able to distribute every year a most creditable volume of reprints of scientific contributions. An important innovation is made with respect to travel. Entire classes of students have visited our college in Peking and make other expeditions in order to become familiar with local conditions.

The Chinese students at Mukden appear to be treated on a basis of absolute equality with their Japanese companions; whereas, in the Japanese Government School at Seoul (Keijo Medical School), a special and more advanced course is provided for the Japanese which gives them certain privileges not enjoyed by the Koreans. The two courses are clearly set forth in the yearly Japanese announcement.[9] In practical gross anatomy, for instance, the Japanese are given 144 hours and the Koreans only 36. No harmful results of the present régime are noticeable, probably for the reason that a missionary institution, the Severance Union Medical College, gives excellent medical training to classes chiefly composed of Koreans which compensates so that highly trained Koreans, as well as Japanese, enter medical practice.

The Japanese Government maintains a medical school in Formosa, which admits Chinese students, and is reported to be in good condition. The Japanese military authorities have closed the former German Medical School at Tsingtau, though the hospital is said to be open. I am told[10] that Professor M. Miyajima, of the Kitasato Institute of Infectious Disease, has recently visited Shanghai in order to report on the advisability of opening there a branch of the Institute. Such action would meet a need which has long been felt for sera of different kinds.

A Japanese society, of which the late Marquis Okuma was president, operates a system of hospitals in the larger cities, such as Peking, Nanking, Shanghai, etc., and a new one is now under construction at Hankow. The entrance to the Dojin Hospital of this society in Peking is shown on page 292. The style of architecture is very characteristic of Japanese buildings in China. While these hospitals are intended primarily for Japanese residents, and occasionally afford asylum to Chinese political refugees, they do take in number of Chinese patients and serve as active centers for the dissemination of ideas of western medicine. The cures which are effected lead the people to doubt the efficacy of native Chinese medicine which is a stride in the right direction for dissatisfaction with present conditions is the strongest motive for improvement.

Japanese drug stores are widely scattered in many towns throughout China. The drugs are not of the best and morphine is often sold in disguise, as has been shown in a careful survey undertaken by the "Peking and Tientsin Times" in 1920. But we recall that other nations hold no monopoly of virtue with respect to either opium or patent medicines. The drugs dispensed in these stores at considerable profit are, at least, improvements on native Chinese remedies which are often made up on the principle that they must be as disgusting as possible in order to frighten away the evil spirits which cause the disease. The stores will continue to be little clinics where informal advice is given regarding minor ailments. Good business demands that the proprietors attempt to give

[9] I am indebted to Dr. E. T. Hsieh for a translation.

[10] By Professor Hiroshi Ohshima of the Kyushu Imperial University.

satisfaction to their customers and not impose upon them to the point of losing their patronage. "A little medicine is a dangerous thing" where it leads to ignoring the valuable advice of competent physicians; but, in China, where there are so few physicians, a little western medicine is certainly better than none at all. It is, at least, a competitor in a small way, and weakens the monopoly of native medicine, which, with its large elements of fancy and superstition, exercises, in my opinion, a strong inhibiting influence upon independence of thought and action.

In times of plague and famine, the Japanese are always among the first to come forward to help. Just at present there is a tendency to disparage their efforts and to look for hidden motives which may not exist. When they contribute to famine relief, it is called propaganda; when they erect a new hospital, it is also called propaganda, leading, it is said, directly to disarming opposition and to making the penetration and eventual control of China easier. Every action in which a selfish motive cannot be immediately seen is labeled in the same way, and they are not slow to return the compliment by suspecting the actions of other foreign nations. There can be no doubt that many Japanese regard the expenditures of the Rockefeller Foundation in China as propaganda pure and simple. An aphorism of the Chinese philosopher, Lao Tzû[11] is *à propos*: "He who has not faith in others shall find no faith in them." This mistrust is lamentable because it makes cooperation so very difficult. As a matter of fact, the absence of organized Japanese propaganda in China with attractive concessions aiming at the establishment and maintenance of cordial relations is most noticeable.

Japanese help comes in a perfectly natural and straightforward way. The Chinese Army Medical School in Peking may be in part regarded as an outcome of the repeated demonstration by the Japanese in North China of the practical value of a really efficient army medical service. Regimental surgeons in the south of China are trained at the Kwangtung Provincial Medical School at Canton, which is below par in both equipment and personnel. During hostilities, officers from the headquarters of the Chinese Red Cross in Peking are occasionally supplied to the southern troops.

Japanese settlements in the treaty ports and elsewhere are, as one would expect, growing much more rapidly than those of other nations. The in-coming Japanese bring with them improved methods of sanitation and for the care of the sick which they place

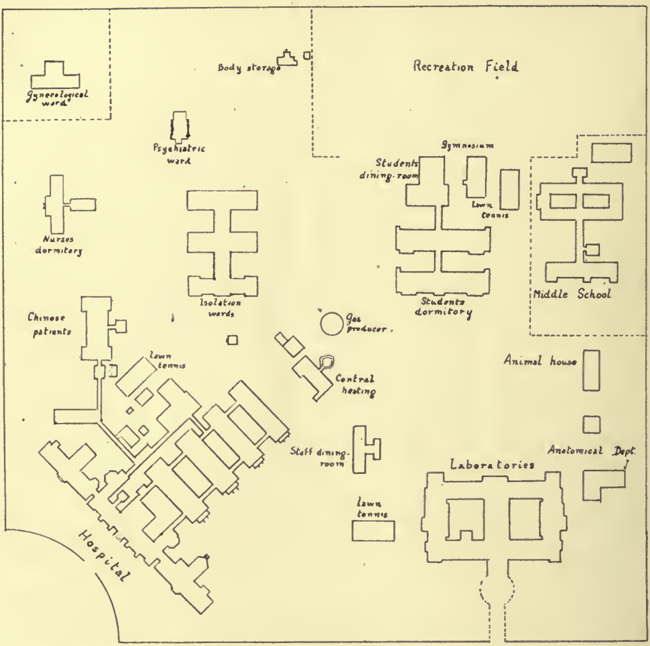
[11] Giles (Lionel), The Sayings of Lao Tzu. London, John Murray, 1917, 53 pp.

at the disposal of the Chinese at a price which the Chinese are usually well able to pay. It is not at all a question of charity, which the Chinese find it so difficult to understand. Their schools and hospitals in China, like those of the Chinese Government, are absolutely free from religious teaching. Conversion to Shintoism is not even a desideratum. The Japanese have numerous temples in China which can be recognized by the peculiar arches, called tori, at their entrances, but there is no attempt to demonstrate, or even to suggest, the superiority of the form of Buddhism which they profess. It is, I think, safe to say that without the tremendous force and inspiration of the missionary motive the Japanese have, indirectly and without any spirit of altruism, accomplished more in the introduction of modern medicine than any other nation. Certainly the results obtained by the non-missionary organizations of any country (except perhaps the United States) do not bear comparison with those of the Japanese. Of the thirteen medical schools under foreign control (not counting Japanese), eleven are under missionary auspices, the Medical Department of Hongkong University is a Government Institution and the Peking Union Medical College is "sympathetic with the missionary spirit and motive" with six of its thirteen trustees appointed by missionary societies.

It is to be hoped that the Japanese will adopt the plan of offering scholarships or prizes to Chinese students to enable them to study in Japan. To be most effective, these scholarships should come from the Imperial Japanese Department of Education in cooperation with the Foreign Office but commercial organizations trading in China are in a position to help. If, for instance, some of the large firms dealing in medical supplies, comparable to Burrows Wellcome & Co., in England, should offer a scholarship to the student graduating at the head of his class in each of the Chinese provincial medical schools enabling him to study for a year in a Japanese Imperial University, it would establish cordial relations and the firm would certainly not be the loser in the long run. This might pave the way for the establishment of a system of exchange professorships between Japanese and Chinese Universities. If the Japanese will only coordinate and systematize their influence in the introduction of modern medicine into China, important results will surely follow for their opportunity is unique.

Japan's Qualifications as Teacher

European nations can help China but the help is as nothing compared with what the Japanese are capable of giving. They



PLAN OF ARRANGEMENT OF BUILDINGS OF THE SOUTH MANCHURIAN RAILWAY MEDICAL SCHOOL, MUKDEN

have almost accomplished the task which China is beginning. Seventy-five years ago, the same kind of native medicine was powerful in Japan. With the aid of their strongly centralized government, they have rigorously attacked it and have almost banished it from the Empire so that the casual visitor has to look carefully indeed to find any traces remaining. The picturesque priest-doctors of Old Japan, illustrated so well in a recent number of the "National Geographic Magazine," are seldom seen. The old Chinese pharmacopœia with its noisome preparations has been cast aside; and acupuncture, or the art of healing by relieving the body of the malicious excess of male or female principles through needle-sticking, has been made unpopular. An intellectual revolution has, in fact, been accomplished. Thanks also to the circumstance that the Japanese have borrowed their writing and their culture from China, it is relatively easy for them to make themselves at home and to understand local conditions. It is fashionable now-a-days to harp on racial differences, but in Peking Cantonese are sometimes mistaken for Japanese; and, when I visited the Tokyo Imperial University with a Japanese friend who out of politeness to me spoke English, he was at first mistaken by his fellow-countrymen for a Chinese. Similarity of this kind is of course exceptional, but it is none the less significant. Nobody would long mistake a European for a Chinese. And, lastly, the Japanese have the advantage of propinquity. With the establishment of a new line of fast steamers between Shanghai and Nagasaki, reducing the time of passage to less than thirty six hours, travel will be greatly expedited. Close estimates show that it costs less than one tenth as much for Chinese students to obtain a good medical education in Japan as it does in the United States. Under these circumstances it is not surprising that some of the provincial governments send more students to Japan than do all the rest of

NEW LABORATORY BUILDING OF THE SOUTH MANCHURIAN RAILWAY MEDICAL SCHOOL DEVOTED CHIEFLY TO INSTRUCTION AND RESEARCH IN THE PRECLINICAL SCIENCES

the world put together. I am informed[12] that the Province of Chekiang maintains approximately thirty students of different kinds in Europe and America as compared with about one hundred in Japan. Students who have to save up and pay their own way find the low traveling expenses and simple scale of living in Japan very attractive.

Though I agree with the late Marquis Okuma that it is the right and duty of Japan to aid China, I do not for a moment advocate anything approaching a monopoly in this respect; for if the help of other foreign powers are withdrawn, or pursued with less vigor, it would be a very real catastrophe. Japan's contribution can be made of great value in spite of the fact that she is naturally unable

[12] Dr. Tsang G. Ni of the Hangchow Provincial Medical School, Hangchow, Chekiang.

to compete on an equal footing with Western nations in the introduction of western culture and philosophy. She gives what she has herself absorbed in the manifold applications of science to human welfare; but China is such an immense country that there is ample room for all the assistance that can be rendered. The goal is still afar off. As a matter of fact, hardly a beginning has yet been made since the large rural population remains untouched. We have to guard against misplaced optimism. China's traditional inertia will probably prevent the change from spreading over the nation with lightning-like rapidity as in Japan. A stable and united government is one prerequisite and Japan can help as none other to this end if she so desires. The calling of the Arms

ENTRANCE TO THE DOJIN HOSPITAL, PEKING

Conference in Washington is in reality a challenge to the liberal party in Japan to arise and throw off part of the burden of armaments, to refrain from military aggression and political intrigue in China and to lead other nations in a constructive program which will eventually place China in a position to help herself and to contribute her share toward "the welfare of mankind throughout the world."

The way is plain—all that is needed to extend Japanese influence is to put in practice a sufficiently comprehensive and well thought out program in which cooperation is the key-word. It is, after all, a problem in racial psychology. During many centuries China has been the intellectual master of Japan.[13] Now a rather delicate adjustment is required in the mental attitude of the new teacher as well as the old master. Japan's great success in adapting herself to the outside world, and the outcome of an unequal struggle with Russia, has bred arrogance, but I am one of those who believe that when she adopts a conciliatory and helpful attitude, China will meet her more than half way. Certain it is that the great masses of China's vast agricultural population have not yet awakened even to a realization of their wrongs. They toil on in philosophic calm and regard all foreigners with indifference. Much depends upon the spirit in which they, through education, slowly come to develop coherence and national ideals. In this, also, Japan will play a leading rôle.

[13] Fujikawa's Geschichte der Medzin in Japan (Tokyo, 1911) is replete with references to Chinese influence in the introduction of medicine into Japan, particularly during the Tang and Ming dynasties. Not only was medicine introduced by travelers and priest-doctors but the Japanese government sent special students to China to study medicine as early as 608 A. D. Not until the coming of Europeans did Chinese influence begin to wane.

A CURIOUS MATHEMATICAL TITLE-PAGE

By Professor F. CAJORI
UNIVERSITY OF CALIFORNIA

"CIRCLES to square and cubes to double would give a man excessive trouble.'' Thus sings old Matthew Prior, indicating that ''many knotty points there are, which all discuss but few can clear.'' Indeed, hundreds of would-be pathfinders of the intellect, from the time of Anaxagoras down to ours, have gone into ecstasy in the belief that they had solved the impossible problem of the squaring of the circle, only perhaps later to be cast into the depths of disappointment upon learning of their failure. Many have died under the delusion that they had accomplished the impossible.

The problem of the quadrature of the circle presents a strange phenomenon in the history of thought. A geometric construction is to be effected on very definite assumptions and restrictions—the use of a pair of compasses and an ungraduated ruler.

One element of strangeness lies in the fact that the problem has no bearing whatever on practical life. The mathematician and engineer can compute the area of a circle to any desired degree of approximation; if they wish, they can carry approximations to hundreds of decimal places, although five or six places suffice in practice.

Another feature constitutes a source of pride to present-day mathematicians. Unlike some philosophical questions which are as far from solution now as they were aeons ago, the circle-problem, after thousands of years of intellectual effort, has been finally and definitely conquered; in 1882 it was proved by conclusive demonstration accepted by all trained mathematicians, that, under the restrictions imposed, the circle can not be squared.

One item of interest, in connection with the quadrature of the circle, is not generally known. The problem suggested an illustrated title-page which is perhaps the most unique that has ever adorned a mathematical book. In 1647 the Flemish Jesuit mathematician, Gregory St. Vincent, published a wonderful geometry, containing genuine pearls of new geometric truth, but unfortunately also a false diamond, the quadrature of the circle. We reproduce the title-page, which presents to the eye the nature of

For this photograph I am indebted to Professor H. Bosmans, S. J., of Brussels.

THE ENGRAVED TITLE PAGE OF GREGORY ST. VINCENT'S *QUADRATURA CIRCULI*, ANTWERP, 1647 our obstruse problem. Seldom has a subtle abstract question found such striking concrete illustration. In the fore-ground are three bearded men in old-time garb. One of them with staff in hand has just drawn upon the ground, a circle and an equivalent triangle. On the right, the sphere and the cube suggest among other things the accomplished cubature of the sphere. As if these two drawings were not sufficient reference to the solution of the great problem, there is shown also the transmutation of the square and circle into each other by the solar beam of light passing through the square opening in a board and forming upon the ground below, a circular illuminated area. *Mutat quadrata rotundis.* One of the cherubs indicates by a pair of compasses that the figure is a circle. Another gives vivid evidence of surprise and delight. We omit descriptions of the twisted and fluted columns and other details, and only point out the challenge which this engraving makes to modern pedagogues, to equal or surpass, if they can, this powerful appeal to the eye.

Recently the present writer experienced a surprise by the discovery that this same title-page (with only very slight changes in unimportant details) was appropriated sixty years later in an edition of the collected works of another noted Jesuit mathematician, Andreas Tacquet. This edition appeared at Antwerp in 1707, some years after the death of Tacquet. Hence this "borrowing" was done by the editors and publishers. Evidently the novelty and impressiveness of the picture appealed to them so strongly that they used it in Tacquet's works even though this mathematician is not associated with the problem of squaring the circle. Tacquet is known chiefly as a teacher and as the editor of an edition of *Euclid* which was translated into English and used in Great Britain as a school book for the larger part of a century. The title-page of the 1707 publication represents therefore the transfer of a fanciful portal originally opening into the mystic realm of transcendental mathematics, to a well-trodden avenue leading to elementary schools.

THE PROGRESS OF SCIENCE[1]

ECLIPSES AND THE EINSTEIN THEORY

Einstein will be the moving spirit behind two expeditions that will spend six months or more traveling to Australia this year to have the opportunity of observing the eclipsed sun for six minutes.

May 29, 1919, when the moon last obscured the whole of the sun, photographs taken by British astronomers off the west coast of Africa and in northern Brazil showed a shift of the images of stars that has, in less than three years, shifted the thoughts of even unscientific people to the Einstein theory of relativity. September 20 of this year is the date on which Einstein's theory can again be put to the test of actual observation.

In an arid country, whose principal vegetation is a prickly plant that will penetrate even fairly thick leggings, a party of American astronomers, headed by Professor W. W. Campbell, director of the Lick Observatory, will set up an observatory. This site will be in northwestern Australia on a desolate coast, but to compensate for the bleakness of the place and hardship of the journey there, it is expected that the American astronomers will have the clearest skies through which to photograph the stars visible due to the eclipse. An Australian warship will carry the party from Sydney to the temporary observatory site. Close at hand there is a telegraph station, Wollal, which will keep the expedition in touch with the outside world.

But the British, whose expeditions secured the photographs of the 1919 eclipse, are going to compete with the Americans in observing. South of Java, 250 miles, on Christmas Island, they will erect their telescope, and they, too, are hoping for fair weather, with cloudless skies, so that they will settle to the satisfaction of all physicists and astronomers whether or not the sun attracts the star light passing by it.

If chance and the elements do not cooperate with the astronomers this fall, it will mean only a postponement of the day of judgment for Einstein's theory. There are more total solar eclipses coming. Including the one this year, there are three in the next three years.

Nearly a year later, September 10, 1923, San Diego will be the objective of astronomical expeditions or there will be telescopes set up in western Mexico. The time that the telescopes can be in action is only about half of that of this year's eclipse, as the totality will be only three and a half minutes, at about mid-day.

The further in the future the eclipses are, the less favorable they are astronomically but the closer they come to the eastern part of the United States. On January 25, 1925, New Yorkers will see the sun extinguished shortly after it rises, and a number of large observatories will have a chance to observe a total eclipse at home without the necessity of a special expedition. The weather conditions of this eclipse are expected to be the poorest of the three.

After this time, if the evidence for or against Einstein is not sufficient, the world must wait until the next eclipse, August 31, 1932, unless by means of photographic plates, sensitized to blue light only, the powerful yellow light of the sun can be ignored

[1] Edited by Watson Davis, Science Service.

Photograph supplied by Underwood and Underwood.

THE LATE SIR ERNEST SHACKLETON AND TWO MEMBERS OF HIS PARTY

Sir Ernest Shackleton, who died from heart disease on January 5, shown at the right, is in conversation with Captain Wilde of *The Quest* and Edal Erikson, a Norwegian member of the expedition. The photograph was taken on *The Quest*, at Southampton, England, shortly before its departure for the South Polar regions.

ABOARD *THE CARNEGIE,* JANUARY 16, 1922
To the left are Captain J. P. Ault, of *The Carnegie,* and Mr. Colin, Captain Frölich Hanssen and Mr. Steen, members of the Norwegian Legation. To the right are Captain Roald Amundsen and Dr. Louis A. Bauer.

and the very blue light of some stars can be made to record itself on the special plates in spite of the sun. That is a possibility, in view of the progress of photography.

Since the velocity of light is a leading factor in the Einstein theory, it is now the subject of experiment by astronomers and physicists. The question whether blue or yellow light has the greater velocity has been answered. Probably varying wavelengths of light have the same velocity. The chances are five to one that the difference in the time of passage of blue light and yellow light through empty space is less than one second in three hundred years. This is the conclusion that has been announced by Dr. Harlow Shapley of the Harvard Observatory after a study of light from the remote globular star cluster, called Messier 5, whose light takes 40,000 years to reach us.

Interest in Einstein has not waned since he came into general notice in 1919 or since his visit to this country in April of last year. The latest Einstein book is not an explanation of his theory, but a book about Einstein himself, "Einstein, the Searcher," a translation from Alexander Moszkowski, a friend and admirer.

EXPEDITIONS TO THE POLES AND THE TROPICS

Although the two poles have been conquered, the frigid zones still attract the typical explorer who goes to unknown parts of the globe to make additions to scientific knowledge.

Last September, Sir Ernest Shackleton and a little party on

Photographed, January 16, by Dr. Louis A. Bauer.

CAPTAIN ROALD AMUNDSEN

On board *The Carnegie* wintering in the Potomac River. Though the day was cold Captain Amundsen made a flying trip from New York unencumbered by an overcoat.

board the *Quest* started south to spend several years on a voyage around the coast line of the Antarctic continent. He planned to bring back scientific data on the magnetism, biology, oceanography, geology and meteorology of that region. Now news comes that Shackleton is dead, even before he began the real work of the trip that he planned as his ''swan song.'' But his expedition will continue.

In Baffin Land at a place called Nauwatta, Dr. D. B. MacMillan and his expedition are wintering. They are busy making observations of magnetic, atmospheric-electric and auroral effects. They are in the land of mysterious polar lights, whose shooting rays dance in rhythm with the quivering magnetic needle. With the cooperation of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, Dr. Louis A. Baner, director, special photographic instruments were carried into the polar regions for the first time. These should give data which will determine whether the aurora borealis comes close to the earth or whether it penetrates no deeper than sixty miles into the earth's atmosphere as Norwegian tests seem to indicate. Unexplored lakes in the interior of Baffin Land will probably be accurately placed on the map by Dr. MacMillan.

About June 1, Captain Roald Amundsen, the Norwegian explorer who discovered the South Pole, will set out from Seattle to make another attempt at drifting across the Arctic Sea frozen in the ice. Aboard the *Maud* will be instruments for determining the magnetism and the magnetic-electric effects at the different parts of the Arctic that the ship will visit. Soundings of the sea and meteorological observations will also be made. There will be little leisure for Dr. H. U. Sverdrup, who will have charge of the scientific work of the expedition. It is rumored that Captain Amundsen, in addition to his interest in the scientific work, has a natural desire to be the first man to visit both ends of the earth.

While the coldest regions are being discovered and charted, there are also scientific men who will contend with the heat and life of the tropics. This spring the Carnegie Institution is again sending parties headed by Dr. Sylvanus G. Morley and Dr. C. E. Guthe into the ancient country of the Maya to learn the details of their ancient civilization. The Field Museum of Natural History at Chicago has announced that there will be six expeditions that will leave for the tropics before the summer is well under way, to be in the field from two to five years. Two geological parties will visit the area from Brazil to Patagonia. The Isthmus of Panama and the state of Colombia will be visited by an archeological expedition and another party will go to the Malay Peninsula to study the ethnology of that region. Peru will be searched by two expeditions, one zoological and the other botanical.

THE CONCILIUM BIBLIOGRAPHICUM

So fast and broad has been the progress of science during the last few decades that the all-around scientific man no longer exists. All that an earnest worker in science can hope to do is to keep fairly well informed in the small corner of the field of science that he has selected. But to keep complete track of the researches in a single subdivision of science is perhaps an even larger task than following a number of matters in a general way.

Contributions to science are being made in practically all the countries of the world, reported in their own journals and in their own languages. The average student has access to only the limited library of his own college or institution. Few are so situated that they can see the bulk of the periodical literature even in their own field or have easy access to many new books.

Speaking in commercial terms, trade associations of science are needed. So are proper sales organizations and publicity departments, but that is another story. The point has been reached when the distribution of scientific knowledge among research factories is, because of the possibilities for the elimination of waste, an important enterprise for the progress of science itself. Production of science requires its proper distribution.

The re-establishment on a firm basis of the Concilium Bibliographicum at Zurich, Switzerland, which has just been accomplished, is an important step in improving the channels for the distribution of science. The International Catalogue of Scientific Literature is now officially dead from the prevalent financial disorder. The Royal Society could not take up its work completed only as far as the fateful year of 1914.

A stream of cards, 3x5, the library standard, has begun to flow out of the Concilium Bibliographicum. The contents of periodicals in the fields of zoology, physiology, evolution and anatomy are listed on these cards with title and author. The subject matter is indicated by a number in the elaborate system of classification that has been devised. Students, libraries and others can get just as many or as few of these cards as they wish. They can subscribe to all, or to those referring to one kind of butterfly. There are now subscribers in twenty-three countries, and one third of the total is in America.

The card system has advantages

THE FREER GALLERY
Located on the Mall in Washington, this is the latest of the group of buildings of the Smithsonian Institution. The Freer art collections are now being installed in it.

over the yearly volumes, months or years late, that are the usual forms of bibliographic work. Cards allow wide distribution in a minimum of time. The references of the Concilium are also assembled in book form by years for libraries and others who want them.

The Concilium Bibliographicum is an American institution, in spite of its location. It is a living memorial —which is the best kind—to Dr. Herbert Haviland Field, Harvard graduate and zoologist, who died in April of last year. In 1895, realizing how lack of prompt references hampers research work, he established the Concilium in the scientific center of Zurich. It never paid expenses. Subsidies from friends, then loans, kept it going and producing, until the war, which stopped the whole project. Dr. Field died suddenly while doing his best to re-establish his life's work. His efforts had been hampered by Europe's post-war curse, fluctuating exchange.

The Concilium has now been put on its feet, its obligations paid off, its staff held together and its future assured by grants of the Rockefeller Foundation, given through the National Research Council. Dr. Vernon Kellogg, permanent secretary of the National Research Council, visited Zurich to accomplish the re-establishment. Dr. J. Strohl, of the University of Zurich, a zoologist and an accomplished linguist, now heads the reorganized staff and has thrown himself, heart and soul, into the work. At present the control of the Concilium is in the hands of the Swiss Society of Naturalists and the National Research Council, awaiting the time that a representative international board can take control.

It is planned to expand the field covered by the work of the Concilium to cover other fields of science as soon as conditions permit. The abstracting of important papers is also being considered.

A CORPORATION FOR THE ADVANCEMENT OF PSYCHOLOGY

All scientific men are concerned with the advancement of the science in which they work, but only psychologists are professionally occupied with human conduct and its control. It is consequently becoming that they should make a new departure in the organization of their own work.

It has not hitherto been possible for scientific men to follow scientific research as an independent profession. There is no way of paying for the work that is of the greatest value to society. Some three fourths of those engaged in scientific research in this country are professors who earn their living by teaching; about a tenth are in the government service; others are in museums, botanical gardens and the like. It is only in recent years that a few scientific men have been employed to do scientific work in endowed research institutions and in industrial laboratories.

There scarcely exists at present any method by which a scientific man engaged in research can be paid in accordance with its value or by which the economic proceeds of research can be used for further work. A single advance in the applications of science, such as the Bessemer steel process, the electric motor, or the internal combustion engine, adds billions of dollars to the world's wealth, but the profits go to the millionaire who keeps a private yacht and to the laboring man who rides five miles for five cents. If one tenth of the economic value of scientific research could be reserved to pay the scientific men who do the work in order that they might adequately carry forward other researches, knowledge and its applications to human welfare would increase as never before.

Like the physical and biological sciences, psychology has supplied to society services worth manyfold their cost. But universities are indigent and government is shortsighted. An individual psychologist has no way to collect payment for his work. The services of psychology to the army in quickly sorting recruits into classes in accordance with their intelligence were worth many million of dollars to the nation, but the psychologists who created the tests were not paid, and only charity is now available to pay for the research necessary to improve the tests and to adapt them to business and industry.

The Psychological Corporation, now granted a charter by the State of New York, with the leading psychologists of the country as its directors, is the first business corporation whose objects are the advancement of science and whose profits must be used for scientific research. Its central office is in the Grand Central Terminal, New York City, and branches are in course of establishment in Boston, Washington, Pittsburgh, Chicago, San Francisco and other cities. The scientific work of the corporation will, however, be done in existing laboratories and institutions. The president is J. McKeen Cattell; the vice-presidents are Walter Dill Scott and Lewis M. Terman; the chairman of the board is Edward L. Thorndike, and the directors include James R. Angell, Richard E. Dodge, G. Stanley Hall, C. E. Seashore, E. B. Titchener, R. S. Woodworth, R. M. Yerkes and the other psychologists who have contributed most to the advancement of their science.

The Psychological Corporation plans to maintain adequate standards in applied psychology, to assure opportunities and proper payment to those competent to do the work, and to use all profits for psychological research. Its charter reads:

The objects and powers of this corporation shall be the advancement of psychology and the promotion of the useful applications of psychology. It shall have power to enter into contracts for the execution of psychological work, to render expert service involving the application of psychology to educational, business, administrative and other problems, and to do all other things, not inconsistent with the law under which this corporation is organized, to advance psychology and to promote its useful applications.

SCIENTIFIC ITEMS

We record with regret the death of Professor Charles Baskerville, director of the Chemical Laboratory of the College of the City of New York; of Dr. Pearce Bailey, the New York neurologist; of Sir William Christie, formr astronomer royal; of Sir German Sims Woodhead, professor of pathology in the University of Cambridge, and of Father Guiseppi Lais, vice-director of the Vatican Observatory.

Sir David Prain is about to retire, under the age rule, from the directorship of the Royal Botanic Gardens, Kew, which he has held since 1905. He will be succeeded by Dr. A. W. Hill, who has been assistant director since 1907. Dr. Hill, before his appointment to Kew, was lecturer in botany in the University of Cambridge, of which he is a graduate.

Dr. Hugh M. Smith, who has been United States commissioner of fisheries since 1913, has tendered his resignation. Mr. Herbert Hoover, secretary of commerce, has written to Dr. Smith: "I believe your service for thirty-six years, rising from the bottom to the top, in one of our great scientific bureaus, is unique in the history of the government. The whole country is under an obligation to you for so long and faithful a service."

Mme. Marie Curie on February 7 was elected a member of the Paris Academy of Medicine. It is the first time a woman has been elected a member of one of the French academies. The committee had presented six names as candidates to succeed the late Edmund Perrier. The five men nominated withdrew their names when they found out that Mme. Curie's name was on the list, and she obtained 64 votes against 15 blanks.

The officers of the Ramsay Memorial Fund announce that the dean and chapter of Westminster have consented that a tablet containing a medallion portrait of Sir William Ramsay should be placed in Westminster Abbey in the place immediately below that occupied by the Hooker tablet. The tablet is being executed by Mr. Charles Hartwell, A.R.A. It is anticipated that the unveiling will take place in October next. At the request of the Ramsay Memorial Committee a commemorative medal of the late Sir William Ramsay has beeen executed by the French sculptor, M. Louis Bottée. The medals will be struck in London when it is known approximately how many copies will be required.

A summer meeting of the American Association for the Advancement of Science will, by recent vote of the executive committee of the council, be held at Salt Lake City from June 22 to 24, in conjunction with the annual meeting of the Pacific Division of the association. Arrangements for the meeting are in charge of Mr. W. W. Sargeant, secretary of the Pacific Division. All members of the association and of the associated societies are invited to be present, and all associated societies are invited to hold sessions. Sections of the association are also invited to hold sessions, but no attempt will be made to have all sections represented on the program of the meeting.

THE SCIENTIFIC MONTHLY

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MENTAL AND PHYSICAL CORRESPONDENCE IN TWINS

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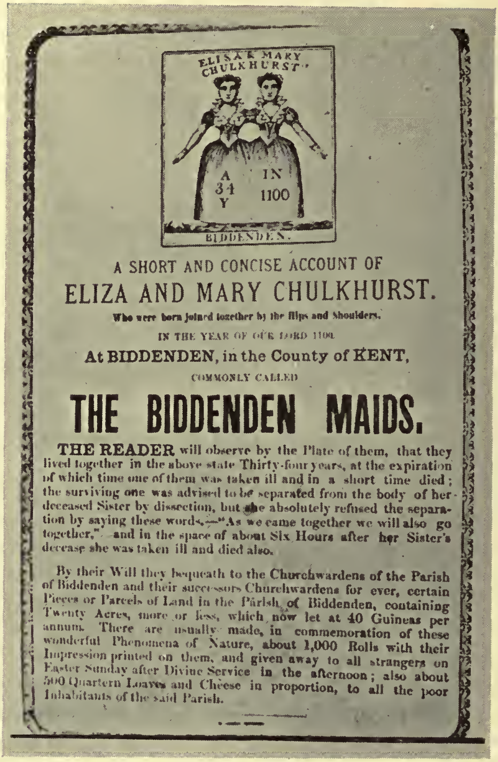
I. The Study of Twins

TWINS have always captured the curiosity and imagination of man. They figure in myths, traditions, superstitions, in art, in humor and in advertising. They are written in the constellations. Recently they have become one of the problems of science. Ancient Assyrians, Babylonians, Egyptians, Indians, as well as Hottentots used to kill both or one of a pair of twins, on the theory that twins were omens of ill luck or a form of sin. Though we hold no such erroneous conception, now-a-days, there is still a great deal of romancing about twins.

An antiquarian could compile a very interesting history of the subject. He could show how monsters and double monsters have left their impress upon legend and superstition. He could review for us the prescientific interpretations of such monsters and twins. Gould and Pyle in their *Anomalies & Curiosities of Medicine* have collected interesting facts revealing the extravagant and absurd character of these interpretations. Classical writings are sprinkled with truthful observations and conjectures; but modern embryology and teratology which have shed scientific light on the problems of twinning may be said to date back only to the eighteenth century.

The popular interest in twins, which is itself a suggestive psychological phenomenon, is by no means of recent date. For example, we have evidence to show that the Biddenden Maids who were born in Kent in 1100 A. D. excited quite the same curiosity which did the Siamese twins in the days of P. T. Barnum. The broadside reproduced from Ballantyne's *Antenatal Pathology* sums up the facts regarding this historical case (Figure 1). Whether these sisters were actually united by the arms may be questioned;


ELISA & MARY CHULKHURST

A 34 Y

IN 1100

BIDDENDEN.

A SHORT AND CONCISE ACCOUNT OF

ELIZA AND MARY CHULKHURST.

Who were born joined together by the Hips and Shoulders.

IN THE YEAR OF OUR LORD 1100.

At BIDDENDEN, in the County of KENT,

COMMONLY CALLED

THE BIDDENDEN MAIDS.

THE READER will observe by the Plate of them, that they lived together in the above state Thirty-four years, at the expiration of which time one of them was taken ill and in a short time died; the surviving one was advised to be separated from the body of her deceased Sister by dissection, but she absolutely refused the separation by saying these words,—"As we came together we will also go together," and in the space of about Six Hours after her Sister's decease she was taken ill and died also.

By their Will they bequeath to the Churchwardens of the Parish of Biddenden and their successors Churchwardens for ever, certain Pieces or Parcels of Land in the Parish of Biddenden, containing Twenty Acres, more or less, which now let at 40 Guineas per annum. There are usually made, in commemoration of these wonderful Phenomena of Nature, about 1,000 Rolls with their Impression printed on them, and given away to all strangers on Easter Sunday after Divine Service in the afternoon; also about 500 Quartern Loaves and Cheese in proportion, to all the poor Inhabitants of the said Parish.

Reproduced from Ballantymes Antenatal Pathology and Hygiene.
Wm. Green & Sons, Edbg., 1904, p. 642.

FIGURE 1. "BROADSIDE" OF THE BIDDENDEN MAIDS

but there is no doubt that by their twin will they bequeathed twenty acres, the income from which the church wardens were instructed to spend in distributing cakes (bearing the impression of their conjoined image) to all strangers in Biddenden, at the close of divine service each Easter; and also "270 quartern loaves, with cheese in proportion, to all the poor in said parish."

About four centuries later, at about the time when America was discovered, we have another historical instance, the dicephalic twins, known as "the Scottish Brothers." They were described in quaint language by the Scottish historian, Lindesay, as follows:

In this mean Time there was a great Marvel seen in Scotland. A Bairn was born reckoned to be a Man-Child; but, from the Waste up, was two fair Persons, with all Members and Portraitures pertaining to two Bodies, to wit, Two Heads, well-eyed, well-eared, and well-handed. The two Bodies, the One's Back was fast to the Other's; but, from the Waste down, they were but one Personage, and could not know by the Ingyne of Man, from which of the two Bodies the Legs and Privy Members proceeded. Notwithstanding the King's Majesty caused take great Care and Diligence upon the Upbringing of their two Bodies in one Personage, caused nourish them, and learn them to sing and play upon Instruments of Musick; who, within short Time, became very ingenious and cunning in the Art of Musick; whereby they could sing and play two Parts; the one the Treble, and the other the Tenor; which was very dulce and melodious to hear. The common People who treated them also, wondered that they could speak diverse and sundry Languages; that is to say, Latin, French, Italian, Spanish, Dutch, Danish, English, and Irish. Their two Bodies long continued, to the age of twenty-eight years; and the one departed long before the other, which was dolorous and heavy to the other; for which many required of the other to be merry. He answered, How can I be merry, that have my true Marrow as a dead Carrion about my Back, which was wont to sing and play with me. When I was sad he would give me Comfort, and I would do the like to him; But now I have nothing but Dolour of the Bearing so heavy a Burden, dead, cold, and unsavory, on my Back, which taketh all earthly Pleasure from me in this present Life: Therefore I pray to Almighty God, to deliver me out of this present Life, that we may be laid and dissolved in the Earth, wherefrom we came.

The Hungarian sisters were born in 1701, and died almost simultaneously in their twenty-second year. They were conjoined twins, similar to the Biddenden sisters, and according to Gould and Pyle excited great curiosity. This curiosity was not limited to the populace. The twins were exhibited all over Europe, were examined by scientists, celebrated by poets (including Pope), described by Buffon in his Natural History, and memorialized in a Latin poem and in a bronze statuette. The sisters Millie-Christine (colored, born 1851); the Bohemian sisters (born 1878); the sisters Ritta-Christina (born in Sardinia, 1829); the Tocci brothers (born in Turin, 1877), all were conjoined twins and more or less famous in their day.

Most famous of all, however, were the Siamese twins (Figure 2), who were discovered in Siam and rescued by a British merchant, in 1824, when they were about thirteen years old. They were rescued in this sense. King Chowpahyi was planning to put them to death, because he thought they might bring evil to his country; but the merchant prevailed upon his majesty to allow them to go away for exhibition. They went directly from Siam to Boston, and later were shown the world over. Although of Chinese extraction, they adopted America as their home, settled down as farmers in North Carolina, under the name of Bunker, and married two sisters at the age of forty-four. They became Christians; and died in 1874.

From the time when they landed in Boston and were examined

From Gould & Pyle Anomalies and Curiosities of Medicine.
W. B. Saunders. Phdpha., 1897, p. 168.

FIGURE 2. THE SIAMESE TWINS AT THE AGE OF 18

by a Harvard professor, they became the object of both scientific and popular attention. A vast amount of literature has been written in regard to them. In 1830 a scientific memoir was read before the Royal Society of London, and is to be found in the Philosophical Transactions of that year. The memoir reports a lack of strong resemblance in Chang and Eng; striking correspondences in their pulse rates and in their tastes; reciprocity of symptoms under similar conditions of disorder; differences in dreams; and a remarkable degree of consent and mutual adjustment displayed in the physical movements of the twins. It is comforting to know that Chang and Eng could playfully tumble head over heels, without the slightest inconvenience. The author of this fascinating report, rather naïvely remarks that "they are at present very much attached to each other." As a matter of fact until their death they showed an affectionate forebearance for one another; and a highly developed sympathy, understanding and adaptation.

To bring this historical retrospect to date, it should be mentioned that there are at the present writing living in Washington a pair of "Siamese twins," natives of the Philippines, boys now in their teens. Under a ruling of the director of the census bureau they were counted as two persons in the last enumeration.

Twins have played a prominent part in modern medical literature, and the annual volumes of the "Index Medicus" and the Surgeon General's catalogue carry a considerable number of titles of articles on some phase of the subject. Significantly enough there is usually one group of references sub-classified under the head of *Twins, one blighted.* Taruffii in his monumental work on Teratology devotes 1,650 pages to the consideration of double monsters.

For biologists, twinning has become a problem of central importance. Bateson has defined twinning as the production of equivalent structures by division; and emphasized its fundamental nature. Important studies in symmetry, asymmetry, teratology, sex and heredity, have been made in this field. H. H. Newman, of the University of Chicago, has made extensive studies of twin production, habitually exhibited in the nine-banded armadillo of Texas; and has written a valuable volume on The Biology of Twins.[1] H. H. Wilder has reported in *The American Journal of Anatomy,* studies of physical resemblances in twins, shown by skin patterns of soles and palms. Galton has made a similar comparison of finger prints in 17 pairs of twins. Baldwin has made physical measurements of 3 pairs of fraternal twins and determined their differences in anatomical ages.

In 1918, The American Genetic Association announced its desire to communicate with twins living in any part of the world. Six hundred twins and parents of twins responded with letters and photographs; and in December, 1919, the Journal of Heredity devoted an entire number to discussion of the data on the general subject. This number contains an article by Dr. C. H. Danforth on Resemblance and Difference in Twins. Goddard devotes two pages to certain eugenic phases of the problem in his work on "Feeblemindedness: its Causes and Consequences."

The present writer, in 1921, published a study of 40 cases of hemi-hypertrophy, and discussed this condition in relation to mental defect and to twinning.[2] Hemi-hypertrophy is a unilateral enlargement of the body, which is interpreted as a developmental

[1] Newman H. H., *The Biology of Twins (Mammals)*, University of Chicago Press, 1917; pp. 186.

[2] Gesell, Arnold, Hemi-hypertrophy and mental defect. *Archives of Neurology and Psychiatry,* Vol. VI, pp. 400-423.

anomaly dating back to an early embryonic stage of cleavage,—a form of asymmetry due to a possible deviation in the normal process of twinning. The relatively frequent complication of mental defect is attributed to an abnormality in this process of bilateral twinning which involves a disturbance of normal tissue development.

The psychological aspects of the phenomenon of twins have not received their full share of attention. There are, however, two notable exceptions. The versatile Galton, who left few human problems untouched, made a suggestive, though rather leisurely, excursion into the subject in his *Inquiries into Human Faculty* in the year 1883. He used the questionnaire method and reported the returns of 80 cases of close similarity. Much of his material was anecdotal; but it was used to good advantage to prove the dominating influence of nature over nurture. He found only two cases of strong bodily resemblance being accompanied by mental diversity. He makes this characteristic suggestion: "It would be an interesting experiment for twins who were closely alike to try how far dogs could distinguish between them by scent!"

In 1904, Thorndike published an important monograph entitled "Measurements of Twins," based on precise measurements of 50 pairs of unselected public school twins from 9 to 15 years old, in 6 mental traits, and 8 physical traits. "The arguments concerned the lack of differences in the amount of resemblance (1) between young and old twins, (2) between traits little, and traits much subject to training and (3) between mental and physical traits, and also the great increase in resemblance of twins over ordinary siblings. The resemblance of twins was found to be approximately .80 or .75 to .80 in amount." The author considers that his data give well-nigh conclusive evidence that the mental likenesses found in the case of twins and the differences found in the case of non-fraternal pairs, when the individuals compared belonged to the same age, locality and educational systems, are due, to at least nine-tenths of their amount to original nature.[3]

"The form of distribution of twin resemblance seems to be that of a fact with a central tendency at about .80 and with a great variability, restricted towards the upper end by the physiological limit of complete identity. Such a distribution would be most easily explained by the genesis of twins as a rule from two ova and by a great reduction of the variability of contemporaneous germs and ova below that of germs and ova developed at different times." (p. 63.)

[3] Thorndike, Edward L. Measurements of Twins, *Archives of Philosophy, Psychology and Scientific Methods,* Vol. I, pp. 1-64.

Thorndike therefore refuses to classify twins into the two classical divisions, duplicate and fraternal. He does not find two coherent species of resemblance; and he doubts that there are but two corresponding modes of genesis (monozygotic and dizygotic). He believes that there is considerable specialization of resemblance in all type of twins. Although he finds that resemblance in general appearance and countenance is correlated by no means perfectly with resemblance in other traits, his figures show a tendency toward such resemblance. The medians of resemblance in (1) three head measurements, (2) in three stature and arm measurements, (3) in perception, (4) in association,—of twins of the same sex (a) closely alike and (b) not much alike in countenance are as follows: 1. (a) 85, (b) 70. 2. (a) 86, (b) 59. 3. (a) 84, (b) 63. 4. (a) 94, (b) 70.

II. A Clinical Comparison of Duplicate Twins

We report herewith a case, or rather a pair of cases, which will serve as a basis for the consideration of the problem of resemblances in twins. We became interested in these two children, not because they were twins, but because of the exceptional superiority of their intelligence; and they were first studied from this point of view. Accumulating evidence, however, gradually convinced us that, regardless of their caliber, they presented a remarkable degree of correspondence in physical and mental constitution. It is this correspondence which is here emphasized. The facts have psychological interest, and may not be without some biological significance.

The twins will be referred to with an impersonal A and B, because there is no intention to publicly extoll them. We are not concerned to reveal their identity—except in the sense indicated by the term "identical twins!"

(a) Developmental History

A complete family chart of the twin sisters A and B would show evidence of superior endowment in the immediate ancestry on both the maternal and paternal sides. Scientific and linguistic ability of high order and physical energy are some of the traits which are found in the two immediate generations. The trait of twinning likewise has a hereditary basis in this instance; for the mother also bore two boys, twins who died in infancy.

Their sisters A and B were born six years later, by Caesarian section, somewhat prematurely, weighing respectively 4.3 and 5.3 pounds. They thus escaped some of the hazard and strains which may accompany birth.

Their prematurity did not hinder precocity. At any rate,

FIGURE 3. TWINS A AND B IN BABYHOOD

they very early showed unmistakable signs of more than ordinary alertness and attainment. At six months A startled her mother by rising suddenly into a sitting position in the mother's lap. Very soon after this B showed the same capacity. (Figure 3.) At 11 months they had both begun to walk and talk; indeed they were talking sentences, such as, "I see you, Auntie, * * *." They spoke clearly with less than the usual infantile lisping; and, according to report, with more than the usual degree of purposive, voluntary speech imitation. In October, 1915, at the age of three they began the study of French, and in less than a year (by April, 1916) they were reading elementary English, French and Esperanto. Their mother was a very constant companion; and stimulated this development by the aid of plays and games, but the children needed no prodding. They were distinguishing parts of speech with the aid of a Teddy Bear at the age of four; and at the same age one of them asked a searching question in regard to the Immaculate Conception. Formal arithmetic was begun at the age of six, and in less than a year they were solving mentally problems in fractions and percentage. They entered Grade III at the same age, and now at the age of nine, they are in Grade VII, doing Junior High School work. They are not prigs: they are attractive, animated, sociable children, with a bubbling sense of humor. They are popular with their playmates. They can take charge of a gymnasium class in which most of the members are two to four years their seniors, and preserve excellent attention and discipline. They speak mature but not pedantic English, and they speak French with the fluency of a native. They have read Genesis in Italian and are now speaking a little Italian. They have read the Book of Knowledge in its entirety in French; and a year ago embarked on Russian. They play duets on the piano; but not with rare distinction. They swim; they ride horseback; they write jingles, and they read by the hour. Their school work does not tax them; they do not worry about it; and they are far from fastidious in regard to the form of their written work.

In this brief general review of their developmental history it is impossible to make any noteworthy distinctions between A and B. They have been inseparable, and abreast. Physically as well as mentally there has been a correspondence. They have both escaped most of the children's diseases; and neither has suffered a physical setback. So that now, as when they were babies, they are practically interchangeable children. The general impression made by physique, countenance, demeanor, conversation is one of complete similarity. A rather thoroughgoing analysis does not seriously disturb this impression of underlying identity of psychophysical make up.

(b). Physical Tests and Measurements

Some twenty-five physical tests and measurements were made to determine the degree of physical correspondence between A and B. The results of this portion of the study are summarized in the accompanying table. An inspection of this table will show that in many items the correspondence amounts to complete identity and that in others it amounts to practical identity. Nowhere was a pronounced deviation revealed. The difference in standing height is one fourth inch in favor of A. The sitting height shows the same difference. Corresponding to this there is a difference of only one pound in weight. This disparity, however, is a variable one and sometimes B is slightly ahead of A in weight. The head girth shows a difference of but one eighth of an inch and the cephalic index which represents the relation between width and length of head shows a difference of only 0.7. The cephalic width is only 0.2 mm. greater in the case of B and the cephalic length 0.1 greater in B.

A very interesting and tangible criterion of anatomical development consists in the degree of ossification of the carpal bones. It is possible to ascertain this degree of ossification by a precise measurement of the exposed bone area as revealed by the X-ray (Figure 4). Such measurement can be made by means of the planimeter.

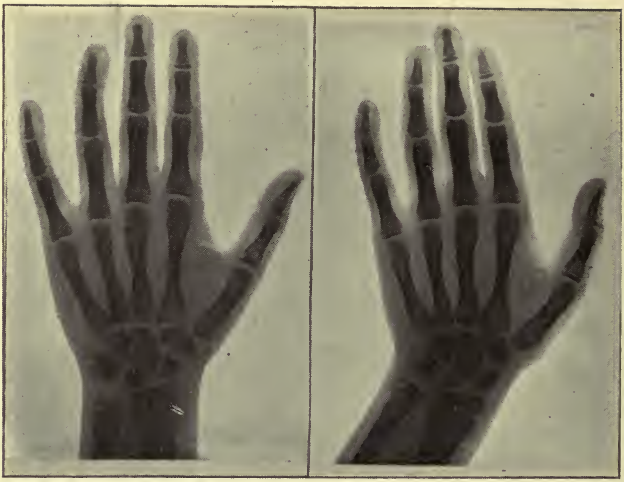


FIGURE 4. X-RAY PHOTOGRAPHS OF LEFT HANDS OF A AND B
Showing close correspondence in ossification of carpal bones.

Since, however, we were purely interested in making a comparison between A and B, our measurements were made by ascertaining the two major right angle diameters by means of a mm. rule. An examination of the table will show that four of the seven bones measured exactly alike. In the three other instances there was a

FIGURE 5. PALM PRINTS OF TWINS
Showing identity of skin patterns of right hands of A and B.
Formula, 9-9-5-5.C.

PHYSICAL TESTS AND MEASUREMENTS OF TWINS, A AND B, AGE 9

Items Compared	A	B
Standing height	48⅞	49⅝
Sitting height	25¾	25½
Weight	56½	55½
Head girth	20½	20⅝
Head width (mm.)	13.4	13.6
Head length (mm.)	16.5	16.6
Cephalic index	81.2	81.9
Diameters of carpal bones:		
Scaphoid	5 x 10	5 x 10
Semilunar	7 x 10	8 x 11
Cuneiform	7 x 11	7 x 11
Trapezium	9 x 10	9 x 10
Trapezoid	7 x ca 7	7 x ca 7
Os magnum	11 x 20	12 x 20
Unciform	8 x 15	9 x 15
Total exposed area	676	724
Friction skin patterns:		
Right palm	9955C	9955C
Left palm	9955C	9955C
Right sole	do.	do.
Left sole	do.	do.
Blood pressure:		
Systolic	95	96
Diastolic	65	70
Pulse (resting)	104	110
Blood agglutination group	II	II
Vaccine pock	do.	do.
Dynamometer:		
Right hand	13	12
Left hand	12	11
Spirometer	78	80
Tapping rate:		
Right hand	130	130
Left hand	127	118
Steadiness	14	17
Dentition	do.	do.
Birth mole (upper lip)	do.	do.

disparity of only one mm. in one or two diameters. Calculating the area on the basis of these diameters it appears that the total carpal bone area of A is 676 square mm. and of B 724. This is a very slight difference indeed and is no greater than that which is often found between the right and left hands of the same individual. According to Baldwin's figures, an average disparity of about 50 square mm. is to be expected between the left and right carpus. Baldwin has made a comparison of the carpal development in four pairs of fraternal (non duplicate twins) and the average amount of difference in bone area of these four pairs is 421

FIGURE 6. PLANTAR PRINTS OF TWINS
Showing identity of skin patterns of right feet of A and B.

sq. mm., a difference over ten times greater than that found in A and B, whom we regard as duplicate twins.

There is no more interesting means of making a physical comparison than that reported by the friction ridges of the skin. These friction ridges are found only on the surfaces of the palm and the sole. According to the comparative anatomist they date back to an arboreal ancestry, when certain animals in their active life among the boughs were much benefitted by the non-skid qualities of such ridges. The ridges were coarser in those days; but we still inherit them in indestructible patterns which appear in the fourth month of intra uterine life and are carried to the grave.

Sir Francis Galton said "Let no one despise the ridges on account of their smallness for they are in some respects the most important of all anthropological data." Even in the ridge details there is absolutely no change in an individual from birth to old age. They furnish, therefore, a powerful aid not only for purposes of identification but for the comparison of individuals. A study of the palms and soles of A and B were made by Wilder's method. The right palms and right soles were mapped out to indicate the major subdivisions of the skin patterns. A remarkable degree of identity was shown in both the palmar and plantar patterns (Figures 5 and 6). The formula for the palm patterns is the same for both palms of both individuals, namely, 9.9.5.5.c. A minute analysis of certain areas of these patterns will show that the developmental correspondence has extended even to some of the minutiæ which are not regarded by Wilder as subject to detailed hereditary control. If the psychological correspondence of these two children approximates to any degree their anthropometric correspondence as indicated by the palm and sole diagrams, it is very great indeed.

A measurement of the blood pressure showed a difference of only one mm., systolic measurement and 5 mm. in the diastolic. Of these two measurements the systolic can be more accurately made and it is also the more important and the more readily ascertained. The correspondence is interesting. The resting pulse showed a difference of about six beats to the minute. A chemical diagnosis of the agglutination properties of the blood was made. In both cases the test showed the blood to belong to group II.

The development of bio-chemical tests for the measurement of individual differences is still in its infancy. The Benedict test for the determination of minute quantities of sugar in normal urine is supposed to reveal personal equations, but the conditions for accurate tests were too complex to carry out. An interesting similarity of a bio-chemical character was, however, exhibited in the reactions of the two girls to vaccination for smallpox. In both instances there was a very slight reaction without constitutional symptoms which occurred at the same time for both children. The dynamometer, spirometer, tapping and steadiness tests are included in the table because they have physical as well as psychophysical aspects. The differences revealed by these tests were very small indeed. The tapping rate for the right hands was identical.

Dentition is of course related to development. The first dentition could not be observed, but when the children were 8 years of age, the right upper permanent incisor was in both children in a similar incompleted stage of eruption. This is shown in the accompanying photograph (Figure 7) and presents a rather

FIGURE 7. TWINS A AND B AT AGE 8
Showing correspondence in eruption of right upper incisor (1 and 2); and in location of tiny pigmented mole near left corner of mouth (3 and 4.)

startling indication of developmental correspondence. Finally may be mentioned one permanent indication of underlying identity of constitution. This is a tiny pigmented birth mole on the upper lip, situated a short distance from the left outer corner of the mouth in both twins. So here "the standard mole of the penny-novelists" could not even be relied upon for the purpose of personal identification, because both twins have the self-same mole! (Figure 7.)

There are several very tiny pigmented areas in the facial skin which are limited to one twin; and there are no doubt other physical deviations which minute study would disclose. Even two hairs, each but a half inch in length, taken from the same head, would as Wilder says, prove to be "absolutely unlike if magnified sufficiently to show the epidermic markings that cover the surface with a fine tracery." By such ultra refined standards, complete identity is a mathematical impossibility; but general, coherent correspondence and absolute identity are two quite different considerations. Our data compel us to recognize a basic developmental and physical correspondence in Twins A and B.

Since this correspondence has expressed itself in such structural details as teeth, skin patterns, birth moles, and cranial and carpal bones, it is not unreasonable to suppose that it should also assert itself in the general architecture and organization of the nervous system. We can gather some light on this point by inquiring into the mental correspondences, through the use of psychometric methods.

(c) Mental and Educational Measurements

The adjoined table summarizes the results of a group of intelligence, performance, and educational measurements of A and B which were made at the Yale Psycho-Clinic, and at the home of the children. The writer wishes to acknowledge the assistance of Dr. Margaret Cobb in the administration of these tests. The cooperativeness of the subjects who entered into all of the situations in the spirit of a game, enlivened with rivalry, aided us. The subjects deserve our especial thanks; for they were indispensable in this particular study.

Mental and Educational Test	A Score*	B Score*	A Age Norm.	B Age Norm.	Remarks
1. Binet, Age 7	188	181	13.5	13	Average I. Q.:
2. Binet, Age 8	179	185	14.75	15.25	A, 183+
					B, 183
3. Vocabulary, Age 7	50	50	14	14	
4. Vocabulary, Age 8	52	54	14+	14+	
5. Vocabulary, Age 9	67	65	16	16	
6. National Intelligence, Age 9	136	155	15	15+	
7. Porteus			12.25	11.25	A shows more foresight.
8. Ship	18	20	11	13	
9. Feature Profile	150 s	250 s	15	10	
10. Diagonal	195 s	70 s	6	10	
11. Triangle	25 s	30 s	14+	14	
12. Knox Cube	7	10	14—	18	
13. Healy A	205 s	135 s	9	10	
14. Seguin Form Board	28 s	30 s	7+	7	
15. Healy Coordination	305	445			A more deliberate.
16. Opposites	40 s	80 s			B spent 45 sec. on last word.
17. Easy Directions	98 s	85 s			No errors; both showed intense in-
18. Hard Directions	175 s	155 s			terest and attention.
19. Symbol Digit	23.4	12.2	12	9	
20. Trabue Language Completion	13	13	13.5	13.5	
21. Kansas Silent Reading	12.9	21.5	12.5	13.5	
22. Woody Fundamentals of Arithmetic	28	26	12.5	12.5	
23. Ayres Spelling	VIII	VIII	14.5	13.5	
24. Ayres Handwriting	60	60	13	13	Differentiation increasing.
25. Drawing (Thorndike)	10.5	10.5			
Accuracy (15)	90%	80%			
Average for combined tests			13.6	13.9	
Average for performance tests			11.75	12	
Standard deviation	2.83	2.91			

*S = second.

The mental examinations were not, of course, all made at one sitting; but the twins were always submitted to the selfsame tests on the same days.

The results of these tests for which we have standardized age norms are plotted on the accompanying chart (Figure 8), in which the solid line stands for A's performance and the broken line for B's. It is hardly necessary to give mathematical expression to these curves. The two lines show a striking degree of cohesion. Note, for example, how they both plunge down on the formboard test, and how equally they rise on the vocabulary tests. The most pronounced disagreement is that shown in the feature profile test. Here there was apparently a more or less fortuitous circumstance, which disturbed B's attack of the problem. Indeed it is quite likely that not a few of the minor disparities shown in the performance scores in various tests indicate variation in the conditions of the test, beyond our control, rather than fundamental differences in mentality. In view of this, the amount of psychological correspondence actually revealed by the tests is all the more significant.

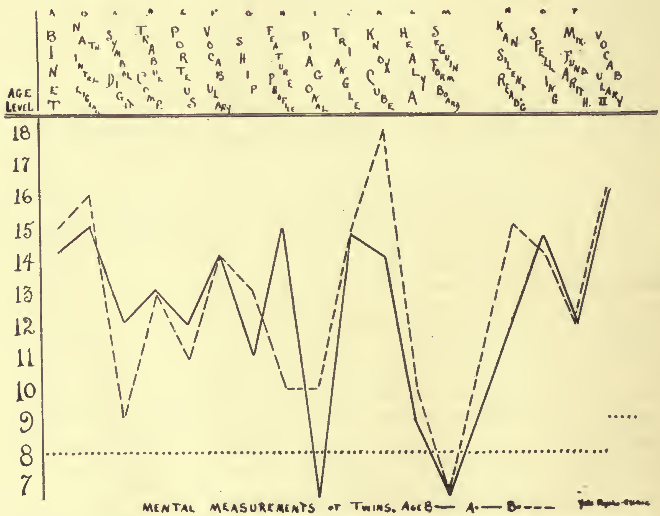


FIGURE 8. GRAPH SHOWING CORRESPONDENCE IN MENTAL MEASUREMENTS OF A AND B

The results are plotted on the basis of mental age scores, the heavy straight dotted line representing the chronological age. The tests in order are (*a*) *Binet*, (*b*) National Intelligence, (*c*) Symbol Digit, (*d*) Trabue Completion, (*e*) *Porteus*, (*f*) *Vocabulary*, (*g*) *Ship*, (*h*) *Feature Profile*, (*i*) Diagonal, (*j*) Triangle, (*k*) Knox Cube, (*l*) Healy A, (*m*) Seguin Form-board (*n*) Kansas Silent Reading, (*o*) Ayres Spelling, (*p*) Woody Mixed Fundamentals of Arithmetic, (*q*) Vocabulary II.

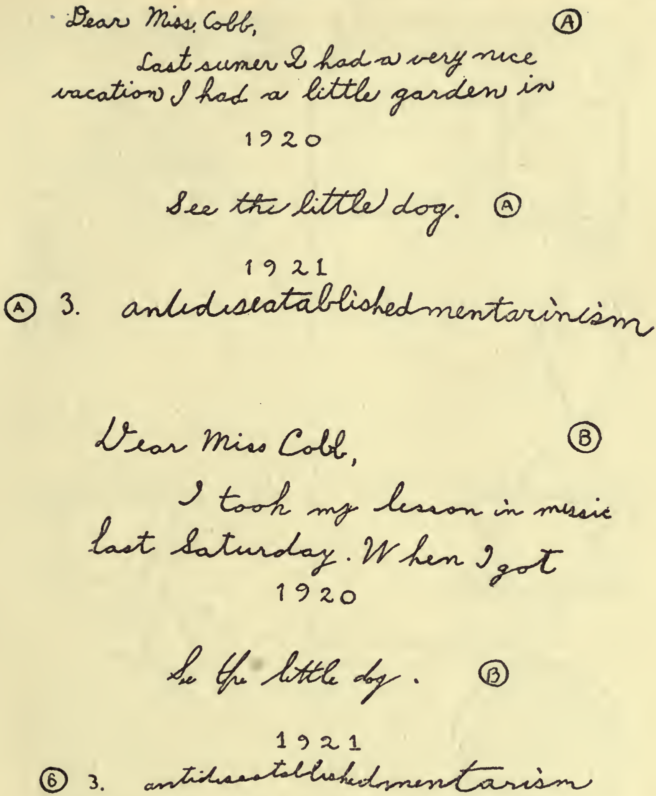


FIGURE 9. HANDWRITING OF A AND B (REDUCED TO TWO-THIRDS)
Showing a moderate degree of similarity in 1920 specimens, and an accentuation of points of difference a year later. The specimens marked 3 show the third trial at spelling the "word," *antidisestablishmentarianism.*

Qualitatively as well as quantitatively the tests revealed a consistent similarity with respect to general alertness, intensity of attention, deliberation, cooperativeness, sense of humor, and emotional reactions. Comparative ratings with regard to quality of responses were attempted in 25 of the Binet tests. In 12 of these our rating was equality, in 13 a slight superiority in favor of B who showed perhaps a little more directness, conciseness and power of generalization. But these ratings were subjective at best, and rested so near to the limit of imperceptible difference, that it would be pedantic to insist on their importance. For once let us insist on resemblance rather than differentiation.

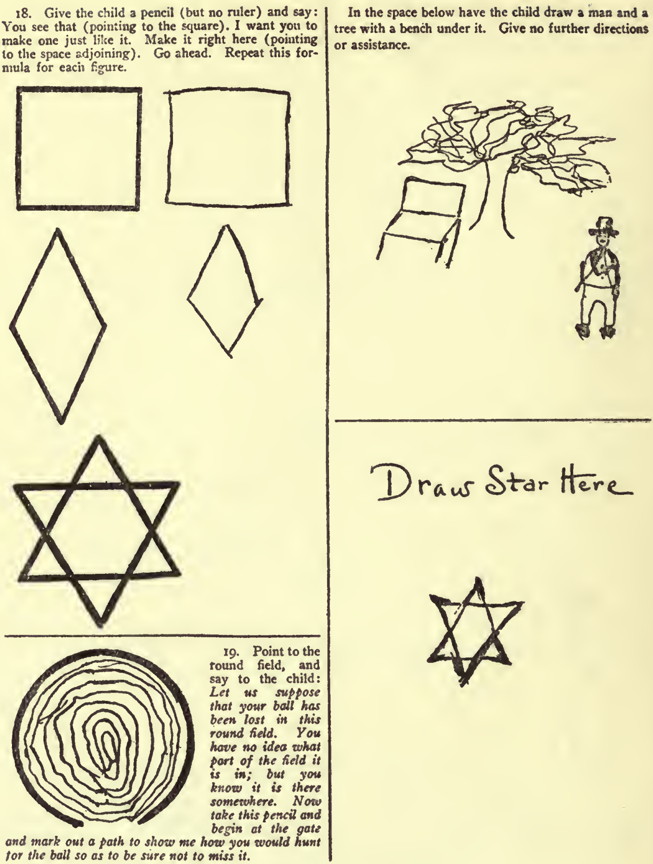


FIGURE 10. DRAWING TESTS—TWIN A

In addition to the purely psychological tests, several educational tests were given to measure achievement in reading, writing, arithmetic, spelling and drawing. The results showed close similarity in every instance, with the exception of silent reading, in which B made a somewhat superior score.

In spelling, the standard Ayres word list was used. By way of good measure, the girls were also given a chance to spell "the largest word in the language." They responded with their usual eagerness. I pronounced, three times, the formidable "word" *antidisestablishmentarianism.* They tried to spell it after each

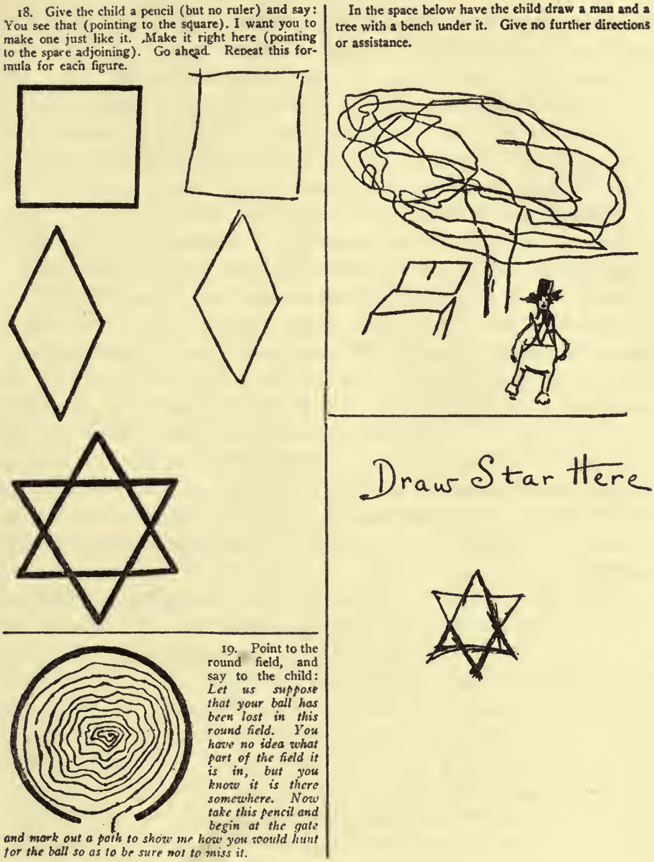


FIGURE 11. DRAWING TESTS—TWIN B

pronunciation. The results of the third trial are shown in the illustration. Both inserted a superfluous *ed,* in the middle; A missed the rest of the word by one letter, and B by three. (Figure 9.)

The reactions of the twins in the field of drawing are pictured in the accompanying illustrations, (Figures 10 and 11). The twins were asked independently to copy a square, a diamond and a star; to trace the route in the ball and field test, and to draw (without copy) a man and a tree with a bench under it. These responses under controlled conditions furnish a basis for objective comparison. The general similarity is unmistakable, as shown by the illustrations. The similarity of the free drawings of man, tree and bench is the most remarkable. It can, of course, be partly accounted for by the conventionalizing effect of reciprocal imitativeness, favored by the intimate companionship of these two children; but after all the fact that this conventionalizing process should produce such an assimilative result denotes an underlying similarity in mental constitution.

Handwriting is an expression of individuality. It is not necessary to go as far as the graphologists do and consider it an index of character; because it is of course subject to fortuitous, mechanical and purely technical influences. However, Wilder and Wentworth are probably correct in their statement that "more than any other single gesture or habitual pose, a man's natural handwriting is the product of what he has experienced, learned, and practiced repeatedly, mind and body cooperating in every stroke." Osborn interprets penmanship as the combined product of muscular habits and mental patterns which "differ in a marked manner in different individuals and this variation radically affects the visible result." On these constitutional variations rests the possibility of identifying individuals and detecting forgery through handwriting.

When it comes to a comparative study of twins, handwriting therefore suggests itself as a psycho-motor test. It must indeed be a delicate test, for complete similarity is apparently very rare. Galton, however, reports one case in which not even the twins themselves, though adults, could distinguish their own handwriting. In our own case of A and B, there was a moderate degree of similarity at the age of 8, as shown by the accompanying illustrations (Figure 9). The reader will note, however, a little more angularity, compression and reduction in size, in B's specimen. These differences in the course of a year have become accentuated, so that the general similarity of the earlier stage is disappearing. That the differentiation will grow still more marked with adolescence is not improbable. And who knows what other chirographic metamorphoses will attend this period, in which individualism in loops, hooks, flourishes, etc., frequently abound?

The vocabularies of A and B deserve particular discussion; because we may feel certain that these two girls have been subjected to a nearly identical language environment. They have been inseparable; they have talked and held their tongues to very nearly the same extent; they have had the same mother, the same mother tongue; they have had equal instruction in the same foreign languages; they have listened, usually at the same time to the same relatives, friends and teachers; have studied the same lessons and have read much the same books. With what results?

It would be fallacious to say, that *because* A and B have been exposed to the same verbal environment, they will be familiar with the same words. Familiarity with words depends upon other factors than mere impression. It depends upon the capacity to assimilate meanings, concepts, contexts, inflections. It depends upon curiosity and attitudes, upon social propensities, tastes, preferences, and above all upon maturity.

Numerous psycho-metric determinations of the vocabulary of children have shown a consistent tendency for the vocabulary score to increase with age, and with intelligence. Vocabulary is so highly correlated with mental development, that even the son of an immigrant, who hears nothing but a foreign language at home, will after brief residence in this country earn a high vocabulary rating, if he is of superior endowment.

Our twins have since babyhood shown a sprightly facility in the realm of words. They have taken much delight in various forms of sound and word play, and have betrayed a lively and often humorous interest in words. Both of the children like to rhyme, and B is blossoming into poetical composition. The accompanying sample is not unpromising, when we consider that the chronological age of the "poetess" is nine!

THE BIRTH OF FLOWERS

When flowers first were born,
The earliest flow'r of Morn,
Was the Rose,
So Sweet and wondrous in its
pose.
The flowers all assembled
To chose their Queen,
The fairest one amongst
them I ween;
The rose spoke up
And said, "The one that
goes latest to
bed."

It was possible to make a satisfactory comparison of the twins A and B by means of a vocabulary test. This test, Terman considers to have a far higher value than any other single test in the whole intelligence measuring scale. The test consists of 100 words derived by random selection from a dictionary containing 18,000 words. An abbreviated series of 50 words of increasing difficulty ranging from *gown* and *tap* to *shagreen* and *complot* was given to both A and B. This virtually constituted a graded scale of 50 individual tests, and revealed a startling degree of resemblance; A failed on 16 of the test words; B failed on exactly the same words, and on only one additional word, namely *harpy*. The calculated vocabulary score of A at the age of 9 is 65 and for B it is 67, a standard equivalent to the average adult level.

VOCABULARY TEST

	A.	B.		A.	B.
1. gown	+	+	26. Mars	+	+
2. tap	+	+	27. mosaic	+	+
3. scorch	+	+	28. bewail	+	+
4. puddle	+	+	29. priceless	+	+
5. envelope	+	+	30. disproportionate	+	+
6. rule	+	+	31. tolerate	+	+
7. health	+	+	32. artless	—	—
8. eye-lash	+	+	33. depredation	—	—
9. copper	+	+	34. lotus	+	+
10. curse	+	+	35. frustrate	—	—
11. pork	+	+	36. harpy	+	—
12. outward	+	+	37. flaunt	—	—
13. southern	+	+	38. ochre	—	—
14. lecture	+	+	39. milksop	—	—
15. dungeon	+	+	40. incrustation	—	—
16. skill	+	+	41. retroactive	—	—
17. ramble	+	+	42. ambergris	—	—
18. civil	+	+	43. achromatic	—	—
19. insure	+	+	44. perfunctory	—	—
20. nerve	+	+	45. casuistry	—	—
21. juggler	+	+	46. piscatorial	—	—
22. regard	+	+	47. sudorific	—	—
23. stave	+	+	48. parterre	—	—
24. brunette	+	+	49. shagreen	—	—
25. hysterics	+	+	50. complot	±	±

+, passed. —, failed.

This degree of correspondence is truly remarkable when we reflect that this searching test, in a statistical sense, compasses the whole wide domain of the English language. Although we must give due weight to the similarity of verbal and academic environment to which A and B have been subjected, do not the results of the test testify even more eloquently to an underlying similarity of nervous constitution and organization?

Incidentally we may record a characteristic reaction which occurred in the course of the first vocabulary test which I gave to the twins at the age of 7. A encountered a word which sounded familiar, but for which she could frame no definition. The word was *civil*,—"Civil, don't know; can't say; and yet I think I know. O, that reminds me: it is like that story about space. A teacher asked his pupil to define *space*. The boy said, 'I can't tell you what it is, but I've got it in my head.'" Thereafter, whenever an unfamiliar word was presented, A smiled slyly, tapped her head and said, "I guess it's that space story again!" Even so, both girls at the age of seven had a vocabulary score of 50, equivalent to the mental age of 14. Moreover, they knew when they didn't know. Mentally inferior children venture wild definitions in the field of the unknown.

There are no satisfactory objective methods for directly measuring emotional and volitional traits. We, of course, secure data concerning them indirectly through so-called intelligence measurements; but we are chiefly dependent upon clinical inference and estimate. Even so, it would require a psychological Boswell to furnish a complete comparative picture of the temperaments and dispositions of A and B. Long continued and intimate observation might reveal some interesting disparities in the emotional sphere. The ordinary observer would probably develop a partiality for one of the twins on the ground that A or B is less assertive, more reasonable, more affectionate, than B or A. But this preference might indicate the inveterate selective and discriminative tendency of human perception, quite as much as a fundamental diversity in the twins.

Assuming that there is at present a high degree of correspondence in temperamental traits: does it follow that such will always be the case? Hardly so. To begin with these children have not as yet come into full possession of all of their mental inheritance. Adolescence brings with it many new psychic characters, and these may not be equally shared, or equally assimilated by A and B. And as we look down the future we must reckon with the differentiating power of differences in fortune, social position or professional career. We have noticed that one twin is definitely more dependent upon demonstration of affection by the mother; that one is becoming interested in the violin, the other, perhaps in poetry. Suppose that one should seek distinction in music and the other in letters. Even such a relatively small disparity in vocation might ultimately create by accretion a very decided difference in mental content, habits of thought, social attitudes, outlook upon life; so that the conditioned reflexes and complexes of A would become quite distinguishable from those of B; an interesting difference in vegetation, growing upon much the same soil. Personality in its higher expressions is always so conditioned by social and educational factors that it would be futile to deny the possibilities of differentiation even with "duplicate twins."

But we are concerned with the present status of twins A and B, age 8. At that age we gave them an opportunity to express some of their likes and dislikes on paper. It was a simple, almost impromptu test; but the results were amazing. They independently answered in writing a questionnaire, which is reproduced with their replies exactly as they gave them.

QUESTIONS ON LIKES AND DISLIKES, ANSWERED IN WRITING INDEPENDENTLY BY A AND B

Question: If you had $1,000.00 to spend, how would you do it? Tell me about it on this page.

Answer: A. I would buy a painting outfit and learn to use it. Take Mother to Europe (because she wants so much to go).

B. I would buy a horse (like Black Beauty), a riding habit, the Universal Anthology for Mother and a barrel of sugar for my horse.

Question: What is the most unpleasant thing you have to do every day?

Answer: A. Practice on the piano.

B. Practise on the piano.

Question: What is the most agreeable thing you do every day?

Answer: A. Ride horse-back.

B. Ride horse-back.

Question: What is most likely to make you angry?

Answer: A. Our dog.

B. Rasputin. (The dog.)

Question: What is it your ambition to be when grown up?

Answer: A. An artist.

B. To teach.

Question: What game do you like best?

Answer: A. Play lady and dress up in Mother's clothes.

B. Mother.

Question: What was the most fun you had last summer?

Answer: A. Going in swimming.

B. Going in swimming.

Question: What is your favorite color?

Answer: A. Green.

B. Green.

Question: What is your favorite book?

Answer: A. Bible stories.

B. The Bible.

Question: What is your favorite song?

Answer: A. Red, White and Blue.

B. Home Sweet Home.

Question: What is your favorite study in school?

Answer: A. Reading.

B. Reading.

It would be easy to exaggerate the significance of these questionnaire results, and yet it is inconceivable that they would have been possible without a considerable degree of correspondence in personality traits. The same conclusion must be drawn from the results of the vocabulary tests made at seven, eight, and nine years of age. The close correspondence in mental level revealed by the Binet ratings is also undeniable. There were several points of difference in the I Q at the ages of seven and eight, but the average for the two testings was within one point,—183.

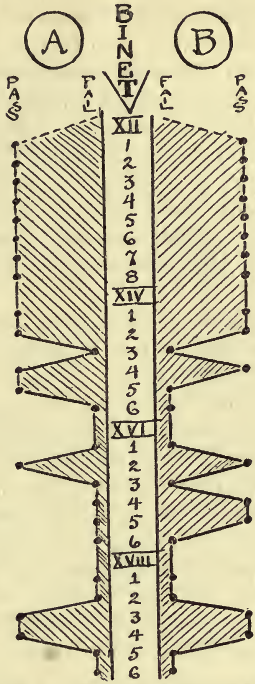


FIGURE 12. COMPARATIVE PSYCHOGRAPH

Showing intellectual correspondence of Twins A and B at age 8. Forty-four graded intelligence tests were given. All the tests at the mental age levels of 8 to 12 inclusive were passed with facility.

The I Q, or Intelligence Quotient, expresses the ratio of mental age to chronological age. If these two ages are the same in a given individual the I Q is 100. If the mental age is less than the chronological, the I Q is below 100. If the mental age is in advance the resulting I Q is above 100. Children with an I Q of 65 or less are usually feebleminded. Children with an I Q of 120 or more may be regarded as relatively superior. The psychological literature reports very few cases with an I Q as high as 180.

A comparative psychograph of the performances of A and B in the Binet tests gives a fair graphic picture of the degree of intellectual correspondence of these two children at the age of 8. The diagram (Figure 12) is so drawn that success and failure are indicated in corresponding meridians. All the tests in the age levels below 12, were passed with great facility and are not included.

One half of the psychograph proves to be almost a mirror image of the other.

(d) General Conclusion

Reviewing, then, the developmental history of A and B, and the results of scores of tests,—the physical, the anthropometric, the psychological, performance and educational measurements; and considering the collective weight and tendency of these findings, and the wider diversity which would have been shown by a similar study of ordinary siblings—it seems highly probable that this pair of twins were of nearly duplicated or identical genetic antecedents.

The general conclusion is inescapable that the consistent similarity between these two children is based upon a fundamental, inherent similarity in endowment. It would, however, be wrong to ignore the equalizing influence of a practically identical environment. Indeed, in studying the development of personality it is rather artificial to bring nature and nurture into rigid contradistinction. Personality represents the resultant cooperative product of both intrinsic and extraneous factors, and the interaction of these factors in highly dynamic relations. It is because these dynamic relations are so sensitive, that any marked psychological similarity even between co-twins at the relatively old age of eight years is impressive. It may even be usual that one of a pair of twins begins with or early acquires a physical or temperamental advantage which gives him a different status in the social situations of life; and initiates a differentiating process which waxes with what it feeds upon. But in the present instance, such a strong differentiating tendency has not become very apparent. I should not be willing to say that it will never come into power. We have already suggested the differentiating possibilities of a wide difference in vocational or social careers. Even now a consistent partiality for one child on the part of the mother, a physical accident or an unshared illness, or an emotional crisis limited to one child, might become the germ for a pronounced differentiation of personalities. But on the whole, the equalizing factors have hitherto with A and B remained dominant.

Among these factors we should mention a pleasant degree of jealousy and emulation. Neither wishes to be out done by the other. For example, when at the age of seven I gave them the delightful privilege of filling my hod with chunks of cannel coal, they both insisted that they be permitted to put on the big gloves and that they also be permitted to put exactly the same number of chunks into the hod. This propensity, which fundamentally is hereditary, has preserved a kind of balance of power and has helped to impress a certain identity on their respective personalities. Neither has become a leader of the other.

The argument that similar experiences have made these children similar does not bear close scrutiny; experience, after all, is a descriptive term for the reactions of an organism to its environment. As Dewey puts it, the combination of what things do to us in modifying our actions, and what we can do to them in producing new changes constitutes experience. From a clinical point of view, the experience argument begs the question. What we really wish to know is to what degree have these children actually had similar experiences. Our conclusion is that they have manifested similarity of experience to a remarkable degree, due primarily to the structural parity of the nervous system with which they were endowed. A similarity of environment has developed a corresponding functional parity. But here again the considerations become involved; for this so-called similarity of environment has consisted not only in the same house, similar beds, similar clothes, similar food and identical instruction; but the twins have had each other, and each has carried around much the same environment, because each apparently assimilated much the same things for her milieu. There has at least been a high degree of reciprocity between nature and nurture!

(*To be concluded.*)

DEHYDRATION AND THE PRESERVATION OF FOODS

By Dr. HEBER W. YOUNGKEN
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THE possibility of partaking of strawberries and apples in regions of the earth remote from their native habitats and districts of production at first thought seems unlikely. Upon later reflection, however, the likelihood seems possible, since we realize that they may be canned, dried or even refrigerated. But the chance of being able to have them in a condition almost like that in which they would appear when gathered in fresh from the garden or orchard and placed on the table with little or no natural flavor removed, after transportation to either of these remote points, is a far different proposition. Yet I hope to show before the conclusion of this article that the ingenuity of man has made it quite possible to enjoy not only the full flavor and flesh of strawberries and apples in arctic or torrid climes, but in addition other fruits, vegetables and meats which are not produced in these regions.

The whole secret of being able to procure the kind of food you want where and when you want it is in its preservation. The reasons foods do not normally keep indefinitely are partly biological and partly chemical. The chemical agents responsible for food spoilage are called enzymes, the biological agents, microorganisms. All living cells of plants and animals normally contain enzymes that possess the power of changing substances insoluble in water into water-soluble substances without themselves suffering any change during their term of activity. These enzymes are produced by the living matter of the cell and remain active after the death of the cell. Some of them have the power of attacking carbohydrates such as starch or inulin, breaking these substances down into water-soluble sugars, others attack proteins such as albumens and globulins, splitting these up into water-soluble peptones, etc., still others attack fats breaking them down into water-soluble fatty acids and glycerin. Some of the enzymes are present in the cells of the food itself, others occur in the cells of microorganisms which attack food. All enzymes require a certain amount of warmth and the presence of water in order to get in their activity.

From the earliest period of the human race of which there are records man has striven to preserve foodstuffs available in season and region of abundance for use in times and places of scarcity. The ancients practiced sun drying of food on a large scale.

The following are the methods chiefly employed in the preservation of foods: (1) Drying, (2) Salting, (3) Pickling, (4) Smoking, (5) Refrigeration, (6) Canning, (7) Dehydration.

Drying of Food

The methods upon which foods are dried are based upon the principles that sufficient heat kills enzymes and the removal of water inhibits the growth of microorganisms, as well as prevents enzymic activity. In some instances, protective layers may be formed through drying by changing the former relationships of tissue constituents. Thus, for example, in the curing of pork, the fat, which is for the greater part isolated in distinct cells, becomes diffused throughout the outer layers of the flesh and forms a water-proof exterior to the ingress of microorganisms.

The removal of water in foods to an extent below the minimum required for the growth of microorganisms is secured in a number of ways. The most common ones are the uses of heat either in the form of sun's rays or from an artificial source. Sun drying is the oldest of these. In regions where the moisture content of the air is low, as in many of the fruit districts of California and other western states, exposure to the sun's rays accomplishes rapid drying. In this method insects and dust frequently have full access to the food. In more humid localities and with other types of food artificial heat is employed and so we have kiln drying and drying by means of centrifugal action. Kiln drying is much employed in the preparation of evaporated foods. In this method materials are laid on a screened floor under which heating appliances are built. The mass of material is stirred up occasionally during the drying. Drying by heat always results in concentrating the solutes. The acids in the juices of many fruits, when concentrated, may be antiseptic, *i. e.*, retard the growth of microorganisms. Frequently the sugars present reach so great a concentration as to plasmolyze the cell contents of any microorganisms present and so prevent their multiplication.

The disadvantages of all these methods of drying lies in the facts that they are slow, not all materials can be so treated and the products resulting do not regain their natural appearance, odor or taste when prepared for diet.

Salting

This is a method of preserving meats and fish. It has been used for many centuries and next to drying is the oldest process known. It is dependent upon the principle that salt abstracts water from the tissues of the fleshy food and so causes a concentration of the solutes within the cells too great for the growth of bacteria. It gives the food a paler color and extracts at least 25 per cent. of the protein content. The great disadvantage in this method is the danger of undersalting or oversalting. Undersalted foods putrefy in time. Frequently the putrefaction is masked and ptomaine poisoning occurs after eating these. Oversalting destroys the natural flavor and extracts much of the nutritive substances.

Pickling

Pickling consists of the preservation of food in brine containing varying percentages of salt, vinegar, weak acids and occasionally condiments. Many foods such as olives, cucumbers, cauliflower, beets, and some meats and fish, are preserved by this method. That pickling is not always a safe method of food perservation has recently been emphasized by many outbreaks of botulism poisoning from pickled ripe olives.

Smoking

This is a method of preserving flesh foods and flesh derivaties such as meat and fish. It consists of first placing the fleshy food in brine with or without condiments for a week or longer. A smouldering fire is then built in a specially constructed chamber. The flesh foods are taken out of the brine and hung up, being exposed for varying periods of time to the wood smoke and heat. The volatile substances in the wood smoke such as creosote, acetic acid and other germicidal substances penetrate the food at least superficially and either kill any putrefactive organisms present or retard their growth.

Refrigeration

Refrigeration is a method of preserving foods which is based upon the principle that cold inhibits the activity of microorganisms. During the past two decades it has revolutionized the meat and eggs industries. In the meat industry it permits slaughtering to take place all the year round and great cargoes to be transported in refrigerating chambers across oceans and continents and through equatorial regions not much the worse for the transporting.

Foods preserved by refrigeration generally command a higher price than those preserved by other methods. This is in part due to the fact that the general appearance of cold storage food resembles that of the perfectly fresh article. In numerous instances, also, refrigeration, for a reasonable length of time, preserves not only the appearance but also the delicate flavor, chemical composition and nutritive value of the original articles.

During the storage of food it undergoes some loss of water and volatile principles by evaporation and various volatile principles may be absorbed from the air of the storage room. But by far the most important point to be considered in this connection is the behavior of the biologic content of the food during this period. It should be emphasized here that refrigeration not only impedes the growth of microorganisms, but tends to preserve them as well. In addition to the organisms present in the food when it is stored, other microbes such as bacteria, yeasts and molds, may gain access to the food from time to time either by actual contact with other things or through the circulating air within the cold storage chamber.

As to whether these implanted forms will survive depends upon their nature and ability to adapt themselves to the conditions existing within the stored food. Some perish, others may survive in the passive condition, still others may survive in their active form, multiplying rapidly. It has been known for some time that some bacteria can grow at a temperature of zero and that many can reproduce at a fraction of a degree above that point. If microbic activity is, therefore, to be inhibited, the food must be frozen.

Methods of refrigeration vary depending upon the article to be refrigerated. In the production of chilled meats, the flesh of mammals is first placed in a cold chamber at a temperature of about $+2°$ for the first 48 hours and then stored at a temperature of $+1°$ or $+2°$ if chilled meat is desired. During the chilling process the enzymes of the dead flesh and bacteria present are active, bringing about a ripening or curing, which makes the meat more tender and gives it a more desirable flavor. If the chilling process be allowed to proceed beyond the point where the muscle sugar is nearly completely fermented, the changes in the meat due to the decomposition of proteid material by bacterial enzymes makes it dangerous and unfit for consumption.

In the preparation of frozen meat, the dressed article is chilled in an air-chamber at $-20°$ until it is frozen solid and later kept at a temperature below $-4°$. Such meat remains practically unchanged for long periods. The difficulty arises when it is thawed. If warmed slowly the melting water crystals are absorbed by the protein material and the original structure of the flesh restored almost completely, but bacteria are always bound to enter in a prolonged process of this kind and cause some decomposition. In order to prevent this, the thawing is usually carried on rapidly and so the normal structure of the meat is not restored. It is softer, darker and moister than chilled or fresh meat and prone to rapid decomposition if kept at room temperature for even short periods.

In the refrigeration of fish and poultry, these articles are chilled by packing in ice immediately after death and frozen as rapidly as possible. In thawing similar changes take place as in frozen meat but the bacterial decomposition proceeds more energetically. After thawing is complete the products spoil rapidly.

Eggs should be stored at a constant temperature which should be between +0.5° and +1° and at a constant humidity of 70 per cent saturation, if superior results are to be attained. But even with the best of control and precautions there is some deterioration in the cold storage article due to the facts that the enzymes within the egg are not necessarily inhibited nor is the growth of all of the bacteria prevented.

Milk is more rapidly changed by bacterial activity than any other food. In up to date dairies it is therefore cooled immediately after it is drawn from the animal and kept at a low temperature until delivered to the consumer. But even at this low temperature the milk bacteria multiply slowly. Freezing alone prevents their multiplication. If the milk is very clean, however, it may be kept sweet for several weeks at a temperature slightly above the freezing point.

Fruits and vegetables are refrigerated at a temperature slightly above zero and at a constant humidity of about 60 per cent. saturation. In spite of modern methods of refrigeration it is not practicable to ship fresh sea foods to distant inland towns or to send some perishable fruits and vegetables of the tropics to colder climes.

Canning

Canning is a method of food preservation the principles of which include the destruction of microorganisms which produce the fermentative and putrefactive changes by heat and subsequently sealing the container to prevent the access of more microorganisms.

The principle of employing heat in the preservation of food had its origin in the experiments of Spallanzani, who in 1765 boiled meat extract in flasks for an hour and hermetically sealed them, after which no change took place in the material. Spallanzani, however, was not aware of the real cause of these changes.

About the middle of the nineteenth century, Tyndall and Pasteur successfully demonstrated that living microorganisms were always found where fermentation and putrefaction took place, that these organisms could be killed by heat and that if substances liable to decomposition which had been sterilized by heat were kept so that no organisms could gain entrance, they would keep indefinitely without spoiling. But long before the causes of fermentation and putrefaction were known canning was discovered.

During the Napoleonic wars the French government faced the problem of maintaining an adequate supply of food for their army and navy and offered a prize of 12,000 francs to the person who could invent the best method of preserving food. Stimulated by this offer, Nicholas Appert, a Parisian confectioner, undertook the task. After several years of ardent investigation he discovered a method which he submitted to the Minister of the Interior. A number of substances which Appert had preserved including meat, vegetables, fruits, milk and soup were examined by the Bureau Consultif, a commission appointed by the minister, which included such men as Gay Lussac, Bardel, Scipion-Perrier and Molard.

This body reported that when the jars were opened after several months, the foods were found to be perfectly preserved and in every way satisfactory in flavor and appearance. On the strength of this report, Appert was awarded the prize of 12,000 francs. It was not until the following year (1810) that Appert published his discovery under the title of "L' Art de Conserver pendant plusiers toules les substances animal et vegetables" ("The Art of Preserving Animal and Vegetable Substances.")

Appert's method consisted of enclosing food in glass jars which were then corked tightly, placed in a bath of boiling water the time varying according to the article treated and taking the jars from the bath at the prescribed time and in a proper manner. Appert later used tin cans as containers. The success of his method was dependent upon sterilization and the absolute exclusion of air. These same principles are applied in the canning of to-day.

From France the canning method was introduced into England by Peter Durand, who in 1810 obtained a patent from the English government for the preservation of a variety of food in hermetically sealed tin cans and glass jars. Among the first to introduce the process into the United States were Ezra Dagget and Thomas Kensett, who in 1819 began to manufacture canned oysters, lobsters and salmon. In 1820 William Underwood and Charles Mitchell opened a canning factory in Boston, where they packed currants, plums, quinces and cranberries.

Enormous losses were experienced during the early years of the canning industry due to the defective nature of the square tin cans. The square can finally gave way to the economically superior round can. A press for manufacturing can tops was invented in 1850.

In 1883 a hand capping machine was patented and later various other kinds of machinery replaced hand labor.

The Civil War did more to stimulate the canning industry in America than any other factor. To-day it is recognized as the main method of preserving foods in this country and likewise the most popular.

Disadvantages of Canned Foods

It is a well-known fact amongst chemists and physicians of to-day that the heat necessary to bring about the successful sterilization of milk, fruits, vegetables and meat destroys vitamines. These vitamines are regarded as absolutely essential for the growth, development and protection of the body against certain diseases such as scurvy and beri-beri.

In writing on the vitamines, Colonel Vedder, M. C., U. S. A., states: "It should also be noted that all canned foods must be regarded as possible beri-beri producers. It has been shown by numerous investigators, including the writer, that heating to 120°C. destroys the beri-beri preventing vitamines in certain foods. All protein foods that are 'canned' must be subjected to about this amount of heat in order to kill all the putrefactive organisms and such canned foods are, undoubtedly, beri-beri producers when used in excess."

I have recently been informed by Mr. P. R. Buettner of Danbury, Connecticut, that canned tomatoes retain some of their natural vitamines due to the protective power of the acid in this fruit during processing.

The second disadvantage of using canned goods is in their great cost of production. From four to seven ounces of tin plate are used for each container. To this must be added the cost of packing cases and the handling, canning and transportation of much water. A third disadvantage is the fact that they have limited keeping qualities. There is always danger of crushing and spoilage in transporting them. Moreover, most of those products, when prepared for the table do not possess the same appearance, odor and taste as those of the freshly prepared articles from the field or garden.

Dehydration

Dehydration in the modern sense of the term may be defined as the process whereby perishable foods with or without previous treatment are subjected to the action of carefully regulated currents of air in which the temperature and humidity are properly controlled.

The method results in the food products gradually losing water, but without giving up their color or flavor or having their cellular structure impaired. Accordingly, the dehydrated food will reabsorb water, swelling up to its normal size and appearance. When cooked it will have the same appearance, flavor and odor of freshly cooked material made from fresh vegetables.

Dehydration dates back to 1850, when Masson, a Frenchman, dried a large number of vegetables and fruits with a blast of warm air at temperature near 70° C. Sometime later, Passburg of Berlin obtained excellent results with vacuum drying apparatus. It was not, however, until the Boer War that products of this nature began to be manufactured on a considerable scale. During this period many thousands of pounds of dried vegetables, mixed so as to form a basis for an easily prepared soup, were produced in Canada and shipped from there to the British Army in South Africa.

Stimulated by the possibilities of marketing products of this nature on a commercial scale, a number of Americans established factories in this country and by 1910 began to manufacture dehydrated vegetables and soup mixtures. These products, however, never became popular, partly because they were not quite equal to the fresh article when cooked and partly because of the great popular demand for canned foods.

War is without doubt a great stimulator of human ingenuity, no less in perfecting methods than in inventing new ones. Just as the Civil War stimulated the introduction of new methods in the canning industry, so the World War established new methods and perfected older ones in the dehydration industry. With the problems of supplying our armies in distant fields and our ships in foreign seas with a variety of foods, and the limit of our tonnage, the food situation became acute. More and more demands were made by the government for dehydrated products in order to save transportation of water and to provide our fighters with fruits and vegetables that could not be obtained in England and France. Thousands of tons of these foods were shipped abroad during the war to the forces of the United States as well as the Allies.

It was the dehydration process that probably enabled Germany to maintain her food supplies during the war. That it was successful in that country can not be doubted when we consider the following statistics: In 1898 there were only three small dehydration plants in Germany. Eight years later the number in operation was thirty-nine, in 1914 it had increased to 488, in 1916 to 841 and in 1917 to about 1,900. By August 1st of this year there were 29 concerns manufacturing dehydrated fruits and vegetables in the United States. To this may be added at least a dozen firms who manufacture dehydrated animal products.

The methods of dehydration employed at the present time are varied in details of procedure. All, however, are founded on the same basic principle, namely, to remove the water contained in and between the cells of the food so as to obtain a product which can not spoil as a result of microbic or enzyme action.

The water taken away by these methods is only replaceable water and so the nutritional value of the food has not been altered. Moreover, if dehydration is applied while the fruits, vegetables or animal products are absolutely fresh, the flavor-giving substances are preserved intact. In the best grades of dehydrated products the rate of evaporation is such as to bring about the removal of water without rupture to the cell walls.

By means of this process the weight of the food is reduced from 80 to 90 per cent. and the bulk is diminished to one fourth or one sixth of the original volume. By means of compression the nearly dried material may be brought to a compact form as, for example, in the Veco products. Not all the water is removed, the amount remaining varying depending upon the character of the food to from 7 to 15 per cent. But sufficient is removed to concentrate the solutes to the extent of producing plasmolysis.

The manner in which the material is prepared influences to some extent the quality of the product. If the first temperature applied to the fresh material is too high, certain changes take place in many vegetables giving them an appearance of scorched or scalded substances and diminishing their water-absorbing power. Accordingly, in dehydrating vegetables, the fresh material should be subjected to air having a low temperature and high humidity and gradually brought to a high temperature and low humidity.

Methods of Dehydration

The methods of dehydration employed at the present time are as follows:

(1). Tunnel Systems. These consist of long chambers or tunnels into the end of which the fruits or vegetables are introduced on screens or racks and through which a strong current of dry air is blown. While there are several modifications in the arrangement of the screens and in the method of heating and driving the air, it may be said that in general the heat is supplied by coils of steam pipe and the air is forced in by powerful fans. In some plants the racks of vegetables are placed on trucks which run on tracks, so that the material is introduced at one end of the tunnel where the temperature is low and humidity relatively high, gradually moved on to where the temperature is higher and the humidity relatively lower and delivered at the other end in dry form. By this means the moisture is uniformly extracted by capillary attraction without destroying the cell structure. On account of the gradual reduction of the moisture content, the cells shrink slowly without breaking down and the product retains all of its natural flavor, color and food value. In other plants the tunnels have side openings where the trays are inserted and removed by hand.

In the Hammond tunnel system, the patents of which are owned and controlled by the Unted States Dehydration Company of Denver, Colorado, the prepared fruits, vegetables or animal foods are placed in a rectangular tunnel and gradually conveyed through it, the moisture, temperature and rate of air flow all being properly coordinated. The air is allowed to take its course straight through, passing over the top of the trays or underneath them. Most of the products are steam blanched or dipped in hot water before being introduced into the drier which operation has been found quite necessary in preserving the color and keeping qualities of vegetables.

The Cook-Kelly process employed in the manufacture of "Cookelized foods" is another of these tunnel systems. In preparing foods by this process, fruits and vegetables are brought into the factory and washed, peeled, pared, sliced, cubed or riced, put on wire screen trays and placed in a rectangular tunnel approximately 35 feet long. Heated air is blown through this tunnel, the currents of this air taking the form of a sine curve as they go upward through one tray and downward through the next and so on. The trays are shoved along periodically which causes the air to reverse its passage through the products on the tray from time to time, evaporating the moisture from the products and carrying the moisture off through the other end of the tunnel.

(2). Vacuum Methods. These have been employed with success in the dehydration of fruits, vegetables and animal products. The apparatus consists of a heavy cast iron chamber containing a large number of steel shelves heated either by steam, hot water or electricity, a condenser and a vacuum pump to exhaust the air from the chamber and maintain a high vacuum on the system. The material to be dried is placed on flat screens which slide into the shelves. Heating is partly by conduction from the metal trays and partly by radiation from the next shelf above. The temperature is regulated by a thermostat, so that overheating is impossible. Through the constant application of a vacuum to the process, the water vapor is removed and the material dehydrated.

This method is particularly advantageous for the dehydration of potatoes and apples or other vegetables containing an oxidase ferment. It is this ferment which causes the darkening of such materials when their flesh is exposed to the air. Since air is removed from the chamber no darkening results by this process. However, if such vegetables are subsequently placed in water, darkening will result, since the ferment has not been entirely destroyed. This is overcome by blanching or steam treatment before the foods are dehydrated. In the dehydration of milk and eggs by the vacuum method, heated rollers are employed. These, with various attachments, are enclosed in a chamber in which a high vacuum is maintained. The heated roller picks up a film of egg pulp or milk which dries rapidly under reduced pressure and is continuously scraped off by a knife as dried flakes or powder. In the dehydration of meats, this method is probably unequalled by any other one in its effectiveness. Large steaks and chops can be handled without oxidation and completely dried. The fats remain white and are not melted. The product is essentially raw meat with water removed. Usually a temperature of 130° F. is employed. Fish, lobster, meat, clams, oysters, shrimps and other protein foods that ordinarily putrefy easily can be preserved in excellent form by this method. Since these products are dried to about 30 to 35 per cent. of their original weight, the concentration of the solutes is too great to permit bacterial development. Most fruits and vegetables require higher temperatures than those to which flesh foods are subjected when dried by this method. With some of the products this method gives good results but is rather severe with others, tending to break down their cellular structure.

(3). Kiln Method. In this method of dehydration, square chambers with sloping roofs and perforated floors are utilized. The floor is heated from below by a stove or furnace. The materials to be dehydrated are spread on the floor to a depth of four or six inches. The hot air from the heating device passes up through the vegetables, removing the moisture, which is conducted through a ventilator in the roof. The mass of vegetables is turned over now and then by men with shovels during the drying. The advantage of this method is mainly its cheapness. The disadvantages are those of overheating or underheating. However, a number of products made thereby have proven satisfactory.

(4). Special Dehydrators. A number of special types of chambers or machines are now in use, differing from those previously considered only in certain details of construction. Many of these have appliances to carefully regulate the drying.

Keeping Qualities of Dehydrated Foods

That dehydrated foods will keep for a long time, if properly prepared, is evidenced by the following occurrence: During the Boer War the British Army in South Africa was supplied with thousands of pounds of dehydrated vegetables mixed so as to form the basis of a quickly prepared soup. At the close of the war one of the Canadian manufacturers was left with 30,000 pounds of this mixture for which he could not find a market, probably due to the fact that consumers much preferred to buy such vegetables in the recent condition. He placed it in barrels which were paraffined and stored it away. Fifteen years later, after the outbreak of the world war, these were shipped to the British Army in Europe and used in the preparation of soups of splendid quality. If dehydrated foods are properly prepared and kept in paraffined containers free from insect pests and ingress of moisture, there seems to be no reason why they should not keep for indefinitely long periods.

Advantages of Dehydrated Foods Over Other Preserved Products

Dehydrated foods are superior to dried or evaporated articles because they regain the natural appearance and keep the natural odor and taste of the fresh articles when prepared for the table. Moreover, they have better keeping qualities.

Their advantages over refrigerated articles lies in the saving of cold storage charges, in the lessened transportation charges and in their superior keeping qualities. Their advantages over canned foods lie in the great saving in freight charges (since the water content is reduced to 5 or 10 per cent.), in their freedom from spoilage, their greater ease of handling, their superior keeping qualities, and in the cheap containers that may be used. Moreover, there is no danger of botulism, nor are any of the vitamines destroyed. Dehydrated foods can be shipped to any part of the globe without deterioration.

Possibility of Dehydration in the United States

While much has been accomplished in the field of dehydration in the United States since the beginning of the world war, the surface has only been scratched. A goodly number of vegetables, fruits and a few animal products are being dehydrated successfully while scores of others have not as yet been taken up. Each kind of vegetable or animal food must be studied separately in order to properly perfect its best means of drying by this method. Dehydration is destined to stabilize the crops of the nation. Year after year, decade after decade, we are confronted by either feast or famine in respect to certain fruits or vegetables.

A good crop one year with correspondingly low prices has often been followed by a small crop the following year with high prices.

With an extension of this industry the surplus of years of great yield can be stored and made available in later years when prices are higher and the crop leaner. In a short time the amount of planting would be equalized and all would be able to secure an adequate supply of these foods at normal prices.

Again, dehydration is destined to conserve food materials. It is a notorious fact that about half of the perishable fruits and vegetables grown in this country is wasted annually on the farm, at the freight station, in transit or in the hands of the commission merchant both as a result of poor transportation facilities and irregularities in marketing.

According to the *Los Angeles Examiner*, "only 40 per cent. of the California products contributed to relieve the famine sufferers in China ever reached them in edible condition." "Had the wasted 60 per cent. been dehydrated, it would not have failed of its merciful purpose."

Again, on account of the strict grading laws enforced by the Potato Growers' Association, it is estimated that about 50,000 bushels of No. 2 undersized, sound potatoes are annually lost to farmers. The potato dehydrating industry is comparatively recent in America and dehydrated potato flour is being manufactured from some of the previously wasted material. With the spread and development of this and other allied industries much of what had previously been wasted will be conserved for the benefit of the people. The dehydration of the sugar beet and the banana offer wonderful possibilities in this direction.

It is conceivable that dehydration, now in its infancy, will within the next decade, when the nature of its products become more generally known, rival, if not outstrip, the other processes of preserving foods.

A PERPETUAL SUBMARINE WAR

By R. E. COKER

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NATIONS of men have battled with each other until they have become weary of war. Now they declare war against war. The recent world struggle, with all its consequences to every one concerned, was enough to reveal the folly of internecine strife. Besides, is it evidence of our boasted wisdom for groups of men to contend in mortal combat with one another while engaged against a common enemy? For all men are allies in a warfare more enduring than the disastrous conflict recently precipitated by the Central States of Europe, more wide-spread and pervasive in its actions, and at least equally critical in its bearing on the survival of the human race.

Our opponents in this war are small of stature, but in numbers they are legion. Conspicuous among these unrelenting adversaries are the tribes of insects. They, as well as others, wage war unceasingly upon us: they besiege our crops, they attack our buildings and our clothes, they destroy our animals, and they even attack our bodies with their poison darts, planting in us the germs of such diseases as yellow fever, typhoid, typhus and bubonic plague. It is like the war that Whitman sings of—"a longer and greater one than any, waged * * * with varying fortune, with flight, advance and retreat, victory deferred and wavering, and yet, methinks, certain, or as good as certain in the end." But—

Assuming that the worst came to the worst, that the insects had acquired mastery both on land and in the air—still we might retreat to the waters hoping to build submerged and protected homes. Should we find safety there? It is true insects are almost non-existent in the sea, but they may have submarine allies. At any rate, we find there other dangerous enemies. Such are the boring animals of various groups which attack submerged structures of wood and even those of stone.

The principal naval powers opposing us are the shipworms, which, of course, are not worms at all, but rather are mollusks and not distantly related to the luscious oyster. It seems remarkable indeed that an animal of such ingratiating qualities and gentle habits as the oyster should have a near relative of even milder appearance which eternally engages in destruction of the property of man. New piling placed at great expense may be destroyed within a period of comparatively few months. Large and expensive buildings may be brought to collapse. Vessels of wood may be so weakened by the ravages of shipworms as to fall an easy prey to storms. Of course, the harm done by shipworms is often anticipated and such measures taken that the ships, buildings and wharves do not collapse, but these preventive measures are effected only at an annual expense which in the aggregate is enormous. The damage accomplished by shipworms each year can hardly be estimated, but when we are told by a reliable engineer that in the northern area of San Francisco harbor alone, the damage by marine borers made evident within a period of two years was estimated by competent engineers to be in excess of 15 million dollars, the imagination can frame some picture of the total losses in all parts of the world—to say nothing of the costs of defense in harbors and at sea.

What is this powerful submarine enemy called by so impotent a name as "shipworm?" If we can imagine an oyster having a very small shell, about the size of one's little finger nail, but with the body projecting from the rear end of the shell for a distance equal to the length of the finger or even of the whole arm, we have a very rough picture of the shipworm. The portion of the body protruding from the shell, practically the entire animal indeed, is surrounded by an extension of the soft mantle which lines the shell. Thus the animal is in the shape of a long tube, having the shell at one end and at the other two small tubular openings called siphons. No matter how far the shipworm may burrow into a plank or a log, the little siphons remain always at the outside pinhole opening through which the animal began its travels and destructive action in the wood. It is through these tubes that the Teredo breathes and derives the greater part of its food. Through one tube a stream of water steadily flows in, while through the other it flows out. In course of its passage through the animal the water bathes the small blood vessels, bringing in fresh supplies of oxygen and taking away the waste gases; it is also thoroughly filtered, yielding up to the animal the minute microscopic organisms and detritus required for food.

It is not strange that this mollusk lives so largely outside of its shell inasmuch as its life in burrows in the wood diminishes the need for a protective shell. Such of the shell as it retains about the forward end of the body is modified to form a grinding organ which is much more effective in its operations than one would suspect from a cursory examination. The shell is marked with ridges that in reality are composed of fine sharp teeth like those of the surface of a rasp. The two halves of the shell are not fitted together like those of a clam, where there is a hinge with an elastic ligament that keeps the shell valves apart except when they are drawn together by two strong muscles that pull together, one being near each end of the shell. In the shipworm the valves of the shell are pivoted above and below and while there are two muscles, as in the clam, it seems that, instead of pulling together, they contract alternately. The alternate action of the muscles therefore throws first the front edges of the shells together and then the rear edges. It is this rocking movement of the two parts of the shell which causes the rasp-like shell to grind away the wood ahead.

These little destructive carpenters are not known to be governed by any union rules but they grind away industriously and at least make a living at the job. For them indeed it is a living wage or death. If one puts an ear upon the surface of a piece of wood in which they are working, the rhythmic rasping sounds heard may give the impression that some creatures within are sleeping soundly. The impression will be erroneous; the sounds indicate merely that shipworms are doing a day's work for a day's wage.

Much of the fine sawdust produced by the rasping of the wood is taken into the stomach along with the living organisms from the water and it is yet a disputed question to what extent shipworms actually feed upon the wood which they continually grind up. To a large extent surely they feed upon organic matter, living or dead, which is carried in the sea water; this they strain out, as previously indicated, while the stream of water passes through their gill plates.

So far we have spoken of shipworms as if they were of one race or tribe. As a matter of fact there are several kinds of boring mollusks called shipworms besides boring animals of other groups. The principal boring mollusks belong to one family which scientists have maliciously named Teridinidæ. There are some boring mollusks which do not belong in the typical shipworm family. Among these is one called Pholas which bores in rocks such as limestone and sandstone, and occasionally wood, but never in hard or compact rocks. Another, euphoniously named Martesia, is found in timbers of wooden ships in West Indian waters. Xylophaga, which is not, as might be thought, a musical instrument, really accomplishes serious damage to marine structures and to the covering of submarine telegraph cables.

Giants among shipworms are the plumed pile-worms[1] which may be three feet in length and have a head diameter of nearly one inch or approximately the thickness of the human thumb. They are said to burrow at the rate of ⅛ inch a day; thus it can be seen that a great deal of damage can be accomplished by a few individuals in course of a few weeks. The increasing effectiveness of the attack may be appreciated when it is considered that they begin breeding at the age of 30 days and that a single healthy mother may cast millions of eggs into the sea water.

But the real king of the shipworms is the pet of our South Atlantic Coast, sometimes known as *Teredo dilatata*. A female which attains a length of 4 feet and a head diameter of 1 inch has the right to her "big head" for she lays one hundred million eggs at a sitting—enough to fill 4 or 5 thimbles. This apparent enormous waste in egg production is rendered necessary because great quantities of eggs or larvæ may be destroyed in the first few hours of life by physical conditions existing in the water or may be consumed as food by innumerable small floating animals.

The "shipworm" of the dykes of Holland[2] is less properly so called because it is not so often found in the timbers of ships as are other species. Its burrows are smaller and more symmetrical and regular than those of the giant pile-worm. It lives and dies within a year. The eggs are said to be held within the body of the maternal parent while they develop into free-swimming larvæ that subsequently escape into the sea. They are believed to remain in this free state about a month, during which they develop a "foot" and a pair of shells, before they settle down on wood and transform into the boring adult form. The number of eggs is estimated at a little less than two million. The free-swimming habit of the larvæ of this shipworm, and of the eggs and larvæ of those previously mentioned, is most significant because it enables the juvenile shipworms to travel long distances with the currents of the sea and thus to invade new territories.

The burrow of a shipworm enters the wood at right angles to the surface as a small pin hole, but soon turns and traverses it obliquely or parallel to the surface and usually downwards. The shipworm never bores completely through the wood but, guided by some instinct, the nature of which we can not define, it turns away just before breaking through the inner face of the wood. If, however, shipworms do not make a perforation completely through the bottom of a vessel they may so fill it with their burrows as to leave little more than an empty shell that is easily broken through by any blow or direct pressure.

Not all marine borers are shipworms. Any boy who has turned over a log of wood in the yard or in the forest may have observed the small "pillbugs" which live beneath the wood. These are crustacea belonging to the same large group of animals to which pertain the crabs, shrimps and lobsters. If a pillbug is left undisturbed for

[1] There are distinct species of this genus on our two main coasts, *Xylotra setacea* of the Pacific and *Xylotra gouldi* of the Atlantic.

[2] *Teredo navalis.*

a few moments it will be observed to unroll itself to assume a flattened form and crawl away. It might interest this boy to know that the pillbug has a relative in the sea called gribble (scientists call it *Limnoria lignorum*) which creeps into small crevices of wharf piles, even those which have been treated with creosote for protection, and, by gnawing away the wood, creates burrows which, when made in large numbers, will soon reduce the creosoted pile to an hour-glass shaped peg. The young have no free-swimming stage but, as soon as they leave the mother, begin to "dig in" for themselves. Hence they form family communities, and new colonies no doubt arise by the drifting of crumbled portions of pile to places where new homesteads may be established. A single square inch of wood has been found to contain nearly 400 individuals, adult and young. Another pillbug borer (Sphaeroma) digs into mud, wood, or even rock itself, but it seems to dig for shelter, not for food. Some of these are known to destroy piling in fresh-water.

Again, there is the feathered crustacean borer, called *Chelura tenebrans,* which works along with the pillbug borers and is known as a destroyer of wood both in Europe and North America. It is related to the familiar sand-hoppers or beach-fleas, though it has some external resemblance to the pillbug borers.

Our tale might be interminable if we proceeded to tell of the boring worms and the little sponges that make the familiar holes in the shells of oysters as well as in rock structures composed of limestone and that are of more economic importance than might at first appear. There are barnacles, too, that bore into limestone and coral.

Perhaps most interesting of all to the collector are the several kinds of boring clams which are often found encased in calcareous rocks. It is an exhilarating surprise to break with a hammer what appears to be a solid rock and in smooth oval burrows find completely formed clams entombed, as it were, within the rock but in healthy living condition. The chambers in which they live will be found to be connected with the outside only by small pores through which, with the usual currents of water, the clams derive their sustenance. Some of these cavities are undoubtedly excavated by the abrasive action of the rotating or rocking shell, but others are said to be found in rocks so hard that the excavation may not be supposed to have been effected solely by the mechanical action of the fragile shell. If an acid is employed in dissolving the rock it seems remarkable that the calcareous shell of the animal is not itself dissolved, and perhaps it would be except for the protective horny covering of the shell.

It is not to be assumed that the submarine war is altogether one-sided and that man has no means of defense against the destructive action of the marine borers. It has been held that, in some cases, at least, leaving the bark on wood piling affords some protection against borers but certainly this is a very poor defense, both because the bark itself may be attacked by borers, though they like it less than the wood, and because the bark is likely to be knocked off or cracked. It requires but a very small opening for the borers to get the first foothold after which their destructive action rapidly extends. Metal sheeting for piling is sometimes employed but a metal such as copper, which will withstand for a considerable period the corrosive action of salt water, is costly, tempting to thieves and liable to injury. Paints and treated burlap are also used but these are liable to damage from the contact of boats or drift, to the formation of cracks, and especially to injury in storms. Nevertheless there are coatings which have been found to give piling a life of 5 to 8 years. Concrete casings have been employed but great care is needed in their application and such casings are likewise subject to injury from the battering of boats against the piles.

An ingenious person once suggested the use of jointed collars of loose floats put in series around the piling with the idea that the continual battering of the floats from wave action would destroy the larvæ of the borers before they could effect an entrance into the wood. It requires, however, such a little break in the surface to harbor the minute larvæ of the borers that the plan does not seem to have been as effective in practice as it appeared to be in theory. Electrolysis and dynamite explosions have been employed for the destruction of the larvæ but the necessity of frequent repetition of the processes and perhaps other deficiences in their operation have prevented their demonstrating such results as could have secured their general adoption. For wood piling nothing more effective has yet been developed than impregnation with creosote oils which, while hot, are forced into the wood under substantial pressure. The protection afforded by creosote is, however, also limited in duration.

Of course wood may be displaced altogether for submerged structures by the use of iron or concrete, but the mechanical difficulties and the high expense of using either material are equivalent to a very high tribute paid for protection from our enemies; or, as we may prefer to put it "Millions for defense but not one cent for tribute!" Call it defense or tribute, as you please; in any event, until additional discoveries may be made, we protect our submarine structures from the depredations of marine borers only through very great expense in initial costs or in frequent replacements.

Shipworms and their allies remind one of the man who made his living suing the railroad. How did he live before the railroad was built? Some one also asked how mosquitoes found satisfaction and profit in life before man invaded their haunts. So the question occurs: Were there no cohorts of shipworms before civilization developed to the point where men "went down to sea in ships" or built structures out into the shore waters. It must be remembered that forests and rivers are nearly as old as the sea, and there were floating logs before there were ships or the hollowed logs that served for transportation of coastal tribes of men. Nor have marine borers been altogether dependent upon the chance log that drifted into their habitat. Along the shores of tropical countries there have long existed forests of mangroves whose aerial roots hang down into the salt or brackish waters, to serve as lodging places for oysters, barnacles and other living things of the sea. Not often can a shipworm find a suitable home in the green and growing tree, but one of its "associated powers," the tribe of pillbug borers, is not disturbed by the presence of flowing sap. No matter how green the stem or root, these "shock troops" assuredly cut their trails through the bark and into the wood, causing eventually the death of the affected piece. The way thus prepared for the main forces, the molluscan borers soon fill the dead wood with their burrows, until finally it is so weakened as to fall away and bear its burden of oysters to the mud.

So when man appeared with his floating and fixed structures, the triple alliance of shipworms, pillbugs, and feathered borers, were not found in a state of unpreparedness. All the methods of submarine attack had been developed, the armies were in training and the invisible warfare began at once. "Sunk without warning" must have been the sad report of one of the early sailors of the sea.

Did the wise neighbors jeer the unfortunate victim of a bold impulse to brave the sea, or did the tribe in sympathy and alarm assemble to propitiate their god? We do not know, but we can imagine that, sooner or later, the cause was sought by some inquiring mind and that in time it was discovered that, by keeping the family log in fresh water and sea water alternately or by regularly hauling it out in the sun, the trouble was obviated—the unseen enemy defeated.

Thus began this war against war, and, as marine structures increased in number, size and complexity, new tactics of defense were evolved. And yet, here we are in the 20th century still relatively defenseless, and only beginning to realize that, did we devote one half the thought and scientific skill to the age-old submarine war that we recently did to a man-made under sea attack, we might have an earlier hope to win a battle of the ages—the battle of the borers.

THE NEGRO ENUMERATION OF 1920

A REPLY TO DR. KELLY MILLER

By LE VERNE BEALES
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IN an article entitled "Enumeration Errors in Negro Population," published in the February, 1922, issue of THE SCIENTIFIC MONTHLY, Dr. Kelly Miller asserts that the 1920 enumeration of Negroes was seriously defective, basing his assertion mainly on the fact that the rate of increase shown for the Negro population between 1910 and 1920 was less than might have been expected under normal conditions. With this utterly inadequate basis for his claims, and presumably without giving any study to data as to Negro age distribution, he declares that the enumeration of 1920, like those of 1870 and 1890, was "so flagrantly discrepant as to demand special explanation and correction." (Page 169.) Disregarding the reduction in the Negro birth rate due to the abnormal conditions prevailing during the last decade, and making no allowance for the excessive mortality due to the influenza epidemic, he estimates that the true rate of increase in the Negro population between 1910 and 1920 was 9.6 per cent., a rate which would be substantially in line with those for preceding decades. In order to obtain this normal-appearing rate of increase, he adds 300,000 to the number of Negroes enumerated in 1920, asserting that the estimated total thus obtained "makes the Negro population behave more or less normally"—despite the fact that conditions were far from normal during the last decade. (Page 176.)

As a matter of fact, a careful examination of all—not merely a part—of the available data which are sufficiently reliable to be worthy of consideration demonstrates the substantial completeness of the Negro enumeration in 1920. The evidence supplied by the census figures themselves is so convincing that there is really little need to consider collateral data. Nevertheless, the birth and death statistics for the Negroes in those states which maintain adequate registration systems have been carefully examined and have been found to be in harmony with the decennial census figures.

It was a well-known and unquestioned fact before the census was taken that there had been, during the latter half of the last decade, an unusual and very considerable migration of Negroes from the South to the North and West. The census confirmed that fact and showed that the migration during the entire decade had amounted to about 400,000. Such a movement would naturally have a tendency to break up the home life and family relationships and result in a reduced birth rate. That this was the case is brought out clearly by an examination of the following figures for Negro children under 10 years of age:

AGE GROUP	1920	1910	Increase (+) or Decrease (—)	
			Number	Per cent.
Total under 10 years	2,409,906	2,509,841	—99,935	—4.0
5-9 years	1,266,207	1,246,553	+19,654	+1.6
Under 5 years	1,143,699	1,263,288	—119,589	—9.5

There is nothing inexplicable about this condition. The departure of hundreds of thousands of Negroes, most of whom were undoubtedly in the younger adult ages, from the South brought about a material reduction in the number of Negro births in that section; but the presence of these migrants in the North and West did not result in any counterbalancing increase in Negro births. The Negro birth rate is much lower in the North and West than in the South, and in some states it falls below the Negro death rate. In 1920, of the 18 northern and western states in the birth-registration area, only four showed natural increases due to excess of births over deaths among the Negro population, the rates of such increase ranging from 1.4 per 1,000 Negro population for Pennsylvania to 5.2 for Massachusetts. The remaining 14 northern and western states showed natural decreases in their Negro population due to excess of deaths over births, ranging from six tenths of 1 per 1,000 for Ohio to 19.1 for Maine. The birth-registration area also includes five southern states and the District of Columbia. Of these, the District and four states show the following rates of natural increase in Negro population for 1920: District of Columbia, 1.9 per 1,000; Maryland, 6.4; South Carolina, 11; Virginia, 12.1; North Carolina, 15.1. The figures for Kentucky indicate a natural decrease of 1.8 per 1,000.

In order, therefore, to test the completeness of the 1920 census figures for the Negro population by comparing them with the results of preceding censuses, it is necessary to make the comparisons between the number of Negroes 10 years of age and over enumerated at each census and the total number enumerated at the preceding census. In this way the births during the decade are eliminated from consideration, and the mortality among the Negro population enumerated at the beginning of the decade is ascertained. The following table shows, for each census year from 1850 to 1920, the total

Negro population and the Negro population 10 years of age and over, as enumerated, together with the percentage by which the number at the ages of 10 and over fell below the total number enumerated at the preceding census:

TABLE 1

TOTAL NEGRO POPULATION AND NEGRO POPULATION 10 YEARS OF AGE AND OVER, WITH PERCENTAGE BY WHICH NUMBER 10 YEARS OF AGE AND OVER FELL BELOW TOTAL NUMBER AT PRECEDING CENSUS: 1850-1920

CENSUS YEAR	Total negro population	Negro population 10 years of age and over	Per cent. by which number 10 years of age and over fell below total at preceding census
1920	10,463,131	8,053,225	18.1
1910	9,827,763	7,317,922	17.2
1900	8,833,994	6,415,581	14.3
1890	7,488,676	5,328,972	19.0
1880	6,580,793	4,472,373	8.4
1870	4,880,009	3,428,757	22.8
1860	4,441,830	3,084,940	15.2
1850	3,638,808	2,500,353	----

The following table gives adjusted figures for 1870 and 1890. The revised total for 1870 in the first column has been published heretofore in the decennial census reports. The revised total for 1890 in the first column is given on page 28 of the Bureau's special report, "Negro Population in the United States: 1790-1915." The revised figures for 1870 and 1890 in the second column have been

TABLE 2

TOTAL NEGRO POPULATION AND NEGRO POPULATION 10 YEARS OF AGE AND OVER, AS ESTIMATED FOR 1870 AND 1890 AND AS ENUMERATED IN OTHER CENSUS YEARS, WITH PERCENTAGE BY WHICH NUMBER 10 YEARS OF AGE AND OVER AT EACH CENSUS FELL BELOW TOTAL NUMBER AT PRECEDING CENSUS: 1850-1920

CENSUS YEAR	Total negro population	Negro population 10 years of age and over	Per cent. by which number 10 years of age and over fell below total at preceding census
1920	10,463,131	8,053,225	17.4*
1910	9,827,763	7,317,922	17.2
1900	8,833,994	6,415,581	17.3
1890	7,760,000	5,525,000	16.0
1880	6,580,793	4,472,373	17.1
1870	5,392,172	3,790,697	14.7
1860	4,441,830	3,084,940	15.2
1850	3,638,808	2,500,353	----

*Adjusted to exclude mortality due to influenza epidemic.

calculated on the assumption that the age distribution at the two censuses in question was the same for the Negroes omitted as for those enumerated. The revised rate for 1910-1920 in the third column has been calculated by deducting the estimated mortality due to the influenza epidemic in 1918 and 1919 (60,000) from the total decrease. The revised rate, therefore, represents the normal mortality during the decade among the Negroes enumerated in 1910.

In preparing the foregoing tables no adjustment has been made on account of the change in the census date from June 1 in 1900 to April 15 in 1910 and to January 1 in 1920, and the effect of immigration has also been disregarded. The numbers of Negro children who reached the age of 10 between April 15 and June 1, 1910, and between January 1 and April 15, 1920, were undoubtedly somewhat larger than the numbers of deaths of Negroes 10 years of age and over during the same periods. On the other hand, the number of Negroes 10 years of age and over as enumerated at each census would be reduced by the exclusion of the immigrants who arrived during the preceding decade. As it would be impossible to calculate accurately the slight effect of either of these opposing factors, they have both been disregarded; but the resultant error is too slight to have any significance as affecting the comparability of the percentages for the several decades.

The rates in Table 1 show conclusively that the 1870 returns were far from complete, and indicate that the 1890 returns were also incomplete, although not to so great an extent as those of 1870; but, as will be seen from the revised rates in Table 2, the decrease due to normal mortality in the Negro population enumerated in 1910, as shown by the census returns for 1920, was in entire harmony with the corresponding decreases during preceding decades.

It may be mentioned in passing that the mortality during the last decade among the Negro population enumerated in 1910, as indicated by the percentage in Table 1, is no more than might be expected from an examination of the mortality rates for the colored population (Negroes, Indians, Chinese, Japanese, and other non-whites) of the death-registration area, which—excluding the abnormal year 1918—ranged from a maximum of 23.4 per 1,000 colored population in 1911 to a minimum of 18 in 1920. For 1918 the rate was 26 per 1,000. These rates do not show at all definitely the total colored mortality, since the death-registration area contains only a part of the colored population, but they do indicate that the Negro mortality during the decade was fully as great as that shown by the decennial census figures.

Thus the census returns for Negroes 10 years of age and over in 1920 not only afford no ground whatever for an assumption that the enumeration was deficient, but in large measure demonstrate their own substantial accuracy, and therefore, in the entire absence of any credible evidence to the contrary, must be accepted. Hence if the charge that the enumeration of the Negro population as a whole was deficient is to be sustained it must be accompanied by proof of an incomplete enumeration of children under 10. No such proof has been offered. Moreover, as has already been pointed out, the unprecedented northward migration of Negroes between 1910 and 1920 resulted in a marked decline in the birth rate, and the census figures show only what might have been expected in this respect. Furthermore, it would be idle to claim that the census takers, while successful in enumerating the parents and older children, were guilty of overlooking scores or hundreds of thousands of the younger children. Such an assumption is unworthy of serious consideration. The most difficult part of the population to enumerate is made up of the roving or "floating" element, which consists mainly of unattached adults—or, at any rate, of adults separated from their families; but the enumeration of children presents no special difficulties.

In order to forestall further allegations of underenumeration based on obvious discrepancies in the statistics for certain age groups, it may be added that these have been carefully considered and are found to have no material effect on the accuracy of the returns for the total number of Negroes aged 10 and over or the total number at all ages. The number of Negro men reported as between the ages of 20 and 35 was probably too small, but the number reported as between the ages of 45 and 55 was probably too large. The obvious explanation of this condition is that there was a general overstatement of the ages of Negro men whose true ages were between 20 and 50, but the total number of men under 55, as enumerated in 1920, is not unduly small. The Negro population of both sexes in the age group 20 to 54 formed 47.3 per cent. of the total Negro population of all ages in 1920, as against 44.6 per cent. in 1910 and 41.8 per cent. in 1900. It is clear, therefore, that there was no serious underenumeration of young or middle-aged Negro men, but merely an overstatement of their ages.

Another test of the accuracy of the 1920 returns is found by comparing the sex distribution of the Negro population as shown by the last three censuses. The males outnumber the females among the Negro population of every northern and western state except New York and New Jersey; and the roving or floating element, which is by far the most difficult to enumerate, is made up mainly of males. If, therefore, there had been any considerable number of omissions in enumerating this element in 1920, the result would have been a decrease in the indicated ratio of males to females as compared with 1910 and 1900. On the contrary, however, the returns show increases in this respect both for the total Negro population and for the Negro population 10 years of age and over, as will be seen from the following statement:

EXCESS OF FEMALES OVER MALES AND SEX RATIO IN NEGRO POPULATION: 1920, 1910 AND 1900

AGE LIMIT	Excess of females over males			Males to 100 females		
	1920	1910	1900	1920	1910	1900
All ages	44,259	56,001	60,900	99.2	98.9	98.6
Ten years and over	34,301	43,150	53,784	99.2	98.8	98.3

These figures alone supply fairly conclusive evidence that there were no wholesale omissions in enumerating the migrant Negroes in the North and West.

Dr. Miller's assertion that "The internal evidence of error is overwhelming" (page 170) may therefore be reversed in meaning; for the internal evidence, when considered in all its phases, certainly sustains the substantial accuracy of the enumeration. Nevertheless, in order to make assurance doubly sure, the results of the enumeration in every county in the southern states in 1920 were scrutinized in comparison with the figures for 1910 and 1900, and a careful examination of the original returns was made for the few counties which showed decreases that appeared suspiciously large as against the increases or decreases during the preceding decade; but in no case was anything found to indicate that the enumerators had neglected to canvass the Negro population generally, or any considerable part of it.

Dr. Miller asserts that—

"... . An acknowledged error of a half million [referring to the census of 1870], it would seem, would put this bureau on the lookout for similar errors in the future." (Page 170.)

And again:

"... . As this bureau has admittedly committed grave errors in enumeration of the negro population in two preceding censuses, it is but reasonable that the obvious discrepancy can be most reasonably accounted for by an error in the present count." (Page 172.)

The present Bureau of the Census is in no way responsible for the errors of 1870 and 1890. The Census Office has been in continuous existence since July 1, 1899, and has been existence as a permanent office, under substantially its present organization, since July 1, 1902. Not one person connected with the census of 1870 is now in the service of the Bureau, and only a very few of the officials and employees of 1890 are in the present office.

Dr. Miller points out that the World War greatly upset the mobile Negro population, and continues:

". . . . There was a mad rush of negroes from the South to fill the vacuum in the labor market caused by unsettled conditions. Thousands of negro homes were broken up and their members scattered without definite residential identity." (Page 172.)

He is thus fully aware of the Negro exodus from the South, but is willing to consider it only in connection with the difficulties in the way of enumerating the migrant Negroes in their northern abodes, disregarding entirely the pronounced decrease in the Negro birth rate which resulted from this unusual migratory movement. He continues:

"In the cities especially, it seems probable that the count was greatly underestimated. The negro migrants lived for the most part in improvised lodgings and boarding houses whose proprietors had little knowledge and less interest in the identity of the boarders. The census official, visiting such boarding houses with a large number of negro boarders would, in all probability, receive an inaccurate underestimate by the ignorant and uncaring proprietors." (Page 172.)

The proprietors of lodging houses were required to do far more than make an estimate of the number of their lodgers. They were required to give the name and as many as possible of about 15 items of information in regard to each lodger whom the enumerator was unable to interview personally. Moreover, it would be an exceedingly unbusinesslike lodging-house keeper who would not at least know how many lodgers he had.

Dr. Miller quotes from an editorial in the Oklahoma City Dispatch, in which it was asserted that 33 Negroes had been overlooked in one block. During the enumeration many similar charges were made by newspapers, chambers of commerce, and other organizations, and some of them were couched in violent and abusive language. These charges were duly investigated and in most cases were found to rest upon very slight foundation or no foundation at all. A newspaper in a certain city having a population of approximately 15,000 asserted that the city had been underenumerated by about 10 per cent. In reply the Bureau offered to recanvass the entire city for the purpose of verifying or correcting the original enumeration if the editor could prove that in some part of the city, to be selected by himself, the enumeration had been deficient to the extent of 2 per cent. The editor then brought the matter to the attention of the local commercial club, which, after investigation, expressed in writing its satisfaction with the enumeration and its belief that the work had been properly performed.

In another city, whose population was approximately 23,000, complaints were made that the enumeration was "so absurd that it amounts to nothing short of an insult," that it was "absolutely ridiculous," and that the alleged errors were due to "gross incompetency of enumerators." The Bureau requested the complain-ants to supply proof in the form of names and addresses of persons omitted. They organized a canvass of a part of the city, secured 1,239 names of persons purporting to have been bona fide residents and to have been missed by the enumerators, and sent these names to the Bureau; but from this number it was possible, through careful and painstaking investigation, to sift out only 91 names of persons who were actually entitled to enumeration and had been missed.

From these examples it is obvious that little credence is to be placed in a mere newspaper statement that the enumeration was incomplete. It is easy to assert emphatically that a city or town has a far greater population than the census returns show, and there is little difficulty in producing persons who will declare themselves to have been missed by the enumerators. But when a thorough investigation is made it is found in the great majority of cases either that the persons were enumerated without knowing it, the information regarding them having been supplied by others, or that they were not entitled to enumeration as bona fide residents of the city or town in question.

One instance of miscalculation on Dr. Miller's part is worthy of special mention, not because it has any direct bearing on his claim of underenumeration of the Negro population, but because it illustrates forcibly the lack of care and occasional disregard of mathematics displayed in the preparation of his article:

> "Even the apparent rapid increase in the white death rate awaits fuller explanation before the figures can be relied upon with assurance. It is curious to note that the birth rate among the whites in South Carolina fell from 32.3 in 1900 to 27.1 in 1919, the death rate rising but slighly from 10.4 to 10.6 during the same interval. And yet the white population of that state increased from 557,807 in 1900 to 818,538 in 1920. There was a vigesimal increment of 250,731 with little or no reinforcement from immigration. This unexplained increment in the white population seems also to discredit the reliability of the recorded mortality statistics within the states so recently added to the registration area." (Page 174.)

There has been no rapid increase in the white death rate. For the death-registration area as a whole (which has been increasing in extent from time to time) the death rate for the white population decreased from 17.1 per 1,000 in 1900 to 12.6 in 1920, and during the entire period there was no pronounced increase from one year to another, except in the case of the rate for 1918, 17.4 per 1,000, which, because of the influenza epidemic, was considerably higher than that for the preceding year, 13.7.

The increase in the white population of South Carolina is in no way inconsistent with the birth and death rates cited by Dr. Miller. In fact, although the death rate for 1900 is probably open to question (the state was not then in the death-registration area), it happens that the figures harmonize very closely indeed. The rate of natural increase due to excess of births over deaths in 1900, according to the figures, would be 21.9 per 1,000 white population, and the corresponding rate for 1919 would be 16.5. Assuming that the annual rate of natural increase in the white population decreased from 21.9 per 1,000 in 1900 to 16.5 in 1919, the decrease in the rate of increase being uniform throughout the period, the vicennial increase would be approximately 257,000, or only about 4,000 less than the increase of 260,731 shown by the census figures (not 250,-731, as stated by Dr. Miller).

To summarize:

Dr. Miller's claims are based mainly on the fact that the increase shown by the Negro population during the last decade was abnormally small. He assumes that the true increase must have been a normal one, despite the fact that the conditions during the decade were abnormal.

The census figures themselves show that the number of Negroes 10 years of age and over enumerated in 1920 bears an entirely normal relation to the total number of Negroes enumerated in 1910. Furthermore, the mortality during the decade among the Negroes enumerated in 1910, as shown by the census returns, is scarcely as great as that indicated by the mortality statistics for the colored population of the death-registration area.

The returns show that the number of Negro children under 10 years of age, and especially the number under 5 years of age, as enumerated in 1920 were abnormally small. This condition was a natural result of the unprecedented Negro migration from the South to the North and West during the decade. Moreover, since the census takers were obviously successful in enumerating all or substantially all the adults and older children, there is no possibility that they overlooked a very large number of children under 10.

The ratio of males to females in the total Negro population and in the Negro population 10 years of age and over in 1920 was higher than in 1910 or 1900, the increase from census to census being substantially uniform. Thus there could have been no wholesale omissions in enumerating the migrant Negroes in the North or West, among whom the males far outnumber the females.

For the foregoing reasons the writer, after a thorough study not only of the census returns but of such available collateral data as have any bearing on the matter, is of the opinion that the enumeration of Negroes was probably as nearly complete in 1920 as in 1910 or 1900, and finds no ground whatever for attacking the 1920 census as inaccurate beyond the small margin of error which is inherent in any great statistical undertaking.

AERONAUTIC ACCIDENTS OF TWO YEARS COMPARED

By Dr. FORD A. CARPENTER

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ON September 16, 1919, the Los Angeles Chamber of Commerce created a department of meteorology and aeronautics and this newest creation in any commercial organization took for its motto "To make the Soil productive and the Air safe." The manager being both a meteorologist and an aeronaut has been able to apply the principles of weather science *directly* to problems of agriculture and aeronautics. The first is being accomplished through climatic surveys of agricultural districts, and the second by making all sources of meteorology available to air pilots. Realizing the necessity of accurate data on which to base the relation of weather to aeronautic accidents, statistics as to flying activities have been collected day by day from the press dispatches during the past two years. While the period is admittedly very short, it is believed that sufficient data have been collected to show the relative importance of weather elements in aerial navigation, the proportionate value of the other factors, and the comparison of these compilations one year with the other.

As has been well said: "An airplane accident is hardly ever due to a single cause. Usually several factors are involved * * * An error in judgment by the pilot is perhaps the most common cause of airplane accidents."[1] Bearing this fundamental in mind we will consider first the statistics of the year 1920-21.

Figures as to airmileage are not available, neither is information as to the airworthiness of the various kinds of aircraft, or the airmanship of the pilots: such phases of the subject, will, of necessity, be neglected in this study.

During the twelve months ending September 15, 1921, there were reported from various parts of the United States 76 aircraft accidents in which 137 deaths occurred. This was more than twice as many as occurred during the previous year. Fifty-eight per cent. of the fatalities occurred among government airmen, 31 per

[1] *Airplanes and Safety,* The Travelers Ins. Co., Hartford, Conn., 1921.

cent. in commercial flying, and 11 per cent. among spectators in ground accidents.

The classification of deaths among officers and others connected with the government shows the following distribution:

Army	59 per cent.
Navy	19 per cent.
Air mail	17 per cent.
Forest patrol	5 per cent.

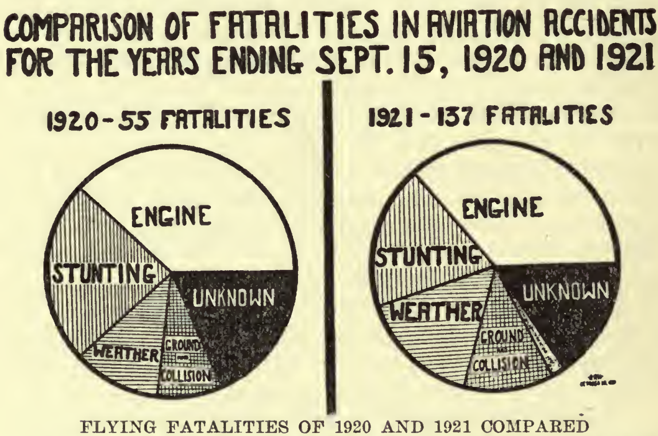
The kind of aircraft in which fatalities occurred are classified thus:

Airplane	83 per cent.
Seaplane	12 per cent.
Balloon	4 per cent.
Parachute	1 per cent.

Comparing the causes of all aeronautic fatalities one year with another we have this table:

	1920	1921
Engine trouble	38 per cent.	36 per cent.
Stunting	24 per cent.	19 per cent.
Weather conditions	11 per cent.	16 per cent.
Collisions	9 per cent.	12 per cent.
Structural defects	0 per cent.	2 per cent.
Unknown	18 per cent.	15 per cent.

Prepared by the *Dept. of Meteorology and Aeronautics of the Los Angeles Chamber of Commerce.*



FLYING FATALITIES OF 1920 AND 1921 COMPARED

The segments of the circles show the percentage of fatalities in all kinds of aviation accidents from five known and one group of unknown causes. It is instructive to note that while stunting as a death-producing feature has decreased from 24 per cent. to 19 per cent., engine trouble still remains the prime cause. The weather conditions of 1920-21 were no more unpropitous than those of 1919-20 so that the increase from this cause from 11 per cent. to 16 per cent. may be laid to the ignorance or disregard of weather indications.

As will be observed by perusing the accompanying diagrams the proportion of accidents resulting from the principal causes remains unchanged. Notwithstanding the advances made in motor construction during the past year fatalities arising from faulty engines was decreased only 2 per cent. Stunting accidents dropped off 5 per cent., probably because of the dulling of the public appetite for such acrobatics. Weather conditions are shown to be an increasing cause of accidents doubtless due to the pilots' insufficient meteorological knowledge. There were an increasing number of collisions in midair and with spectators. Structural defects, as such, first appeared last year as the cause of 2 per cent. of the fatalities.

Transportation over the sea, on the land and through the air will never be rendered absolutely safe for we have to deal with human fallibility and the changing elements. It is only needful to call attention to the fact that notwithstanding long familiarity with the water, marine accidents show little diminution in proportion to the passenger-mile. With railroads such is not the case for vigilence and scientific control have reduced fatalities most markedly during the past decade. However, that next newest method of transportation, the automobile, does not show a decrease in the number of people killed by it, but rather an increase. As to aerial locomotion, a study of accidents indicates five ways of making it safe and dependable:

1. Improve the motor in dependability; devise a new motive power if necessary.
2. Absolutely eliminate stunting by penal statute except as a military measure.
3. Educate the pilots in meteorology; make every airman a meteorologist as every mariner is weatherwise.
4. Increase vigilance in the inspection of aircraft.
5. Strict supervision of flying fields and the education of the public in their attitude towards aerial navigation.

Public confidence in practical aeronautics will come with increased safety: no other element is so vital. That the air will be made safe for general transportation is assured for the need is imperative. Time is the only inelastic thing given to man and everyday flight, outdistancing the locomotive or the automobile, is the only way in which the busy man may increase his day's work by annihilating time.

WHY THE MOVIES MOVE

By DONALD A. LAIRD
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OVER nine tenths of us are now confirmed movie goers. The remaining one tenth will without doubt soon be enthusiastic converts to the silver screen, while those few who do not attend or are not regular in their movie habits either do not know what they are missing or else it is physically impossible for them to attend.

Among the millions who are weekly movie goers there are at the most only a few hundred who understand why the pictures seem to move. Every one knows that countless thousands of pictures are flashed on the screen in rapid succession and in such wise as to produce the effect of motion. This is about the limit of common knowledge regarding why the movies move. But after you have read and understood and remembered this account of the why of the movies you may count yourself among the few hundred who understand how the effect of motion is produced.

It is easy to take things for granted without striving for an understanding of them. This is the great American characteristic. We are too easily content with a half truth or with a superficial explanation.

As adults we seem largely to have lost the thoroughgoing inquisitiveness which characterizes certain periods of childhood. Then we asked what, why, where, when, how, and ended up with why is it that way. Now as adults only a single, cursory question is asked and, lest we betray ignorance or slowness to comprehend, we let an "Oh, yes! That is so" take the place of the series of follow-up questions which should be put to clarify and explain things.

The best intellectual tonic we can experience as adults is a reversion, as it were, to this inquisitiveness of our childhood which forced us to stick to a problem until it was satisfactorily and genuinely solved or understood.

When one really once understands some of the applications of science in providing the comforts and recreations for his daily life, one comes into a realization of the wonderful progress of science with a clearness and a force which can be obtained in no other way. And at the same time one has his appreciations of the newer conveniences and luxuries vastly deepened.

So pause from time to time as you read this article and reflect upon the marvelous complexity and achievement of the daily movie. And, by the same token, make the attempt to spread this curiosity and appreciation out into the numerous phases of applied science which touch upon your life from the electric grill in the morning to the violet ray bath at night.

The story of the development of the motion picture industry is a fascinating bit of history in financial organization and international trade competition. Why the movies move is as fascinating a morsel from the recent history of applied science and the progress of mechanics.

The present excellence of clearness, freedom from flicker, and the illusion of motion in the movie are due to the ingenious application and capitalization of certain facts primarily from the field of psychology. It will be necessary to review these interesting discoveries in order to establish a basis for an understanding of why these pictures, which are really intermittent, motionless and flat, nevertheless appear to be continuous in motion, and to possess depth,

There are three questions for us to answer regarding the motion picture. First: Why is it that the pictures seem continuous when as a matter of fact the screen is in almost total darkness sixteen times a second and in partial darkness sixteen or more additional times each second? Then the second question is: Why do we get the impression of motion from these pictures which in reality are absolutely motionless? And, third: Why do the pictures have the appearance of depth when in reality they extend only to the right and left, and up and down and do not possess any objective third dimension or depth?

It is to the eye that the motion picture makes its first appeal. And since it is through vision that the apparent motion is perceived it will be necessary for us to take up first of all some phases of the structure and function of the eye as a basis for our understanding of the movies.

I

The human eye is a miniature camera, capable of a large variety adjustments. The eye is wonderfully responsive, and automatically so, to the slightest change in light, color, or position. But it is not without its defects and shortcomings even in so-called normal eyes. It is by the capitalization of some of these peculiarities, which almost amount to defects, that the movies are made possible.

Just behind the pupil of the eye is a small crystalline lens that automatically adjusts itself to different distances and conditions of vision. The eye thus differs from all other cameras in being self-focusing.

No light can enter the human eye except through the lens, since the remainder of the eye forms a light-proof box. The rays of light which pass through this lens into the eye are focused upon the inner surface of the eyeball. This is covered with a layer of highly specialized nervous substance which is acted upon by changes caused by the light. This specialized layer is called the retina and corresponds to the sensitive film or plate in the ordinary camera.

In the camera the momentary exposure of light causes a chemical change on the sensitized surface of the film. But before the picture can be brought into view further chemical changes must be effected by the photographer in the processes of development and fixation.

Not so with this marvelous human camera. Although vision is essentially momentary in character, due to the continual movement of the eye itself, exposure follows exposure and chemical change follows upon chemical change. There is not time to call in the photographer to develop and fix the pictures after each exposure. Indeed, there is no need.

Nature has provided the human camera with a chemical substance sensitive to light which automatically renews itself. This material is called rhodopsin, or visual purple, from its appearance in freshly dissected eyes. This visual purple permeates the entire retinal structure and is probably the keystone to vision.

The development and fixation in the human camera takes place mainly outside the eye. This occurs principally in the brain, to which the eyes are connected by a direct nervous pathway. The retina of the eye is the outpost of the brain, but the nervous material in the retina is not affected directly by the rays of light focused upon it by the crystalline lens.

There is an interesting bit of experimental evidence which demonstrates this beyond doubt. Retinas which have been washed free from all chemicals which might permeate the network of nervous fibers have been used for experimentation. It has been found that in order to stimulate this purely nervous structure of the eye directly the light must be so strong as practically to destroy these nervous elements. And still it is a matter for common observation that we can see, that is, our retinas are stimulated by lights of weak intensity.

The only explanation is the one already suggested. The light acts first upon some photo-chemical substance which bathes the retina, and the changed chemical composition which the light waves bring about stimulates the nervous parts of the retina.

Just what this substance is remains an open question. There is some evidence to indicate that it is not the visual purple. For example, Kühne found that through continued exposure to light the visual purple in a frog's eye was completely bleached. Still the frog reacted to light and changes in light in a practically normal manner after this thorough bleaching had taken place.

The visual purple is probably the chemical medium for the adaptation of the eye to light or dark illumination. In passing from the open air into the darkened motion picture theater it takes some time for one's eyes to "get used to the dark." This is technically known as adaptation, and its chemical basis in the eye is the visual purple. This same substance may have a prominent part in the general vision, or another still undiscovered chemical substance may be the basis for vision.

At any rate, vision is primarily photo-chemical. Without the intervention of some photo-chemical material the energy which we call light has no ordinary effect upon the eye.

The light which is focused upon the retina by the lens alters the arrangement of the molecules in the photo-chemical substance. This changed chemical condition stimulates the nervous endings in the retina and these carry their impulses to the brain where they are developed (perceived) and fixed (remembered).

This photo-chemical structure in the retina of the eye is not only the keystone in ordinary vision; it is through some of its properties that the motion picture is made possible. We will now turn our attention to those properties of this substance upon which the motion picture depends.

Every material mechanism exhibits a property which physicists term *inertia*. By virtue of this property matter tends to remain in a state of uniform inactivity or uniform motion unless acted upon by some external force. One finds many illustrations of this in every-day life. Let us take an example from automobiling. If it were not for the inital inertia to be overcome there would be no need for a shift of gears from low through intermediate into high in order to get the machine under way. The initial sluggishness or inertia of the machine has to be overcome before the automobile can be propelled at its usual speed. And when once under way it will continue to move when the power is shut off; it is necessary to apply the brakes in order to bring the machine to a halt. The effects of inertia are met with both in starting and stopping an automobile.

But what has this matter of inertia to do with motion pictures? A great deal, indeed. An example or two will suffice to demonstrate the inertia which is present in the eye.

It is only to be expected that we find inertia in the organ of vision since we have found the eye to be mecano-chemical in operation. Inertia is found in the eye as in any other material mechanism.

Inital inertia—the inertia to be overcome in starting—manifests itself in the retina in what is known as the latent time. A few hundredths of a second elapse between the moment a beam of light falls upon the retina and the beginning of the resulting nervous impulse in the retina. This time is consumed in overcoming the molecular inertia of the photo-chemical stimulating medium.

In the case of the automobile the inital inertia can be overcome quickest by the highest powered car. In the case of the retinal lag—the inital inertia—the latent period also decreases with an increase in the intensity of the light.

This initial lag in the retina is difficult to demonstrate except with the aid of intricate laboratory apparatus. The retinal persistence, or what corresponds to the inertia of stopping in the automobile, however, is easily demonstrated. In a recent issue of *The Journal of Experimental Psychology* I described a new apparatus for the study of visual after-images. A rough and ready demonstration apparatus along the same lines can easily be improvised.

Stand in a dark room with the eyes about two feet from a round, gas-filled, clear glass electric bulb. Remain in the dark for about five minutes so the visual purple of the eye may becomc adapted to the dark. Then switch the light on for just an instant, watching the bright yellow filament closely.

What is seen after the light is switched off? Although all stimulation is removed an identical image of the red-hot filament remains for a considerable length of time and is seen as if it were projected out in space in front of the eyes. Move your eyes and you will find this image follows the movements of the eye, showing that it is not imaginary but really in the retina. This phenomenon is due to the inertia and is termed retinal persistence.

This retinal persistence is always present and the experimental procedure simply accentuated it in a manner to make it readily observable. All ordinary visual images persist for about three thousandths of a second at the full intensity of the original stimulus, even after it has ceased to act upon the eye. Intense stimulation, such as the gas-filled bulb and the movie screen give, or long continued stimulation, causes the terminal inertia to remain for a much longer time.

This identical image which remained after the stimulus was withdrawn is known as the positive after-image. After this positive after-image fades away it is followed by another which is the exact reverse in coloring and hence called the negative after-image.

If you will try the light bulb experiment again you will observe, after the positive after-image has disappeared, a line identical in form and position with the red hot filament, but opposite in coloration. This is the negative after-image. Under these conditions it is usually so dark as to be easily seen even in the already dark field of the eye. Usually this dark image is seen fringed with a narrow light greenish-yellow band. When colors are used to cause these negative after-images, they always have the complementary coloration. For example, the negative after-image of a blue square of paper is yellow, the negative after-image of a green paper is red.

Negative after-images have little to do with the movies except in colored projection. They are simply mentioned here that some adequate comprehension may be given of the great complexity of the retinal inertia as it is manifest in visual persistence. It is also largely through a study of these after-images that the nature of the photo-chemical properties of the eye was first brought under observation.

We are now near an answer to the first problem which we set up regarding the movies.

As almost universally projected at present, sixteen separate pictures are flashed on to the screen within one second. In the earlier machines, as in Edison's kinetoscope, the film was passed steadily. But with the bright illumination and large pictures now in use the picture has to be still while on the screen. Otherwise nothing but one great, big, rectangular blurr would be seen.

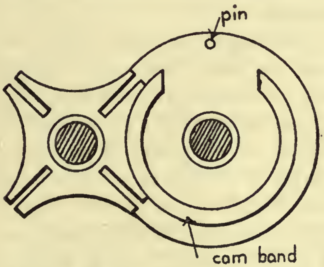

Figure 1. Maltese Cross Movement for jerking the pictures before the lens one at a time. The pin wheel revolves steadily, the cam band holding the Maltese cross firmly in position until the pin enters the slot; then the cross is turned 90 degrees. The axle that carries the cross also carries a sprocket which meshes with the openings in the film and jerks it down picture by picture as the pin pulls the cross around one-quarter of a turn.

In order to accomplish this still projection of the individual pictures to produce the motion picture each picture is jerked before the lens one at a time. A "Maltese Cross" movement, such as is used for the escapement in Swiss watches, jerks the film down picture by picture in the modern projector. That the film may be held rock steady after the intermittent "Maltese Cross" movement has pulled it down it is passed through a tension gate which holds the film tightly at all times.

The clearness, freedom from flicker and illusion of motion are all furthered by the addition of the shutter. This revolves in the path of light of the projector and is timed so that the large blade of the shutter completely cuts off the light while the intermittent movement is pulling down the next picture. The film is thus not seen while in movement but only after it has come to rest.

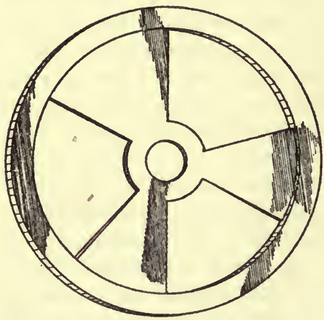

Figure 2. Shutter which revolves in front of the lens, interrupting the path of light. The large blade cuts off the light while the film is being jerked down; the smaller blades are the "flicker" blades.

This shutter cuts the light completely off from the screen while each picture is being jerked into place. Sixteen times in each second the screen is in complete darkness. In addition to this there is a "flicker" blade or two in the shutter which passes in front of the picture and partially shuts off the light while it is being projected on to the screen. The purpose of this "flicker" blade will be mentioned and explained directly.

In view of the findings of our brief survey of the properties of the eye and especially the manifestations of the retinal inertia it will now be possible for an adequate explanation to be given for the apparent continuity of the movie which is actually intermittent.

Retinal persistence is the key. Although the light thrown on the screen is interrupted thirty-two or more times each second a positive after-image of each picture remains until the next picture is projected in full intensity on the screen. The actual period of darkness on the retina is bridged over by the retinal persistence. This is what gives apparent continuity to the motion picture.

The shutter is a significant factor in giving the pictures clearness by shutting off the movement of the pictures as they are jerked into place. The absence of flicker, however, is also largely due to two other factors, namely, the intensity of illumination used and the "flicker" blade of the shutter.

The duration of the retinal lag and persistence varies according to the intensity of the stimulus, which, in this case, is the brightness of the light. As the intensity of the illumination increases, the period of lag decreases, while the period of persistence increases. Thus with the strong illumination which the modern electric arc furnishes, the appearance of continuity is furthered and the intervals of actual darkness are covered by brighter positive after-images than would otherwise be possible.

If the same films and projection apparatus that are now used to project the motion picture were combined with the old acetylene light source there would be a reappearance of the flicker due to the lengthened lag and shortened persistence. It is therefore apparent that the bright illumination not only gives clearness and brightness, but also aids in the steadiness, continuity and the elimination of the flicker.

Now to take up the part of the "flicker" blade. Upon first thought it would seem disastrous to introduce any more flicker than absolutely necessary in order to cover each jerk of the film. Obviously such is not the case. The reason for this will be made clear by reference to some laboratory experiments.

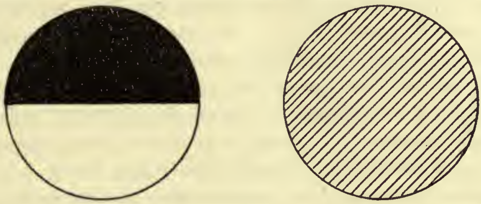

Figure 3. When a disc composed of two sectors such as is shown at the left is rotated with sufficient speed the colors fuse and produce an intermediate grey such as diagrammed. Before the proper speed of rotation is reached flicker is present rather than fusion.

When a disc composed of two equal black and white sectors is rotated by an electric motor whose speed is under control three series of phenomena are observed as the speed is increased. With only a few revolutions each second it is still possible for the two sectors to be clearly seen. As the speed is gradually increased, however, there seems to be a slight admixture of color with the black and white sectors which now appear to be pulsating slightly. These colors are known as Fechner's colors, after the pioneer in psychological investigation who first observed them. They are due to peculiarities in the photo-chemical materials in the retina.

The second phenomenon occurs when the speed of rotation is still further increased. This is known as flicker. The even, pulsating, rhythmical alternation of the black and white observed with the slower speed is replaced by an unsteady, wavering flicker which produces a great strain on the eyes. This experimental flicker is similar to the flicker which accompanied the earlier attempts to project motion pictures.

Increasing the speed of rotation still more causes this flicker to become more and more steady until at last a certain point is reached at which fusion is produced. When this is reached, the unsteady, fluctuating flicker is displaced by a blend of black and white which appears as an even, smooth, grey. In contrast to the strain of the flicker, this fusion of the two colors is pleasing to look upon and resting to the eyes.

Stated in terms of the retinal inertia, this fusion results when the stimuli impinge upon the retina with such rapidity that the initial lag of the one blends or fuses with the residual persistence of the other.

Without the "flicker" blade on the shutter of motion-picture projector the intervals of light and darkness are so far separated that only the flicker phenomenon is produced. If the speed of the projector were increased so as to overcome this flicker it would result in each picture being shown for so short an interval that there would scarcely be time for each one to overcome the inital lag of the retina. With the addition of this "flicker" blade, however, the number of interruptions is doubled without increasing the speed and thus fusion is made to replace flicker.

It will be recalled that in the experiment just described the resulting fusion was neither white nor black but an intermediate grey. This lessening of intensity by the interruptions follows a definite course which is predictable by Talbot's law.

In modern motion picture production the overcoming of the flicker has also resulted in lessening to a considerable extent the apparent intensity of illumination in the projected pictures. But through the aid of the intense electric arc and the mirror screens the lighting used is so high powered that the resulting fusion is still bright and clear.

II

The illusion of motion in the photo-play can not be explained in the positive way in which we accounted for the appearance of continuity and the clearness and freedom from flicker. There is still some controversy among psychologists regarding the perception of visual motion in ordinary life. The problem is gradually becoming settled, but in fairness we must review the chief accounts which are current. Then we can not only decide which one best explains the visual perception of motion in the motion picture but we can also see what the motion picture can contribute in a constructive way to these theories.

There are several of these classical theories which must be mentioned in this connection. Eye movements have been used for a long time to account for the perception of motion by the eye. This theory holds that the eye follows moving objects and that we get the impression of motion from the strain and tension on the six muscles that move each eye. There are two major objections, however, which seem to render this theory untenable in its usual form.

In the first place, the more recent experimental work indicates that after all our judgment of the movements of the eye muscles is very inaccurate. If our knowledge of these movements were used as a basis for an interpretation of motion in the external world such motions would be grossly misinterpreted to say the least. A second fatal bit of evidence against the theory is that in addition to our inaccurate knowledge of the eye movements, the movements themselves do not conform to the external motions or objects with any degree of accuracy. This is plainly shown in the illustration of the movements of an eye in following the outline of a circle.

We must look, then, to the nervous and retinal elements of the eye rather than to its musculature for an explanation of the perception of visible motion.

The phenomena of retinal streaming has been used by some psychologists as a partial explanation of the perception of motion by the eye. This starts from the fact that there is an after-image of movement. If you look at a moving stream from a bridge and then turn your attention to the bank of the stream the latter seems to be moving in a direction opposite to that of the stream. This is a negative after-image of movement and its explanation has been attempted by assuming an actual movement on the part of some of the retinal elements. But we have no corroborative evidence of this streaming of the retinal elements, in fact, what we know of the actual structure of the retina tends to contradict this assumption. It is quite improbable that the perception of motion is due to an actual and corresponding movement of certain elements in the retina.

Photograph, taken by Professor Stratton, of the movement of an eye in following the outline of a circle.

For some time it was also stated by some psychologists that there is a special sensation of motion. This was done by the earlier introspective psychologists who used the inner experience of motion, which could not be analyzed further, as the basis for their classification of the senses. The other criteria for a sensation, however, they ignored. They did not stop to analyze the physical stimulus to determine whether or not it was unique or a part of other stimuli. They also neglected to search for or indicate the sense organ which is necessary if there is to be a special sense of movement. Obviously as a special sensation movement fails to meet these requirements.

If we analyze movement as a stimulus we find that it resolves itself into a series of changes in the stimulation of the retina. Are these changes continuous and steady in ordinary vision or are they seen only in certain progressive stages as in the motion-picture film? In other words, is the stimulation which produces the movement in the motion picture the same or different from that of daily life? We shall have an answer to this in a moment.

The eye is constantly in motion; it is never at rest for more than a few hundredths of a second at a time. Ordinarily we are completely unaware of these constant movements of the eye, but they are present and have been accurately observed and studied in detail in the laboratory. In reading a line of print, for example, the eye does not progress evenly and smoothly, but makes five or six irregular jumps.

Partial blindness characterizes the eye during these periods of their motion. For a time it was thought the eye was completely blind while in motion. It has been proved now that during these periods it is not completely anæsthetic although it senses only a vague, indefinite, hazy blurr at most.

Thus in ordinary vision, although the moving object may be progressing at a uniform rate, the actual retinal stimulation is jerky due to the incessant movement of the eye. Ordinary vision is essentially momentary in character and cross-sections motion in various phases, just as the motion-picture camera photographs progressive phases of the action. In either instance there is no difference between the perception of motion. The motion itself is not seen. What is seen is the change in positions and a blurr which may be looked upon as the sensory index of the change.

The perception of motion, both actual and pictured, is largely a matter of apperception. The movement between the positions actually seen is supplied by the mind from its storehouse of past experiences. The successive pictures shown or scenes perceived

2 1 3 4 5
out of sight they anchored their ships behind a

THIS IS AN ACTUAL RECORD OF THE EYE PAUSES IN READING A LINE OF PRINT BY A FAIRLY EFFICIENT READER. ALL OUR VISION IS CHARACTERIZED BY THESE MOMENTARY FIXATIONS OF THE EYE

serve as a framework along which the mind can fill in the idea of motion. The apparent motion results not alone from the successive stimulation in advancing position, but includes the synthesizing activity of the higher mental processes. The motion picture is no exception to real life in this respect.

And neither is the perception of motion by the eye an exception in the filling-in activities of imagery and expectation. The same filling-in activity of the mind is at work in reading. Only a very few of the letters in any line are really clearly seen, the remainder are supplied by the mind's integration. It is for this reason that the inexperienced proof-reader passes over error after error; in ordinary perception the eye touches only the high spots, the mind does the rest to round out and complete the awareness of objects and activities.

III

Emphasized again, we find these inner activities at work in the perception of depth, or nearness-farness, in the three dimensional objective world and in the flat two dimensional world of the photo-play.

Our ordinary environment extends not only to the right and left, and up and down, but some objects are also seen close to us while others are far away. This nearness-farness is depth or the third dimension. Just how we perceive depth was one of the first problems to receive the attention of the early experimental psychologists.

The main criteria which we have to assist us in the perception of depth take issue from the fact that our vision is normally binocular. Two eyes make us much more accurate in the perception of the third dimension than would otherwise be the case.

Two brief examples will suffice to indicate the rôle of the second eye. Close one eye and glance around your room. You will notice a loss of the plastic appearance of the furniture. It all looks flat and as if it were in one plane. Try walking around with the same eye closed and find out how inaccurate is your perception of distance.

With one eye still closed attempt to touch your index fingers together about a foot in front of your eyes. See! You missed by from one to three inches, may be more. Try doing the same task now with both eyes open. You will bring your fingers together on the first trial.

There are two prominent ways in which the fact that our vision is normally binocular contributes to our perception of depth. In the first place there is the matter of convergence. When looking at near objects the muscles on the nasal side of the eyeballs contract so that both eyes may be directed toward the objects. With far objects it is the muscles on the temporal side that contract. There is thus a measure of convergence in terms of muscle strain.

More important than convergence is the disparity of the retinal images. Since the eyes are separated by a few inches each one sees a given object at a slightly different angle from the other. You can easily demonstrate this by holding a closed book at arms length in front of you with the back of the book toward you. Look at it first with one eye and then the other. The difference between the two views is marked indeed and in each case the appearance lacks plasticity or depth.

When the same book is seen in the same position by the same eyes simultaneously a different appearance is noted. The two widely disparate views have fused into one which has depth and relief.

This principle of disparity is used in the ordinary stereoscope. The two pictures on the card are taken from a slightly different angle. When viewed through the stereoscope the prismatic lenses bend the rays of light so that the pictures are seen by each eye as if they were of a single object in front of them. Since the pictures have the requisite disparity the resulting appearance is one of a single object in clear relief.

It is not known how it is that these two images which are physiologically different still combine to form a perception that possesses the quality of depth. The important thing, however, is that such is the fact. And in this we again have an example of the integrating activities of the mind.

Motion pictures are flat and lacking in any real quality of depth or any qualities that will give convergence or disparity. Then how is it that nevertheless the observer receives the impression of depth from this representation which is in a single plane? In answering this we shall be initiated still deeper into the almost mysterious processes of integration that are accomplished by the nervous system.

At the outset it is evident that we are certain of our perception of the third dimension in the photoplay. The actors not only walk from right to left but enter and exit through a door at the rear just as they would on a real, three dimensional stage. Then we see the screen troopers gallop away and out of sight into the distant hills. There is no denying the fact that we receive the impression of depth; and there is no denying the fact that as an objective quality depth is lacking in the motion picture.

While the most accurate and predominant factors in the perception of depth are the physiological ones of disparity and convergence, there are still a large number of so-called secondary factors which assist materially in building up these perceptions. It is more fitting that these factors be termed psychological rather than secondary and of late this has come to be the common practice.

What we have long known as perspective is perhaps the most important psychological factor. Distant objects are smaller than near objects; the lines in the visual field converge toward a vanishing point. Perspective is significant in normal, binocular perception of the three dimensional world; it is ultra-significant in the flat world of the motion picture, and even painting for that matter. It is largely this factor which gives apparent depth to flat representations. Artists have long made conscious use of this in their paintings; the Japanese and Chinese still create pictures in which the perspective is omitted. This results in a characteristic flatness and unreality in appearance.

Again in this perspective we find the integrating activities of the nervous system prominent. Although distant objects cast a smaller image on the retina than near objects the former are still interpreted, not as small people and things, but as of usual size but more remote.

Distant objects are also partially hidden by those nearer the observer. Very distant objects are also seen through a haze and are higher in the field of vision. Shadows are another factor in producing the impression of relief. Without these shadows a photograph would be flat and lack plasticity. Amateur photographers usually overlook this and their photographs are characteristically "flat" in appearance.

The motion pictures utilize all these psychological factors to give the spectators the impression of depth. In addition they take advantage of certain common illusions by having the action take place in the background rather than in the foreground; through this procedure the impression of depth is increased. Sometimes the action in the background is provided by the sea or by a breeze waving the trees. It does not need to be human action to produce the illusion.

The scenic arrangements of the photo-play are selected not alone for their artistic features but, as well, for their depth producing qualities when projected on to the screen. Although this objective screen presentation is flat and without depth, it is possible to take advantage of these psychological factors and thus produce screen dramas as full of depth and plasticity as they are of action and human interest.

Paneled walls in the screen settings are popular with the directors since these enhance the perspective of lines; round tables are discarded in favor of long rectangular ones for the same reason. The rooms used in filming the various scenes are enormously exaggerated as to depth, not primarily to produce an appearance of lavishness, but that the factor of depth may be made to stand out clearer in the projected, flat picture.

What can the scientist predict as to the future development of the technique of the photo-play? In the first place, there are hindrances to any great future development in the elimination of flicker due to the rather large individual differences in the retinal lags. It is necessary for the projection to meet the requirements of the great majority of the spectators, and there will always be some who, through physiological idiosyncrasies, do not receive the continuity of impression and clearness at its maximum. It would not be impossible for those who can afford the luxury to have their eyes tested for the factors involved in motion picture projection and have a projector built to meet their individual requirements just the same as glasses are ground to order.

Daylight projection is not impossible but will remain a dream for many years. Certain features of the flicker phenomena are a serious handicap in achieving this end. The fusion phenomena takes place with the slowest speed and with the weakest illumination when the general illumination is at its weakest. As the general illumination is increased it becomes necessary for the speed of interruption, or the illumination of the screen, or both to be increased greatly in order to overcome flicker and retain fusion. Mechanical difficulties at present are not such as to make projection of motion with a bright illumination of the theatre out of the question.

Another handicap in the production of fusion is in the fact that apparent motion appears on the screen. This complicates the fusion and in cases of jerky or sudden motion tends to produce flicker of itself. The basis for this is demonstrated in the laboratory where simply moving the hand between the eyes and the revolving sectors which are fusing immediately brings about an occurrence of flicker. One observes this from time to time in the commercial motion picture, especially in the news reviews where football action is portrayed. The government war films of marching soldiers afford a good example of this where fusion takes place from the trunks of the soldiers up, but where flicker is seen in the same pictures where the movements of the legs complicate the projection.

Colored projection will always be hampered not only by the expense and great mechanical difficulties involved, but also by the fact that the lag varies with the colors and it is impossible to get the smoothness that is obtained with black and white. Negative after-images of the colors which are projected with a light stronger than is usual in daily life also contribute to the difficulty of successful colored projection.

The effect of depth will always suffer so long as it is necessary for the photo-play spectators to view the pictures at distances and from angles at which they were not photographed. The maximum effect of depth is obtained when one is at the same position in relation to the scene at which it was photographed. This is one reason why extreme side seats are undesirable. And at the same time no position in the auditorium is perfect in this respect for the various scenes are photographed from different angles and distances.

The photoplay is rapidly becoming an art unto itself and is receiving the merited attention of students of art and aesthetics. Fundamentally, however, it is a triumph of applied science and is only one of the many examples of the rapid progress which has been made in this field in the more recent decades.

THE SUB-CONSCIOUS—WHAT IS IT?

By Professor A. T. POFFENBERGER
COLUMBIA UNIVERSITY

WHEN one examines the literature concerning the subconscious he meets a mass of contradictions. It is a concept which has become popular only in recent years; yet it is perhaps three hundred years old, having been first proposed by Leibnitz about the year 1600. By those who accept it, it is considered one of the most important discoveries of the age; by those who do not accept it, it is considered nonsense. In it some find the means of curing most of the human's ills, others find the belief in it a symptom of an ailment itself requiring radical treatment. The very name subconscious seems to be self contradictory: it is a consciousness of which we are not conscious. The believer speaks of his subconscious as though it were as familiar a possession as his teeth or his hair, and yet by its very nature the subconscious can be directly known to no one—it can only be inferred. The subconscious has become so popular that one meets the term on every hand, in conversation, in the newspapers, even in the doctor's consulting room. It is quite as familiar a term as "camouflage," or "normalcy," yet it is one of the most abstruse of meta-physical or, if you prefer, of scientific conceptions.

Now the recent popularity of the concept of the subconscious rests largely upon the fact that it forms the basis for a number of theories and doctrines which are very interesting to people, such as psychoanalysis, spiritualism, mental telepathy, those wierd multiple personalities so well represented by Robert Louis Stevenson in Dr. Jekyll and Mr. Hyde, and the hysterias which are of an equally mysterious sort. There has seemed to be in the mental phenomena covered by the above mentioned terms and in others less striking in character, a real need for some concept which shall bring them all within the law of cause and effect. Without at this time attempting to give a definition of the subconscious or even of consciousness, some of these mental experiences will be reviewed, beginning with the simplest and most easily verified and passing to the more complex and less well-established ones. After this survey of material needing explanation, the subconscious will be described as it has been conceived by various authorities. I will then present an alternative view, according to which the concept of the subconscious would be made to appear superfluous.

(1). I see a play at the theater and for several days following

I think nothing about it, but on Sunday, when my mind is more at rest, I live the play experience over again. Where has the experience been in the meantime? This you will recognize as a simple illustration of memory, in which an impression is received, lost from consciousness and later recalled.

(2). I am reading a book in which I am very much interested. I follow the intricate thread of the story, and get the fine shades of meaning, and neglect entirely such mechanical matters as the letters making up the words, and even some of the words themselves, the margins of the pages, the style of the type. And yet my understanding of what is written depends upon at least some of these matters, for any changes in them will alter the meaning. How can they thus register their effect, contribute their share to the meaning of the whole, and I not see them?

(3). Wordsworth thus expressed a belief common to the normal man in the following lines:

> The eye it cannot choose but see;
> We cannot bid the ear be still;
> Our bodies feel where'er they be,
> Against or with our will.

And yet it is a well-established fact that one does pick and choose among all the objects which come within the range of his senses, those which he shall look at, listen to and feel. Without this picking and choosing life would indeed be a "blooming, buzzing confusion." Still those aspects of our surroundings which we did not choose to observe, which were neglected in favor of others, are sometimes recalled. I am very much absorbed, let us say, in reading Well's "History of the World" and am oblivious to all my surroundings. I see none of the objects around me, hear no sounds, feel no pressure of the clothes upon my body. But I suddenly recall that the clock has struck eleven. How is it possible for me to recall this experience, which I did not have?

Or perhaps I am granted an introduction to Charlie Chaplin, the king of moving-picture comedy, and, after this good fortune, I am besieged with questions about him. How did he look? Does he really wear a mustache? And his feet—are they really like that? What kind of a hat does he wear? I am much confused to discover that I can answer none of these questions. I fear my veracity may be questioned—perhaps I did not really meet him. Now it is said by Morton Prince, who has for many years been interested in such matters as this, that if I were to allow myself to be hypnotized, I could in that state answer all these questions correctly. How is it possible to give forth information while under hypnosis that I was never conscious of, that so far as I know, I have never experienced?

(4). I am listening to the roar of the distant surf, which is made up, as every one will readily agree, of millions of tiny waves breaking upon the shore. The sound produced by any single one of these tiny waves is quite too faint to be heard. The sum of them we do hear, however. How can a million unheard stimuli produce one that is heard? A million zeros added together ought still to leave zero. The effect of each tiny wave has been described by one authority as an "imperceptible psychic occurrence." The meaning implied here is that the experience may be psychic or mental and yet not be perceptible.

(5). Let us take another case of the same sort. Suppose that you are asked to decide which is the heavier of two weights, one of them weighing 100 grams and the other weighing 102 grams. These two weights, if lifted one after the other by the right hand, will be indistinguishable to you, that is, they will seem identical in weight. Suppose then that you are given the second weight of 102 grams and a third weighing 104 grams. These two weights will also seem identical to you. But if you now compare the 100 gram weight with the 104 gram weight, you *can* tell which is the heavier. You have then this proposition: No. 1 is identical with No. 2; No. 2 is identical with No. 3. Therefore, No. 1 must be identical with No. 3. (Two things which are equal to the same thing are equal to each other.) But it is not, and you have proved it, because you can correctly distinguish between them. How shall we explain this contradiction between logic and experience?

(6). The student of mathematics meets a problem that he can not solve. He works upon it for days and even nights, but to no avail. Finally, when about to give up, he wakes some morning with the correct solution in his mind. Or perhaps the correct solution occurred to him in a dream. The following is an instance which was reported to me a few days ago: A certain member of a college faculty has been computing numerous partial correlations, a very tedious statistical operation, and has been very much interested in seeking a short-cut method of solution. A few nights ago he dreamed a method which reduces the time of computing partial correlations to one twentieth of the time required to do the same thing by the original method. Now how was this problem solved if the individual did not consciously take part in the solution? And he will testify that he did not in his waking moments.

(7). The sudden flashes of genius, the inspirations which are often responsible for great inventions, are much like the case just described. What is their source? To their owner they seem to be spontaneous, and he does not recognize them as the product of his thought.

(8). From the type of case just described, it is only a relatively short step to those that go by the name of automatic writing. One sits as if in a trance, or perhaps conversing with an associate, while his hand writes answers to questions whispered into his ear, all unknown to him. Or perhaps as in the case of Patience Worth, a popular figure a year or two ago, the hand composes poems quite beyond the comprehension and capacity of the woman herself, and writes in languages unknown to her. To quote from a description of her case in *The Psychological Review,* "The meaning of what is written is, naturally enough, frequently not understood by her. Neither its form nor its substance is determined by her consciousness. They are apparently the creation of a self whose existence she is, for the most part, completely unaware of. And this self is no mere by-product of a more fully developed mind. Patience Worth is a personality of tremendous creative energy." Where shall we look for the explanation of these mysterious and startling occurrences?

(9). Rivers, the English psychologist, has shown that questions of a somewhat similar sort arise in connection with the study of the animal kingdom. The tadpole with all his tadpole habits—to omit the possibility of tadpole thoughts—becomes a frog with a need for an entirely different equipment of behavior. What has become of the tadpole habits in the fully developed frog? What prevents them from encroaching upon the frog habits, and playing havoc with the frog's well ordered life? Or take the frog itself, an amphibian. While living under water, where are his land habits? While on land, where are his water habits? Why do these habits not interfere with each other? How is this shifting from one set of habits to another possible without interference?

Or, to return to the human species, take the statements of Paul in his First Epistle to the *Corinthians,* Chapter XIII, "When I was a child I spake as a child, I understood as a child, I thought as a child; but when I became a man, I put away childish things."

Here is a set of problems quite like those cited for the frog. Where are the childish things put, so that there shall be no cropping up of childish speech at inopportune moments to embarrass the man?

(10). Consider now a rather mysterious case, but one which is reported in the literature as authentic. A certain man loses his affection for his wife, and matters go from bad to worse until he hates the sight of her. About this time he goes blind and remains so for years. He is permanently cured of his blindness when informed that it is a functional disturbance, the result of his wish that he might never have to see his wife again. He was barred by his religious scruples from the more customary remedy for such difficulties. How could this man have such an unfortunate wish and not know it, and how could that wish have such a terrible effect upon his bodily mechanism?

(11). There must be included in our list of cases, the so-called phenomena of mental telepathy which have been investigated by the societies for psychical research. In such cases there is reported to be a communication between minds through channels other than those of the senses. Ideas are said to come directly into the mind of the recipient. Cases have been reported and investigated in which such communication is said to have taken place over a space as great as 5,000 miles. By what means are these mental experiences to be explained? Whether they represented real cases of telepathy or not makes little difference, explanation is still necessary.

To pass from these cases to those of supposed communication between the living and the dead is not such a great step if one believes the former to occur independently of the sensory and motor mechanisms of the body. What is the solution for all these phenomena of mental telepathy and spiritualism?

Each of these instances which I have cited, whatever attitude one may take toward them, demonstrates a real need for explanation. How are these things possible? How shall they be interpreted? In order to help us in answering these questions, let us look to the older and more firmly established sciences to discover how they handle somewhat similar problems. Take astronomy for instance. In mapping the behavior of the planets and determining their course through the heavens, certain aspects of their behavior could not be accounted for in terms of the influences exerted by the known neighboring planets. Explanation required that there be some other influence at work. What then more natural than to conceive of this influence as being like those already known? There must be another planet, exerting gravitational force sufficient to produce the effects noted, and to exert this force the planet must be of a certain size, distance and position with relation to the other heavenly bodies. Such a planet was looked for and Neptune, at first a concept, became a fact.

In physics and chemistry there was need for explanation of certain physical phenomena. To satisfy this need the molecule was conceived, in character much like the elements already known. Later the behavior of the molecule needed explanation and this in turn led to the concept of the atom. The atom, then, is endowed with the characteristics necessary to produce those effects for which explanation is sought.

In physiology much the same procedure has been followed. In communities where certain types of food are used rather exclusively, certain diseases are prevalent. Thus the users of polished rice and corn in great quantities are subject to the disease pellagra. Communities which eat their rice unpolished and live upon mixed diets do not have this disease. The disease is then due to lack of something in the body which is necessary for its normal functioning. This particular something, which has never been, so far as I know, directly experienced, is given the name vitamin. The vitamin is then endowed with the characteristics necessary to explain facts which are observed. Many illustrations of concepts thus formed could be taken from the various sciences. These concepts remain constructions of the mind until man can experience them with his senses, whereupon they become facts. The planet Neptune is a fact, the atom and the vitamin remain concepts.

To satisfy the need for explanation of the mental experiences which I have cited, and which do not seem adequately accounted for by reference to consciousness alone, what more natural, then, than to hypothecate another consciousness having the same general characteristics as the one we know but separate from it—a subconsciousness? The particular characteristics of this subconsciousness will be those that it needs to have in order to account for the phenomena that it was conceived to explain, just as the planet Neptune needed to have certain characteristics to produce the known effects. When experiences pass out of consciousness, they enter the sub-consciousness. The sound of each tiny wave that contributes to the roar of the surf, does not affect our consciousness, therefore its affects our sub-consciousness, and only the sum total reaches our consciousness. We do not see the margin of the page, the typographical errors, the spelling of the words in the book we are reading, but they are registered on the subconscious. If mathematical problems are not solved in our consciousness, they must be solved in our subconsciousness. We are not conscious of the wish to lose our sight—it is a subconscious wish. We do not keep track of the passage of time while asleep, but the subconscious does. Our consciousness gets its data by way of the senses, the subconscious communicates with other minds more directly. The answer to one or many of these questions, the need for explanation has been satisfied by the *concept* of the subconscious.

Since the subconscious is created to satisfy needs for explanation it is differently conceived by different authorities according to the needs that they feel. Each of the illustrative cases that I have cited gives a clue to a certain concept of the subconscious, which may be found in the literature.

There are those who look upon the subconscious as simply a repository for memories. What is no longer in consciousness has passed into the subconscious. Along with this there usually goes a very far reaching assumption, namely, that since everything passes into the subconscious, no experience is ever actually lost, but remains in the subconscious, and is capable of being recalled if the proper means be used.

This concept is expanded still further. Not only are all the accumulated experiences of the individual's life time stored here, but even those of his ancestry immediate and remote. It is said by those who hold to this view that the proper devices will also reveal these stored memories. To cite just one case taken from a book advertised as having received a prize given by the French Academy of Sciences: A young woman traced her history back through eleven previous lives, in which she was a great variety of individuals. In the ninth life, for example, she was a male guard of the Emperor Probus who ruled in the year 269 A. D. This case illustrates well the extremes to which assumptions may be carried when based on a simple but unverifiable concept.

Then again there are those who think of the subconscious as a device for recording experiences to which we are not attentive—so-called marginal experiences—as illustrated by the failure to see the margin of pages, etc. According to this view, Wordsworth is right and all objects that come within the range of our senses make their impression either in the conscious or the subconscious. It is difficult to imagine to what an extent this addition would expand the content of consciousness. Add to this also the view that the subconscious can perceive stimuli that are too faint to be perceived by consciousness, as illustrated by the perception of the sounds from the minute waves making up the surf, and you have material for making the subconscious thousands of times as populous as the conscious. There is very evident here the danger which arises from an unchecked expansion of a concept.

I will describe a third form of the subconscious in somewhat more detail, because it is the basis for the whole system of psycho-analysis with which most persons to-day have at least a reading or conversational acquaintance. The subconscious is made the repository for memories, imaginings, dreams, wishes and fears which are out of harmony with the ethical standards and ideals of the individual. There are certain contents of consciousness which must be ostracized. Since nothing can be forgotten, these unwelcome guests are driven out of consciousness, and suppressed into the subconsciousness. There is according to this view an open door between the two chambers of consciousness. Undesirable content may be removed from consciousness, but it tends to return the way that it came. There is a constant struggle to prevent the return into consciousness of what is undesirable. A censor is hypothecated who or which shall be keeper of the door and which shall admit through the door into consciousness only those contents which are desirable. But these evil ideas are not to be so easily outwitted. They try to disguise themselves by appearing in a modified or symbolic form and thus slip past the censor. Or they wait until night when the censor is fast asleep and then slip into consciousness in the form of dreams. Or, if the censor is not then asleep he is less alert and cruder symbolism is effective in gaining a passage into consciousness. Sometimes even during full wakefulness one may find himself coveting his neighbor's wife because a malicious idea has slipped past the censor.

Now the evil contents of the subconscious have the same relation to the bodily mechanisms as do those of consciousness. Just as worry may destroy the appetite, fear may paralyze the limbs and strong expectation sharpen or dull the sensitivities, so the subconscious fears, wishes, etc., may be responsible for dire physical ills. Witness the case of blindness as the fulfillment of a wish not to see one's wife, which was cited earlier. The psychoanalyst can cure these ills. He must find the cause which is hidden in the subconscious, and appears in consciousness only in the form of dreams or cunningly disguised in the form of symbols. The psychoanalyst solves the symbols, interprets the dreams, discovers the wish, the fear and the evil thought, shows it to the patient, and a basis for the cure is then established. The treatment consists in a re-education of the patient, in developing in him a saner attitude toward his life's problems, a stronger courage to meet his fears, a sense of personal responsibility for his wishes.

Finally, the subconscious is considered by some persons to be quite like consciousness in its functions, and to be very closely related to consciousness, with the same powers of associating, creating and elaborating the material assimilated through the senses. Such a subconscious would be like the co-conscious described by Morton Prince, and represented by his cases of double personality. This basic notion of the subconscious is then enlarged to embrace functioning far transcending that of consciousness, so that the products of the subconscious activity are of supernormal character. Thus James in one of his letters written in 1901 says, "I attach the mystical or religious consciousness to the possession of an extended subliminal self, with a thin partition through which messages make irruption. We are thus made convincingly aware of the presence of a sphere of life larger and more powerful than our usual consciousness, with which the latter is nevertheless continuous." A still further extension and elaboration of this form of the subconscious frees it from all necessary connection with the physical body and allows it to float free to communicate directly with other consciousness of like sort, whether the physical body previously housing it is dead or alive. Such a view is interestingly described by F. W. H. Myers in his "Human Personality."

I have elaborated at length upon the need for explanation of a mass of experiences and the satisfaction of this need through the concept of the subconscious. I have pictured this concept as it appears to its champions. Let us now briefly examine the subconscious in the light of the criteria which science demands that every concept shall satisfy. These criteria are:

(1). The experiences which the concept is to explain must be facts of observation.

(2). The concept shall not conflict with known facts.

(3). The concept shall resume the largest range of facts.

(4). The concept shall be the simplest possible to explain the facts.

The first of these conditions is peculiarly difficult to satisfy. When applied to our problem we find the validity of many of the experiences which I have listed certainly open to question. Some of them depend upon introspective report. They may be checked, however, if studied under experimentally controlled conditions. They do not lend themselves readily to such a check, but where it is possible, the check has often not been employed. Is it, for example, a fact that nothing is ever entirely forgotten? How shall we prove it one way or the other, and upon which side rests the burden of proof?

The application of the second criterion, that there shall be no conflict with known facts, offers some difficulty also. The objection has been raised that the one essential fact about consciousness, that needs no proof, that is self-evident, is its quality of being known, its quality of being an individual's own experience. The subconscious cannot be directly known, cannot be part of one's own experience. It therefore lacks that which makes consciousness what it is. It is self contradictory. It is a non-conscious consciousness, a contradiction of terms. To push this criticism further would lead into the realm of metaphysics. There is too little agreement about the ultimate nature of consciousness itself to derive much help from this source in the solution of our problem.

The third and fourth criteria, as to simplicity and range of facts covered can be more easily investigated. Is there an alternative concept which will be simpler and cover a wider range of facts, or are there already generally accepted concepts sufficient to account for the experiences accounted for by the subconscious? One alternative is the view that what is not conscious is physiological, that nothing need be interposed between consciousness and the functioning of the nervous mechanisms with which consciousness is correlated. Let us apply this concept to a few of our illustrations. The neural patterns or neurograms, as the traces of activity which are left in the nervous system have been called, are according to this view, sufficient to account for the facts of memory. Memories are forms of potential consciousness in the sense that when the neural patterns become active, consciousness results. The view that nothing is ever forgotten or entirely lost would be untenable since these neural patterns of memory fade out with age just as the habit patterns do or as any impressions made upon organic tissue do.

Those striking conflicts between logic and psychology where stimuli too weak to arouse consciousness may by summation become conscious are easily explained in terms of the inertia of the central nervous system and the well established facts of summation of stimuli. In the case of a simple nerve reflex with its center in the spinal cord, a stimulus may be too weak to produce any muscular reaction at all, but if the same weak stimulation be frequently repeated, a full muscular response will follow. So the sound waves produced by a single tiny ocean wave may not be sufficient to overcome the inertia of that part of the nervous system concerned with hearing, but a million of them acting together may quite conceivably break through this resistance and cause the roar of the surf.

The interrelations among the neural patterns, the changing tensions within the patterns themselves, the facilitations and inhibitions that one pattern exerts upon another; these together with the conscious processes of association correlated with them are sufficient to account for much that has been attributed to the subconscious, such as the sudden solution of puzzling problems, the bursts of genius, awaking at a pre-established time, and the shiftings of habit systems and memory systems illustrated by the simple case of the tadpole and the frog. Take for instance, the supposed solution of a puzzling problem during sleep. In the examination of the problem from all sorts of angles, many sets of associative connections, wrong patterns as well as useful ones have been established. There is interference among these associative patterns—the wrong ways of dealing with the various stages as well as the right ways are fresh in the mind, and the nervous patterns of both sorts are ready to act. Let a night's sleep intervene, and certain associative connections weaken, leaving others relatively stronger. An entirely different set of relations is established among the neural patterns. When the individual awakes and his neurograms become active, the right solution corresponding to these neural readjustments, "pops into his mind."

A much simpler case may illustrate the point better. One is writing on the typewriter and makes a simple mistake, thereby forming a wrong associative connection between sight of a letter and the appropriate muscular response. He tries again and repeats the mistake—the nerve impulse takes the course of least resistance which is the recently used association path. How shall the error be corrected? A night's sleep is not in this simple case necessary, but a few moments of rest will serve to give the older, more frequently used, right connections the ascendency over the newer wrong one, and the word is correctly written. The same type of interpretation covers that multitude of cases of slips of the tongue and pen, and failures of habit mechanisms which to the psychoanalyst come under the head of the psychopathology of every-day life. Such cases of interference among association paths are known in laboratory terminology as reproductive interference. It may seem that the chances of hitting the right solution of a difficult problem in this way are very slight. Genuine cases of this sort are about as rare as you would expect them to be under these circumstances. It is their rarity that makes them so conspicuous when they do occur.

If we add to the concepts just described, the influence of motives, determining tendencies and deeply rooted springs of action, which may be thought of either in their conscious or physiological aspects, you can account for the phenomena which in the subconscious are explained by the censor and symbolism.

One is born with certain tendencies to action already established, a large share of which are commonly included in the term instinct. Some of these tendencies are, in the light of our social customs, good and some are bad. All are modified, developed and cultivated in the course of our education into forms of behavior which conform more or less closely to the demands of society. Some of these, of course, need more modification than others. These instinctive forms of behavior, as well as their modifications, are conceived in terms of neural patterns. Now when the natural sex impulses, for example, are modified by training, we need not think of both the modified and the original neural patterns as existing side by side or one beneath the other. The one has rather been modified into the other and ceases to exist. On the side of consciousness, the neural patterns are represented by determining tendencies prescribing in a positive fashion, what the individual shall do, when these neural patterns become active, rather than in a negative fashion determining what he shall not do, by the repression or inhibition of the original mechanisms. Thus in the properly trained individual the censor, with its suppressing activities exerted against what is wrong, gives way to the functioning of neural patterns and determining tendencies in the direction of what is right. The honest man is honest not because he keeps the thief in him suppressed, but because his training has developed tendencies which guide him in the path of honesty.

The phenomena of symbolism have been ably interpreted by Professor Hollingworth in his book, "The Psychology of Functional Neuroses," in terms of redintegration, or the tendency to reproduce the whole of a past experience when only a part, and sometimes a very unessential part, of the original stimulus is present. Here we have only the familiar mechanism of association in consciousness, and neural patterns or neurograms in the nervous system, with no intervening subconscious or other mechanisms.

Finally, recognize the flexibility of the imagination and the influence upon mental experience of expectation and suggestion, and you can account for the phenomena of telepathy, spiritualism and similar mysteries, if these survive at all the application of the first criterion of a concept, namely the proof of their existence as facts.

For such interpretations as I have illustrated, not a single new concept need be added to those which are already in good standing in the sciences of physiology and psychology. To the majority of psychologists this sort of interpretation, which assimilates the facts into a system of concepts already in existence, seems to satisfy more fully two of the demands of science, namely, simplicity and range of facts covered, than does the construction of a new concept. It further avoids the danger of adopting a concept which has been made to connote so much that is mystic, extravagant, and even charlatanical in character.

There is one objection which has been raised against the substitution of consciousness and brain activity for an intermediate subconscious, co-conscious or super-conscious. It is the demand that each science shall stay within its own realm. The physiologist must not introduce a psychological conception into his chain of cause and effect, nor must the psychologist fill up the gaps in his reasoning with cells and nerve currents. A conception must be in the same terms as the phenomena which it is designed to connect. The conceptions of psychology must all be constructed within the psychological series. The conceptions of physiology must be constructed within the physical series. The mathematician insists on regarding bodies as bounded by continuous surfaces, whereas the physicist is compelled to regard them as bounded by discontinuous atoms. Neither of these modes is more true than the other. The question is merely which one has the greater practical value in the particular sphere of thought in question. Add to this criterion of practical value, the two criteria previously discussed, namely, simplicity and range of facts covered, and the shifting from science to science and from physical to mental would seem to be justified.

The best established and scientifically supported concepts are not objects, but mental experiences erected upon the sum total of facts known. New facts are accumulated and concepts change. A planet was conceived to explain a set of facts and led to the discovery of Neptune. The molecule was conceived as the physical unit to explain a set of facts, but gave way to the atom; this in its turn has been replaced by the electron. What may be the fate of such concepts as the vitamin and the subconscious in the future only the future will reveal. Science performs its legitimate function today when it resumes known facts under concepts which at once are the simplest, the most inclusive and the most in accord with other known facts.

DISEASE AND INJURY AMONG FOSSIL MEN AND THE BEGINNINGS OF SURGERY

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THE remains of ancient stone age man occasionally show evidences of disease and injury. These evidences among the neolithic and paleolithic races of western Europe have been studied by Raymond and LeBaron, and mention of sundry other lesions is to be found in the writings of Keith, Manouvrier, Ruffer, Baudouin and other students of anthropology. These studies are based on remains of human races found in western Europe, since no representatives of the stone age men, as they are called, have been found in the western Hemisphere. The remains of these early races are scanty, and many of the skeletal elements are normal. Some few, however, give us an insight, because of their pathological conditions, into the possible cause of their pathology and the necessity of the introduction of surgery to care for these injuries. Trephining, itself a traumatism, was introduced quite early among ancient man, as were finger amputation, cauterization and possibly scarification. These phases of primitive surgery have already been discussed in previous contributions and it remains to point out the original need for surgery, the factors underlying its development, as well as the data on which these conclusions are based.

Man's oldest representative, or man's precursor, is identified in the oldest well-authenticated skeletal manlike remains found in 1891 by Dr. E. Dubois, at that time a surgeon in the Dutch Army, stationed in Java. In the leisure of his station he had undertaken paleontological excavations along the banks of the Bengavan River, near Trinil, in the central part of the island of Java. He found, quite widely scattered, a calvarium, some teeth, a portion of a jaw and a left femur entire. These important remains were described by Dubois in a finely illustrated quarto issued at Batavia in 1894. His work was immediately received as one of the greatest contributions to the study of the antiquity of man. Although a very extensive literature has developed concerning the antiquity of man, this discovery still ranks as the most marvelous revelation of man's ancestry so far known. The interest to us in this curious ape-like form is that the femur shows

FIGURE 1

Anterior view of the left femur of the oldest known human representative, *Pithecanthropus erectus*, portions of whose skeleton, 500,000 years old, were found in 1891 in a river deposit in Java. The femur shows an extensive medial exostosis due to some chronic infection or other irritation along the line of the tendinous attachment of the iliopsoas and pectineus muscles. This is the oldest example of human pathology.
Posterior view. After Dubois.

marked exostoses (Figure 1) indicating the presence of a pathological condition of great severity. This is the oldest evidence of pathology in a humanoid form.

On account of the very great interest attached to such a discovery the pathology has been widely discussed. The great pathologist Virchow, who was also an eminent student of anthropology, called attention to the similarity of the medial exostoses on the femur of the ancient form to those seen in modern femora. He exhibited a number of these which he had selected from the collections of the Berlin Pathological Institute (Figure 2).

The next oldest known form representing man is that designated Eoanthropus, meaning the dawn man. Sir Auckland Geddes, after an examination of these Piltdown remains, decided that this ancient Englishman, who lived and died thousands of years ago, had suffered a pathological alteration of the bones of the skull. He based his conclusions on the remarkable thickness, coupled with

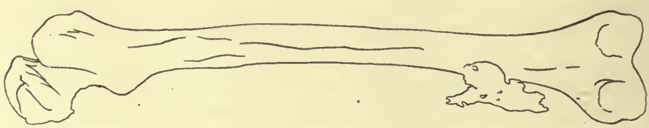

FIGURE 2

Modern human femur showing medial exostoses similar to those exhibited by the *Pithecanthropus*. These drawings were used by Virchow to demonstrate to the anthropological society of Berlin that the pathology of the most ancient man-like form was similar to modern pathology. Some scholars had argued that the femur was not human, being misled by the pathological deformation.

the characteristic outline of the temporal ridge, which can only find their diagnosis in Acromegaly. He fails, however, to differentiate this condition from Paget's disease which produces a similar pathology. It is possibly due to this factor that the remains were preserved. Thus it is seen that the oldest representatives of man had suffered from disease. Where there is a disease or injury even among wild animals, there is always some instinctive, though primitive, means of healing. While from the actual evidences nothing whatever is known of the state of surgery during the most ancient periods of man's development, may we not safely surmise that these primitive ape-like humans pondered in a vague way, over the means of curing disease and injury and thus laid a foundation for the development of that knowledge of surgery which we see emerging from the darkness in the late Paleolithic and early Neolithic races thousands of years later? An instinctive licking of an injury is the forerunner of antiseptic appliances, or the sucking of pus wounds. Quietness and seclusion after fracturing a limb was the instinctive act preceding the use of bark, skin, or hardened clay splints.

The most famous of the skeletal remains representing men of the old stone age, when surgery had its first recorded existence, are the portions of a skeleton of an extinct species of man found in a cave in the valley of the Neander River, in the Rhine province of Prussia, hence the individual is known as the Neanderthal man. The proximal end of the left ulna had evidently been fractured (Figure 3) since there is a marked widening of the articular fossa. The left humerus also shows signs of injury in consequence of which it doubtless remained much weaker than the right bone. Virchow thought that the condition of the bones of this ancient man indicated *rickets*. If so this would be the oldest evidence of rickets in man, but Schwalbe restudied the question and decided that there was no evidence of malnutrition and his conclusions are widely accepted.

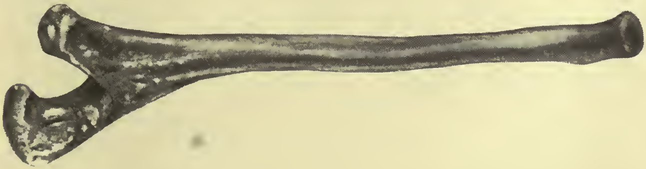

FIGURE 3
Left ulna of an ancient man, known as the *Neanderthal man*, whose skeleton, found in a cave in the valley of the Neander river of Europe, has aroused considerable interest on account of the primitive human characters which it exhibits. This skeleton, which is about 75,000 years old, shows evidences of injury in the divaricate olecranon, possibly due to a severe blow on the elbow producing a fracture. Drawn from a photograph of the original by Hrdlička.

One of the most interesting cases of ancient injury which has come down to us is a specimen of a lumbar vertebra of a late stone age man, showing an arrowpoint deeply embedded in the visceral surface. Older injuries of a similar nature teach us that ancient man was liable to such inflictions incident to war and the chase. During this period wounds made by blows from stone hatchets, arrow and spear points are fairly common. Many of these injuries as shown on the remains found in the ancient sepultures show evidences of long standing and final healing, thus pointing, indistinctly to be sure, to some preventive measures being taken. LeBaron from his study of ancient human skeletons arrived at the conclusions that early man reduced and fixed fractures with great perfection, evidenced by the great numbers of well-healed fractures. Among 18 cases he examined only 3 had healed badly.

Nearly all types of fractures are found among the remains of ancient man. The frequency of spondylitis deformans is striking. Pott's disease was occasionally observed. Alteration of skulls due to ulcerations; scoliosis; various hyperostoses; caries of bone and teeth; atrophy of the skull; exostoses and osteomata and many varieties of arthritides indicate to us the variety of afflictions to which early man was subject. It is no wonder that, with this array of pathology to contend with, early man saw the necessity of dealing with them. While many of the earliest recorded evidences of surgery were developed as a phase of religious procedures, there must have been many therapeutic measures known to them which have not been recorded but whose presence we may infer from the pathological evidences of their skeletal remains. Surgery then in its earliest beginnings was derived from three sources: (1). Instinctive acts after injury or during the progress of a disease; (2). Surgical operations on the body which though developed in connection with religious practices often had therapeutic results; (3). Voluntary mutilations, practiced apparently since the earliest dawn of humanity. This was the condition of pathology and surgery among those man-like creatures of the hills and forest from whom the modern human races have slowly evolved.

THE PROGRESS OF SCIENCE[1]

GOVERNMENT CONTROL OF RADIO TELEPHONY

WASHINGTON, during the past month, has been the scene of a conference that has laid down the rules of the ether and has furnished the basis of America's youngest, fastest-growing and most astonishing industry. It was twenty-five years ago this summer that Marconi patented the first wireless apparatus in England. But the immediate events that precipitated this conference on radio telephony called by Secretary of Commerce Herbert Hoover have been only a little over a year in development. The electron tube made possible the transmission of the human voice by wireless with as much ease as over the ordinary wire telephone. During the war electrical engineers and physicists succeeded in using effectively the radio telephone between airplanes and ground stations. This accomplishment, hastened by the stress of war, has led to post-war development of the radio telephone.

On December 15, 1920, the Bureau of Markets of the Department of Agriculture and the Bureau of Standards of the Department of Commerce in cooperation took a step largely responsible for the new move-

[1] Edited by Watson Davis, Science Service.

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MR. HERBERT HOOVER

Secretary of Commerce, who presided over the recent congress of radio-telegraphy at Washington, where Mr. Hoover has installed a radio receiving apparatus in his home as well as in his office

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Postmaster General of the United States

ment. A short market and weather report in telegraphic code was sent out by radio from the Bureau of Standards as an experiment. For four months this trial service was kept in operation and the amateur radio operators on the farms near Washington were able to give their fathers information that had an economic value. They liked this prompt news, and on April 15, 1921, the air mail stations at Washington, Omaha and St. Louis took up the work of scattering the Department of Agriculture information.

From then on the story of radio rivals that of a rush to a new gold field. Manufacturers of apparatus saw the possibilities of selling outfits if they broadcasted music and entertainment, newspapers radioed news, and even the phonograph shops, little suspecting a formidable rival, advertised records by playing them into the ether. Radio became an industry. It ceased to be only a plaything for scientifically inclined boys. It came out of the laboratory into the world.

But back of this new-born industry is the radio engineer, the physicist and the electrician. The radio boom caused a cluttering of the ether. There was a demand for government regulation. The first task of science was to aid in formulating wave length allocations and the regulations that will govern future radio communication. Radio is a public utility. Broadcasting of governmental information has first rights on the ether, according to the recommendations of the conference.

In addition, the Bureau of Standards was asked to solve these problems: (1) The reduction of the rate of building up (increment) of oscillations in radiating systems. (This rapid building up of oscillations occurs in damped wave and interrupted continuous-wave transmitters, and may be eliminated by the substitution of other types of transmitter. It may, however, be reduced in these types by proper circuit arrangements.) (2) The reduction of harmonics in continuous wave transmitters and of irregularities of oscillation ("mush" in arc transmitters and "swinging" of the frequency in all types of continuous wave transmitters not employing a master oscillator). (3) The comparison of the variable amplitude method with the variable frequency method of continuous wave telegraphy. (4) The preferable methods of telephone modulation to avoid changes in the frequency of oscillation. (5) The proper circuit arrangements of regenerative (including oscillating) receivers to avoid radiation of energy (as by the use of a radio-frequency amplifier with an untuned antenna or with a coil aerial). (6) The use of highly selective receiving apparatus, including a list of approved forms. (7) The use of receiving coil aerials instead of antennas, with special reference to high selectivity. (8) The reduction of interference with radio communication of other electrical processes, such as the operation of X-ray apparatus and electrical precipitation. (9) The study and standardization of wave meters.

In addition, the conference recommended that the Bureau of Standards make a study of the relation between the normal reliable range of a station and the antenna power on the basis of the use of reliable receiving apparatus, and of the width of wave band required for satisfactory radio telephony.

While the technical problems of radio telephony were being considered by a conference presided over by Secretary Hoover, engineer, Dr. Hubert Work, physician, was sworn in as postmaster general, the second scientifically trained member of President Harding's cabinet. It is said that Mr. Hoover is the first engineer to hold a high official position in the government of the United States since George Washington.

U. S. NAVY BLIMP, INFLATED WITH HELIUM GAS

Certainly there has never before been an engineer and a physician in the cabinet. Dr. Work is president of the American Medical Association. Mr. Hoover at the time of his appointment to the cabinet was president of the Federated American Engineering Societies.

Mr. Hoover has been giving the engineer an opportunity since the present administration began. Elimination of waste in industry, the unemployment conference, building and housing research, and radio regulation have all come about through his engineering. Soon after Dr. Work joined the cabinet, there was the unusual occurrence of a postmaster general presiding over a session of a conference on the public health in the United States.

THE HELIUM AIRSHIP

During the same period that radio has been rapidly passing through its adolescence, the lighter-than-air phase of aerial navigation has received a series of discouragments. First came the *ZR-2* disaster in England, then the *Roma* collapsed on our own territory. These were accompanied by two administrative blows to airship building, the decision of the British to abandon airship building, and the prohibition by the Allies of dirigible construction in Germany after a Zeppelin has been built for the United States.

Within a few days after the *Roma* disaster, undaunted by misfortunes and prohibitions, commercial interests announced plans for the beginning of airship transportation in this country. Within a year a corporation hopes to have large rigid ships, built partly in Germany according to the design of Dr. Johann Schutte, in operation between New York and Chicago.

Inflammable hydrogen added to the horror and magnitude of both the *ZR-2* and the *Roma* disasters. In this unhappy way, public attention has been called to helium, the safe balloon gas. This "rare" gas, only in recent years first discovered in the sun, promises to lessen greatly the dangers of lighter-than-air transportation. All who have been concerned in the commercial development of helium hope that Congress will provide sufficient funds for the work now in progress and that the Navy blimp *C-7*, which this fall demonstrated helium to be a practical balloon gas, is only the forerunner of future American airships, held aloft by the safe gas that at present only America can produce.

THE BLIMP IN FLIGHT

THE SCHOOL OF HYGIENE AND PUBLIC HEALTH OF THE JOHNS HOPKINS UNIVERSITY

THE Rockefeller Foundation has made a gift of $6,000,000 to the Johns Hopkins University for endowment and buildings for the school of hygiene and public health.

Since this school was opened in 1918 the foundation had furnished the funds required for its maintenance from year to year. With the acceptance of the present gift the trustees of the university assume full responsibility for the future needs of the school as they develop.

This new type of institution places emphasis upon the development of preventive medicine and upon the training of health officers. Under the direction of Dr. William H. Welch the school has made substantial progress in the four years since it was established. Twenty-seven states and ten foreign countries are now represented in the student body numbering 131. The faculty of the school comprises scientists in the fields of bacteriology and immunology, sanitary engineering, chemical hygiene, physiological hygiene, medical zoology, epidemiology, vital statistics and public health administration.

The regular courses of study lead to the degrees of doctor of public health, doctor of science in hygiene, and bachelor of science in hygiene. A certificate in public health is given to those completing certain special courses. Short courses or institutes are provided for health workers in service who can not be absent from their positions for more than a few weeks at a time. Last year thirty-six health officers from eight states took these short intensive courses.

Up to this time the school has been housed in old buildings, situated in the center of the city of Baltimore, and formerly used by Johns Hopkins University for laboratories of physics, chemistry and biology. The present gift, in addition to providing endowment, will make possible the erection of the new building for the school on a site adjacent to the Johns Hopkins Medical School and Hospital.

Work on the main building, the

plans for which already have been drawn, is expected to start this summer. It will be located on a site which has already been acquired at the southeast corner of Monument and Wolfe streets and is so designed as to admit of its liberal expansion. The contract for its erection will be let as soon as the architects, Archer & Allen, of Baltimore, have completed drawing the detailed specifications

The enterprise will be part of a general scheme of building to be started by the university this year, including in addition to the new school of hygiene, which will cost $1,000,000, $800,000 for the new Woman's Clinic and a new pathological building, the contracts for which have already been let; $500,000 for a new chemical laboratory at Homewood and between $400,000 and $500,000 for dormitories at Homewood.

SCIENTIFIC ITEMS

We record with regret the deaths of Dr. John Casper Branner, long professor of geology and later president of Leland Stanford Junior University; of Charles William Waidner, chief of the Division of Heat and Thermometry of the Bureau of Standards; of Rear-admiral Charles Henry Davis, formerly superintendent of the Naval Observatory; of Charles Leonard Bouton, associate professor of mathematics at Harvard University; of Frank Bottomley, the English chemist, and of Senator Ciamician, professor of chemistry at Bologna.

Dr. Harlow Shapley, who was appointed director of the Harvard College Observatory last fall, has been elected to the Paine professorship of practical astronomy, which has been vacant since the death of Professor Edward C. Pickering, in 1919.

Professor Solon I. Bailey, of the Harvard College Observatory, sailed on March 1 from New York to Peru to take charge of the Harvard astronomical station at Arequipa. He is accompanied by Mrs. Bailey and by Miss Annie J. Cannon of the observatory staff.

Dr. Vernon Kellogg, zoologist, secretary of the National Research Council, Washington, D. C., and John W. Davis, attorney, of New York City, formerly ambassador to Great Britain, have been elected trustees of the Rockefeller Foundation.

Dr. George E. Hale has resigned as president of the Pacific Division of the American Association for the Advancement of Science to attend the meeting of the International Research Council in Brussels. Dr. Barton Warren Evermann, director of the Museum of the California Academy of Sciences, has been elected president to succeed Dr. Hale, and will give the address at the meeting to be held in Salt Lake City from June 22 to 24. It will be remembered that the American Association for the Advancement of Science will hold a summer meeting at Salt Lake City in conjunction with the Pacific Division.

The Rockefeller Foundation has given six million dollars to Johns Hopkins University for the endowment and buildings of the School of Hygiene and Public Health.

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THE RELATION BETWEEN RESEARCH IN HUMAN HEREDITY AND EXPERIMENTAL GENETICS

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I. Introductory

THE workers in any primarily biological science need at frequent intervals to spend a certain amount of time in considering the research methods and aims of their science with a view to possible changes.

The more their branch of science is dependent upon or correlated with other allied sciences, the more urgent becomes such a procedure.

New discoveries of a fundamental nature in one branch of science should have a strong influence on related fields. In fact, such changes, when they exist, are bound to make their presence felt sooner or later outside their immediate field, and it is the desire to assure that it be "*sooner*" rather than "*later*" that justifies the expenditure of time and effort in continually looking about for such unutilized or unfulfilled relationships.

The sooner any such relationship is recognized and admitted, the sooner can progress of a firm and lasting nature be made in both branches of research concerned.

It is with just such a relationship between the genetical aspect of eugenics and the field of experimental genetics that the present paper hopes to deal. The existence of this relationship has long been admitted, but the full scope of its extent, possibilities, and responsibilities does not seem to be completely realized at present.

In order to bring out the facts in the case more clearly, it will first be advisable to review briefly the general lines of progress in research on human heredity in the past two decades. We may then consider this progress in its relationship to the contemporary advance in the field of experimental genetics, and in so doing bring out the need for certain changes in the methods of research in human heredity. Finally, we may outline a program of possible studies in human genetics which could be undertaken at once, be built up gradually, and eventually be utilized as the foundation of a more exact and lasting approach to our proper understanding of the inheritance of human traits.

II. The Past Progress of Research in Human Genetics

Investigations in the genetic aspect of eugenics may be said to have progressed along two main lines, or perhaps better, from two different viewpoints. On the one hand, biometrical interpretation of data has been continued by the Galton laboratory, under the direction and leadership of Karl Pearson, while, on the other hand, the search for mendelizing characters has been carried on chiefly by the American School of Eugenicists under Davenport.

The biometric school, which has avowedly used statistical methods and a non-mendelian approach to the problem, has established the *fact* of inheritance of many traits. Such publications as "The Treasury of Human Inheritance" and "Biometrika" contain the records of a great number of painstaking and meritorious investigations by this group of workers. The *type* of inheritance involved, however, remains, under these methods of analysis, obscure and unapproachable.

The mendelian school has gone farther, for, in addition to having established the *fact* of inheritance for many traits, it has been able in not a few cases to procure evidence bearing on the *type* of inheritance as well.

The exactness with which the cases of mendelian inheritance in man have been established is not, and can not be, under present methods, of the same order as that of a result based on experimentations. The question of which cases are, and which cases are not, well established is, therefore, to some degree a matter for personal opinion.

We may, however, take the opinion of a careful and conservative geneticist, such as Castle, as a fairly safe guide in estimating the number of cases of apparently mendelizing characters in man.

In his text-book on "Genetics and Eugenics," 1920, Castle lists some twenty-three characters as having been found to be mendelian, and approximately thirty-two others as either "non-mendelian" or unanalyzed. In presenting these cases there have been many publications from, or inspired by, the Eugenics Record Office of the Carnegie Institution of Washington. This institution has indeed provided funds and personnel for the great majority of the research which has procured the evidence for the type of inheritance involved in most of the cases recorded by Castle. To a consideration of the ultimate value of this work, we shall return later. In the meanwhile one may mention such researches as those of Goddard on feeblemindedness, of Davenport and Weeks on epilepsy, of Bulloch and Fildes on hemophilia, and of Estabrook on the Jukes, to obtain an idea as to the sort of research that lies at the basis of the cases cited by Castle.

Recently the work of Mohr, on brachyphalangy, and of Stanton and Seashore, on musical ability, has continued, by methods of direct observation, the lines of mendelian analysis in as careful and painstaking a manner as the means of collecting the data have made possible. Their work represents the farthest advance in methods at the present time.

Without going into the details of the work cited, we may say that upon the rediscovery of mendelism, efforts were made by the majority of eugenicists to extend that law to humans, and that, broadly speaking, these efforts have been successful.

III. The Relation of Progress in Genetics to Eugenic Problems

While these investigations in human heredity have been under way, research in experimental genetics has been far from idle. Its progress has, in fact, been enormous, and the relatively recent developments of our knowledge as to the basis of certain hereditary characters has brought to light new genetic principles of the greatest importance.

Thus, to Mendel's original laws of segregation and of independent assortment and recombination of the genes, we find added, by the work of Morgan and his associates, linkage, crossing over, limitation of linkage groups, and the intra-chromosomal questions of interference and the order of the genes.

Obviously, these new discoveries open up a wide horizon, and introduce us to a type of detailed genetic analysis not formerly imagined. They also, however, focus our attention upon the nature of our data on human inheritance, in order to observe whether these data are sufficiently accurate to be amenable to analysis by the finer tests mentioned above.

When this question is calmly and dispassionately considered, we are forced to the conclusion that data on human inheritance, collected by the present methods, are not sufficiently accurate to justify their being used to determine the degree of linkage or crossing over, or such matters as the limitation of linkage groups, interference, or the order of the genes.

Thus, while "family histories" and reports of field workers give information of greater scientific value than data less carefully obtained, they have certain fundamental and unavoidable inaccuracies. For example, evidence obtained by field workers concerning the individuals who are themselves interviewed is probably fairly accurate. So, too, is the documentary evidence submitted by an individual of responsibility and intelligence concerning her- or himself. The mass of information in family records, or that obtained by field workers concerning dead or absent individuals is, however, too uncertain to use in the finer methods of genetic analysis.

It is the fact that geneticists have clearly recognized this situation, while many eugenicists have given little sign of having done so, which has brought about the existing prejudice. Such prejudice certainly exists to a marked degree and forms one of the most unfortunate but telling bits of evidence of the need for radical changes in the method of eugenic research.

There can, moreover, be no narrowness present as a factor in the situation, for the geneticist has been living in plenty and does not wish a changed attitude on the part of the eugenicist for any selfish reason. Rather he expects of the eugenicist merely a critical attitude, involving realization of the fundamental weakness in his data and steps to correct it.

While experimental genetics was in its infancy, (1905-1910), one did not hear from geneticists so much criticism against, or sense so much distrust for eugenicists. Because, however, since that time, eugenics has made little or no progress towards a truly experimental attitude we now find a real breach between these two sciences. This is most unfortunate, for they should be closely related and entirely sympathetic.

Undoubtedly the geneticists have been a bit unreasonable in expecting the immediate adoption of experimental methods by eugenicists. On the other hand, there is much to justify their attitude of criticism. Thus we find that among more than one hundred papers given at the recent International Congress of Eugenics, not one paper on human genetics introduced us to data of sufficient accuracy to provide evidence on the degree of linkage, the order of the genes, or the size and nature of linkage groups.

Another piece of evidence as to the rôle played by the work in human heredity in the advance and conduct of experimental genetics is seen in the bibliography of a modern text-book such as Morgan's "Physical Basis of Heredity." Here, among approximately six hundred references, we find less than two per cent. are to works dealing primarily with human heredity.

Evidence of this kind must not be taken as an indication that we should expect research in human heredity to prove the best field for pioneer work in experimental genetics. To do this would be asking too much. There is, however, a serious aspect to the question when we realize that present methods in human inheritance studies will not give us the chance to utilize the definite methods of genetic analysis now possible. It is not a matter for chagrin, but involves an unfulfilled duty. If eugenics is ever to be an applied science, it must be able to predict with a fair degree of accuracy the results of individual matings. Without this, no practical system of mate selection can be suggested. Since the question of mate selection is daily becoming of more general interest, this line can not and should not be avoided. If advice as to what type of consort shall be chosen is given in individual cases under the conditions of our present incomplete knowledge of quantitative values in human heredity, we shall soon be in serious trouble. This will result if and when advice is given and followed with a markedly unsuccessful outcome. A few such cases would be sure to give the existing interest and confidence in the eugenic movement a severe and possibly permanent setback.

The non-scientific public expects great achievements and accuracy in the case of any process which is supposed to be scientific. If, however, "science" fails, they are quick to turn and rend it with ridicule and an exaggeration of its weakness. This means that those who have at heart the success of the eugenic movement, must, therefore, before it is too late, take a definite stand against overinterpretation of data within their particular field, or else be prepared to experience an ever increasing lack of sympathy on the part of the biological sciences and the educated public.

As before stated, it seems that we owe it to the future of human genetics to face the situation fairly and frankly. To do this, the fundamental interdependence of experimental genetics and human genetics has been made the keynote of the situation.

In working out a program for work on human genetics, we are faced with certain inherent characteristics of our material. The fact that these form definite limitations in some cases, forces our attention to them whether we desire it or not. In considering them, however, we shall, I think, find that the obvious disadvantages are not without some compensations and alleviating circumstances, which may easily be turned to our advantage.

Thus, while the slow breeding of mankind makes it impossible to expect or hope for the great numbers obtainable from laboratory material, and lengthens the space between generations to a somewhat disquieting degree, yet it offers opportunities of a peculiar nature as well.

For example, the long period of adolescence gives us a remarkable chance to develop to the fullest extent the study of the unfolding during ontogeny of the hereditary traits, and to weigh with a high degree of detail the influence of such external agents as training, education, and other similar forces, upon the individual and its descendants. We can and should know our human individual—whether ancestory or progeny—in as many stages of his ontogeny as we possibly can. This is the peculiar opportunity afforded by human material. We can not ignore it by attempting a classification of our individual based on fragmentary information—but, rather, we should utilize it to the fullest extent. What might then, at first, be considered as a handicap, may with patience and careful planning be turned into a valuable asset. No insect material can give us this chance—and when we consider that laboratory mammals afford us an excellent basis for the development of methods of research applicable to humans and for a "comparative" genetic analysis—we begin to see the real possibilities of the situation.

In a somewhat similar way it has been objected that in man we can not control the matings made; this indeed is true. But if we can not control the matings, we can, at least, record them and, by finger prints and blood tests, check on data. This is no small advantage, and makes the eventual utilization of carefully collected data certain and of great value.

We have already dwelt on the inaccuracy of information based on anything short of exact tests or measurements of the individual in question—an inaccuracy which makes change imperative. As an aid in establishing and extending the desired methods of observation and recording, will come the definite cooperation of the individuals themselves, or of those controlling them, once results of promise can be shown.

The possibility of introducing some such program as the one suggested will be scouted by many—and in some cases, indeed, by those now engaged in eugenical research. Until a point of view generally similar to the one above outlined is adopted, however, we may expect that the work in human genetics will fail to carry real conviction to experimental geneticists and to the public at large.

It is entirely probable that the attitude that eugenics is or should be primarily dependent upon genetics may be seriously questioned. Should this be the case, however, it seems that a short consideration of the apparently non-genetic aspects of eugenics will bring home to us the fact that we are, even in these subjects, actually relying on genetic information before we can hope for progress.

Thus in the eugenic aspect of the immigration problem, we are faced at once with the fact that we are dealing with *race*—a fundamentally genetic problem. Racial *differences* in fecundity and susceptibility to disease will determine just what numerical rôle any given nationality will play in forming the future population. Differences in type of mental makeup and in degrees of mental capacities from the viewpoint of intellectual achievement, moral responsibility and adaptibility to a new environment will be essential matters in determining the value of various nationalities as sources of potential citizens. The physical and psychological traits of various combinations and types of hybrids among the different European and Asiatic nations, attained under the conditions of life in the United States, will give the best possible criterion as to their permanent value as constructive elements in the formation of the future American nation.

Similarly, the question of legislation involving eugenic measures must frequently appeal to our knowledge of genetic principles as applied to man. Unless the environmental influences not transmissible to future generations can be separated from those differences that are truly genetic, we shall be at a loss to know how strict our system of segregation and confinement of criminals should be. So, too, unless we know the degree of inheritance of criminal traits in different racial combinations, we shall not know whether a similar legislative treatment of all individuals, regardless of their racial composition, is either justified or wise. So, too, in efforts to determine parentage, genetics through blood tests may be useful if properly evaluated.

Thus, in any scheme of general education along lines of eugenic measures, we are faced again and again with the fact that the limiting factor in the situation is our knowledge of the laws of genetics as applied to the particular subject in question.

In thus presenting briefly some of the factors operative in maintaining a proper relationship between genetic research in man, and experimental genetics, an effort has been made to bring out the fact that we have reached a point where a recasting of our methods of gathering data on human inheritance for this purpose is imperative.

The work in human genetics already accomplished has given results so promising that we should be able to enter a new long-time program with enthusiasm and complete confidence as to its final outcome. If we can, in this long-time program, obtain, as we go, data for *immediate* interpretation and at the same time lay the foundation on which eventually a scientific and experimental study of human heredity may rest, we shall have initiated a line of investigation worthy of the loyal support of all experimental geneticists and of the best efforts of those intimately connected with eugenic research.

IV. The Proposed Program

A. *General Considerations.*

In suggesting a program of this type, no one can be more clearly conscious than the writer, of the need for encouraging discussion and cooperation between geneticists and eugenicists before any definite scheme of work is adopted. In fact, it is probable that an "acceptance in principle" of some such outline as that here given will be sufficient action at the onset. This will give opportunity for the introduction of modifications either of methods or materials as the work progresses. Some such elasticity is necessary, for it is not humanly possible to foresee all the problems which are bound to arise.

In the main points, however, there is real hope of agreement provided the inadequacy of present methods of collecting data is frankly admitted. Obviously, the new program to be adopted involves (1) more accurate methods of collecting data as to the biological nature of both physical and psychological traits of human individuals, (2) the utilization of data so collected for three main purposes, (a) the contrasting of naturally existing different biological groups of individuals in respect to characters recordable by direct observation, (b) the building up of an ever increasing detailed knowledge, by the method of direct observation, concerning the individuals from birth to death, and (c) the continuation of this process to include the descendants of such individuals. By this means, pedigrees will eventually shape themselves which are of sufficient accuracy to be considered quite as exact from an experimental point of view as are many of those of laboratory mammals used in genetic research.

Much is heard of the unselfishness of science and its devotees, and of their willingness to sacrifice their individual capacities and efforts in the search for truth. Yet it is doubtful whether there would be even the slightest chance for the adoption of a viewpoint similar to the above unless it can be shown that the returns to be expected during the lifetime of the observer are in themselves sufficient to enlist his interest.

Fortunately, the value of the "immediate" returns is, in the case of the suggested eugenics program, so great that one is justified in considering some of them in detail, despite the recognition of the fundamental selfish element always present, which often makes a similar consideration necessary even in other cases having little or no merit.

In outlining the possible problems to be investigated, it will be advisable to keep in mind the features of particular interest to the United States. The problems of other nations will, however, be sufficiently allied to ours to make the utilization of some slight modification of the lines of work suggested here, entirely feasible.

Bearing in mind then, that the prime requisites of the new attitude is direct observation, we must first seek to ascertain where the best opportunities for such observation exist.

B. *Opportunities and Problems.*

The chance to study human material from the various viewpoints shortly to be considered is offered at many times during the lifetime of the individual. At many of these points the information desired could be obtained with a minimum of effort and with great accuracy.

Thus, maternity hospitals, primary schools, secondary schools, colleges, city and state institutions, general hospitals (of all grades), military and naval units, factories and large commercial concerns, offices of dentists and physicians, social and church organizations, employment bureaus, boy and girl scouts, census officials, immigration stations, Y. M. C. A.'s and Y. W. C. A.'s and similar organizations are some of the points at which it would be possible to obtain data of biological value by physical or mental examinations conducted by properly trained observers.

Obviously, the earlier in the life of the individual we begin to gather the data, the more will be the genetic and the less the external contributions to its character; the earlier, also, shall we be able to recognize the initial stages in the appearance of both beneficial and harmful hereditary traits. In the former case we should be able to assure proper opportunity, physical and mental, for the exceptionally endowed individual, and, in the latter, apply at the earliest possible moment the restrictive, corrective or curative measures necessary for such deficients as might be found. The economic saving would be enormous, but even so it would be only a tiny fraction of the permanent biological benefit to the race.

Clearly, maternity hospitals provide us with the chance to observe directly the individuals at birth. Their records are, or could be made, inclusive of information concerning many physical and even mental attributes of the child. Studies on the sex-ratio, body length, weight, head form, early growth rate, incidence of abnormalities or disease are only a few of the questions easily capable of being investigated by direct observation in such institutions.

Certain of these points have already been successfully investigated in laboratory mammals or in man. As a single example of this, the variations in the sex-ratio (number of male progeny to each one hundred female progeny) may be briefly considered.

Variations in the sex-ratio are of importance economically as well as biologically. It is therefore important to investigate the various factors which underlie their modification.

Hybridization has been recognized as one such factor. R. and M. Pearl (1908) and the writer (1919) showed that in man the progeny of matings between parents of different nationalities had a higher proportion of males than those between parents of the same nationality. The same fact has been found to hold true for races of birds (Ducks, Phillips; Pigeons, Whitman, and Riddle; Pheasants, Geoffrey-Smith and Haig-Thomas; Poultry, Davenport, Pearl; and in laboratory mammals, Rats, King; Mice, Little.

In a somewhat similar way, King (1918) showed that more males proportionately occurred in the first litter among rats than among subsequent litters from the same parents, and the writer found the same to be true in humans (parents from white races and of the same nationality), when the first births are contrasted as a group with the subsequent births. This fact, for example, has a possible bearing on the popular belief that in time of war an excess of males above the "normal" ratio is produced. There might be an interesting element of truth in the popular belief, because in war time the proportion of first births in the population is greatly increased. If, now, these produce an excess of males, it would follow that this fact would be noticed and remarked on, since, at that time especially, men are at a premium.

The occurrence of sex-linked lethal factors killing approximately fifty per cent. of the male progeny in certain matings has been frequently observed in insects (Morgan and his co-workers). Evidence for their existence in mammals, (mice, Little, 1920) and in man (Little and Gibbons, 1921) has been offered. The evidence in man is statistical and can not be made more definite until our methods of collecting data have become more accurate.

The sex-ratio of stillbirths in man is a matter of the liveliest interest. On the one hand, it bears on this same question of lethal factors, and on the other, it provides important evidence on the sex-ratio at conception—and thus on the possible control of sex in mammals through the selection of one or the other type (male forming or female forming) of sperm.

So also, the sex-ratio of illegitimate births is worthy of investigation. There has been a certain amount of evidence obtained (Heape, 1908) that there is an excess of females among the progeny resulting from illegitimate births. It would be interesting in this connection to see whether the use of contraceptive methods, or possibly an unusual occurrence of endocrine abnormalities (due to the unusually high number of mental defectives among the mothers of illegitimate children) have altered the secretions of the female reproductive tract sufficiently to mean that a selection of female-forming sperm is being made, and the male-forming sperm more frequently eliminated during their passage through the female generative tract.

In the primary and secondary schools of great cities we have remarkable opportunities for work of some of the types which we have outlined. Representatives of many different nationalities are brought together in essentially similar environment and are under almost daily observation for long periods. The chance is clearly given to study differences in mental capacity of individuals, nationalities, and races. Particular talents may be studied and many of the investigations now being made with exceptional children could be extended and supported by approach from a new angle.

The preliminary experiments of Vicari (1921) on mice have shown that F_1 hybrids produced by crossing Japanese waltzing and albino non-waltzing mice (the two parent stocks being thus from different laboratory races) made a better record in learning a simple psychological problem than did either parent race. This suggests strongly that the well known phenomenon of hybrid vigor, or heterosis, applies in the case of at least some mental characteristics as well as in physical traits.

It would be of the greatest value to compare the school records and psychological tests of children whose parents are of the same nationality with those of children whose parents are from different nationalities. Later the records of back-crosses and of F_2 hybrids could be similarly studied.

So, too, the study as to whether there was correlation between general or specific mental capacity and grade of skin color in mulattos would be extremely interesting.

Growth curves and resistance to children's diseases are other matters on which children of "hybrid" and "pure" matings could be compared. In this case, if the analogy with the laboratory mammal holds, we should expect the first generation hybrids to be clearly superior.

Other viewpoints and matters for investigation as applied to the school material would be quite as important. Thus, it has been long debated with considerable warmth of feeling as to whether first-born children were inferior mentally and physically as a group, or last-born children superior as a group, to other children as a whole. The material for settling, or at least throwing light on, this point seems to be in a condition to gather in the schools.

The effect of age of parents at the time of birth of the child, or of transference of an individual from one environment to another, of birth and rearing in the city as compared with the country, are all of them interesting and contrasted points of view that may be investigated profitably and economically.

It is also, at least theoretically, possible that by the extensive use of mental tests, methods may be devised for recognizing the carriers of recessive feeble-mindedness. If this were actually accomplished, the value to the community would be enormous.

C. *Training of Observers.*

We must not send out as observers individuals who look for anything except accurate, concrete, and unbiased data. There must be no reliance on "hearsay" or "reported" evidence of any type. The judgments as to any individual's traits or abilities, physical or mental, must be recorded as standardized measurements from direct observation. In this way, any mistakes of methods or technique will become evident at the earliest possible moment, and modifications can thereupon ensue. If the "field worker report" type of information be relied on, we shall have inaccuracies continually introduced by the varying personal equations of both the observer and the observed.

The acceptance of this last general point means that a large body of observers capable of and interested in taking accurate observations must eventually be trained and organized. The need of some such body of trained observers should not, however, prove any source of worry to us. The idea of training eugenic workers for the specific purpose of research is already in practice.

At the present time, field workers so trained are sent out to collect data from a critical point of view without, in many cases, ever having performed an experiment in animal genetics. This seems to be one of the points on which genetics and eugenics clash sharply. There would perhaps be real hope for reconciling the two if such field workers had been given a laboratory course in genetics, or if they merely went out to measure and record by standardized methods certain mental or physical traits of individuals by direct observational methods. In this last case, training in accuracy, and some knowledge of each field worker's "individual error" would be indispensable.

But the training of specialized field workers, or "field observers" as they might perhaps be called, is expensive and is only one of the ways to go about gathering data based on measurements. There are in addition two great groups of individuals, either or both of which might easily be specially trained, and who could, in the course of their professional duties, obtain data of the utmost scientific value. These are medical men and the teachers of primary and secondary schools.

A properly planned and executed lecture course with demonstrations would give the average medical student some ideas on the gathering and recording of biological data. This would suffice for arousing his interest and at least introduce him to the genetic point of view. Individual researchers in eugenics or organizations conducting eugenic research could then arrange with medical men for the joint interpretation of the data which the medical man had gathered.

The same principle could be followed in the case of school teachers in whose training a course on the biology of their material, and on means of recording data could most profitably be inserted.

The suggestions as to the training of medical men and teachers, as well as to the modification of the functions of the eugenic field worker, are all of them based on essentially the same principle. This involves the clear separation of the function of *collecting and recording of data from its final interpretation,* unless all the collectors and observers are, in the highest degree, trained in scientific methods and thought in either genetics, general biology, or both. They should confine themselves to the mechanical and, in so far as possible, impersonal work of gathering data in the form of permanent, records, obtained from standard tests under direct observation.

With data of this type we should find the experimental geneticist becoming more frequently interested in a problem of human genetics than he ever can be under the existing methods.

In colleges as well as in other educational institutions, the employment of observers to collect and record data will result in educating the general population of the institution in the problem under consideration. The whole scheme will undoubtedly work out on the basis of compound interest and result in a steady increase in the numbers and efficiency of workers.

The value of collecting data in large business concerns or factories is also clear. Here one will be able to gather information as to efficiency under certain performance tests, as well as on the general mental attributes of accuracy, consistency, and industry. Psychological tests of the type of those in use in the army are already in a state of development sufficiently advanced to be of great value.

D. *Conclusion.*

The program as outlined is admittedly incomplete and in tentative form. Generally speaking, it utilizes natural gathering places of people at all ages, and by a continuation (with certain modifications) the training of eugenic field workers, together with the training of school teachers and medical men, it plans to interest an ever increasing group of observers who will gather by methods of direct observation, data on human genetics.

It proposes to decrease to a minimum, or to abandon, except for the preliminary work, methods of pedigree study as at present practiced, and by the processes outlined above to replace it gradually by pedigrees more nearly comparable in their degree of accuracy with those obtained by experimental geneticists working with mammal material.

It proposes to collect data on such subjects as birth, length and weight, head form, sex-ratio, rate of growth, susceptibility to disease, incidence of abnormalities (morphological and physiological), mental capacity, specific and general, age at maturity, as well as the variations commonly recorded such as hair color, shape, eye color, skin color, et cetera.

Furthermore, as indicated above, any and all of these points may be analyzed on the basis of contrasting the progeny of relatively pure (inbred) and hybrid (outbred) matings, of first births as compared with subsequent births, of young parents as compared with old, of negro with white and other racial types, of country bred parents with city bred, of college graduates with non-college graduates, of parents who were first children compared with those who were not, of brunettes versus blondes within any particular nationality, of parents suffering with various diseases as opposed to those not so afflicted, of births out of wedlock compared with legitimate births, of parents from tropical climates as compared with those from temperate or arctic, and eventually of children born to the same parents in one climate compared with those born from the same parents in a new environment.

The above plan has its justification in the belief that under the present methods the breach between eugenicists and geneticists will become wider and wider, and without it eugenics will not be able to utilize the existing genetic methods of analysis and so maintain its place among the truly experimental sciences. Because the permanent welfare of the eugenic movement is at present prejudiced, a radical and immediate shift in viewpoint on the part of those directing eugenic research and thought is urged.

By looking ahead to the time when the pedigrees built on the new plan are beginning to take definite form, we can rest assured that there will be ample reward in the shape of information sufficiently accurate to warrant a detailed program of "mate selection" work at just about the time that the public as a whole is ready for it, and in an approach to the problems of human heredity in a way not now possible.

In the meantime, we shall have accomplished a great amount of research of direct biological and economic value to our country, and shall have laid a firm and respected foundation for research in human genetics throughout the world.

MENTAL AND PHYSICAL CORRESPONDENCE IN TWINS. II

By ARNOLD GESELL, Ph.D., M. D.
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III. The Basis of Correspondence and Disparity in Twins

The problem of resemblance in twins is one of critical significance. If we could solve it with any completeness even for one pair of duplicate twins, we should thereby gain much insight into more general problems of heredity, development and education. Dr. Morton Prince has called double personality a veritable gold mine for the study of psychological phenomena. Duplicate twins represent double personality in a different but no less pregnant sense.

Individual differences among unrelated human beings are almost infinite in variety. We do not expect even two leaves from a forest to be exactly alike; much less human beings. Persons prominent in public life often have a double; but the degree of identity will usually not bear very close inspection. Very rarely indeed do police bureaus find cases of even apparent physical duplication among criminals and crooks. A remarkable and authentic case, reported from the U. S. Penitentiary at Leavenworth, Kansas, relates of two colored prisoners, Will West, No. 3426, and William West, No. 2626, whose photographs and Bertillon measurements as well as names were strikingly alike, and who with their hats on were almost indistinguishable. But even this resemblance proved to be superficial, and did not rest on any developmental identity.

The question of correspondence and disparity in twins involves, of course, the deeper problem of the genesis of twins. It can not be said that this problem has been solved. Biologists have for some time accepted a classification of human twins into two distinct types: (1) fraternal twins, who may or may not be of the same sex, who show ordinary sibling or fraternal resemblance, and are presumably derived from two separate eggs (dizygotic); (2) duplicate twins, who are always of the same sex, closely resemble one another, and supposedly originate from one fertilized egg only (monozygotic). The existence of both types of twinning has been indisputably established in the lower animals. There can be little question about the occurrence of dizygotic (biovular) twinning in the human family. There has, however, been some question in regard to the frequency of mono-zygotic twinning; and the possibility of reconciling specialization of resemblance and disparities in co-twins with this mode of genesis. Biologists and embryologists, however, continue to recognize two distinct types of human twinning. Obstetricians have adopted the same distinction, and maintain that it is usually possible by an examination of the placenta and foetal membranes to determine whether any given pair of twins was mono- or bi-oval in origin.

Thorndike, as we have seen, seriously doubts whether twins represent two distinct modes of fertilization and genesis, and thinks there is no need of it, whatever, to explain the facts of the likeness of twins, "for the closest likeness grades off gradually into notable difference as one ranks twin pairs by their resemblance." (Figure

From Thorndike's Measurements of Twins. Archives of Philosophy. Psy. and Sci. Methods. Vol. I. p. 44.

FIGURE 13. THE FORM OF DISTRIBUTION OF RESEMBLANCE IN TWINS

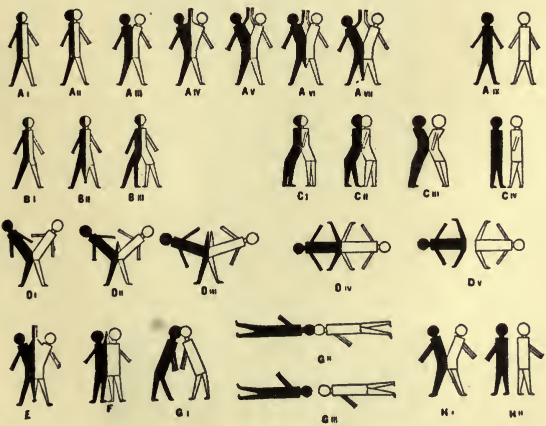
13) He admits that there is an increase in the resemblances of children born at the same time over ordinary siblings; but thinks it is due to a reduction of variability among germs produced at the same time. In his series of twins, he found that even the most similar twins differ markedly in some traits. This specialization of resemblance he holds disproves the existence of the identical-twin species. "The most identical twins will in *some* respect be less like each other than ordinary siblings." His argument is summed up as follows:

> The objections to the genesis of any considerable percentage of twins by the development of two individuals from one ovum after fertilization are: first, this specialization (of resemblance) which is well nigh universal; second, the non-appearance of any such well-defined group of especially similar twins; third, the fact of triplets, all three as identical as any two twins; fourth, the too great frequency of close resemblance.

Let us consider some facts regarding the development of twins, which may perhaps diminish or divert the force of these objections.

Bateson has given us a very broad conception of twinning in his formula "the production of equivalent structures by division." He regards it as a fundamental manifestation of life. "When I look at a dividing cell, I feel as an astronomer might do if he beheld the formation of a double star; that an original act of nature was taking place before me.'' Cellular division, as such, is not twinning; but the tendency of the divided or repeated parts to assume symmetrical relations may be so regarded; and this tendency is an almost universal feature of biological mechanics. The fact that the experimental embryologist can bring about the growth of a paired structure by a simple wound of a single limb bud reveals the fundamental nature of twinning. Of similar significance is the fact that Loeb produced a 90 per cent. increase in twins by a simple immersion of his experimental eggs in lime-free sea water, which caused the segments of the living eggs to fall apart as they were formed. Newman, likewise, regards the phenomenon of twinning as a ''very fundamental process almost universal in the field of biology. For wherever we have bilateral doubling, we have twinning in some form.''

From this point of view every bilateral individual may be conceived as being morphologically a pair of twins. This view is so legitimate that it need not be called paradoxical. The human individual is undoubtedly derived from a single fertilized cell. He is monozygotic in origin. From this zygote, through a process of symmetrical division, develop all his right and left hand homologous organs and the right and left halves of his ''unpaired'' organs and structures. He is a product of developmental duplicity. Now in the case of true, complete monozygotic twins, this process of duplication has been carried to such a degree that two offsprings



From American Journal of Anatomy, Vol. III, p. 473.

FIGURE 14. WILDER'S DIAGRAMS SHOWING THE INTER-RELATIONS OF VARIOUS SORTS OF DIPLOPAGI AND DUPLICATE TWINS

result from the single ovum. A perfectly symmetrical bilateral individual on the one hand, and a perfect pair of duplicated individuals on the other represent the ideal extremes of the process of twinning. Between these extremes there are many gradations and deviations, some of them benign, other monstrous, in charac-

From Gesell's Hemi-hypertrophy and Mental Defect, Archives of Neurology and Psychiatry, Vol. VI, p. 409

FIGURE 15. A CASE OF HEMI-HYPERTROPHY. AGE 13

ter. Instead of a full twinning of the whole body, there may be twinning of various parts or only of one part. For example in the type of twinship known as *diprosopus diopthalmus,* described by Ballantyne, "the size of the head and the presence of two noses may be almost the only signs of duplicity."

Wilder's diagram, reproduced in Figure 14, shows graphically some of the numerous interrelations of diplopagi and duplicate twins. We should, I think, add the condition of hemi-hypertrophy to this series. Hemi-hypertrophy would be represented by a drawing in every respect like the normal figure A1, except that one half would be portrayed as definitely larger than the other. Hemi-hypertrophy is a total unilateral enlargement of one half of the body. This rare anomaly may be interpreted as an atypical or imperfect form of twinning,—a variant of the same process which may produce a double headed monster, or a completely symmetrical individual. Sometimes the disparity of the two sides of a hemi-hypertrophic individual is so great that there will be eight teeth on the enlarged side when none have erupted on the other; as though the individual had two physiological ages, or as though he were two different, conjoined hemi-creatures! Careful measurements of a case of hemi-hypertrophy, studied by the author when the subject was 13 and 20 years of age, showed that the mild gigantism was a permanent condition and involved apparently the whole right side. (Figure 15.) The right half of the nose was larger, the right nares twice that of the left in diameter, the right palpebral fissure was wider; on the same side the cheek and lips were fuller; the arm was larger, the right hand was relatively more enlarged than some of the other structures; the right leg and foot were similarly enlarged. On palpation the hypertrophied side had a more doughy feel than the left. This suggested redundancy of the subcutaneous tissue, but the roentgen rays showed that the bones themselves had participated in the hypertrophy. (Gesell, *Op. cit.*)

Davenport regards size or stature as a unit character of inheritance, subject to mendelian principles; but this does not assist us in interpreting the curious stature anomaly embodied in hemi-hypertrophy. We are probably dealing with some quantitative imbalance in the processes which normally determine symmetry and twinning.

Newman has made suggestive researches into heredity and organic symmetry in armadillo quadruplets. He has noted some cases in which one lateral half of the body has quite a different number of scutes from the other half, and one of these halves resembles the maternal condition. Since each set of quadruplets have the same genetic constitution in as much as they arise from one zygote, he concludes that some irregularity in the mechanism of the mitotic cell division is responsible for the anomalies of symmetry. This factor is by no means a simple one. "Now in the armadillo there are many evidences of a system of symmetry common to all of the quadruplets, upon which has been superimposed a secondary symmetry system between twins. This in twins is more or less obliterated by a tertiary symmetry between the antemeric halves of the single individuals."

R. G. Harrison discusses rules of symmetry in his monograph "On Relations of Symmetry in Transplanted Limbs." This study is based on 462 cases of grafting of limb buds in amblystoma punctatum. He agrees with Morgan that the potential factors of symmetry reside in the constitution of the egg. "It is the intimate protoplasmic structure that underlies symmetry." Likewise reversal of symmetry. "As an alternative to the hypothethis of rotation, we might consider reversal as due to reversal of molecular asymmetry according to analogy with the behavior of optically active compounds." "There is an analogy between the production of enantiomorphic limbs and the production of situs inversus viscerum, as effected by Speemann. (Speeman obtained a large number of twins in Triton by constricting the eggs in segmentation stages or in early blastula. In many of the cases one individual, usually the right, developed complete situs inversus viscerum.) Either the reversal may be due to reversal of the intimate structure, or it may take place in spite of the intimate structure through the direct action of mechanical factors on the individual parts of the differentiating system." (*Journal of Experimental Zoology*, Vol. 32, p. 1.)

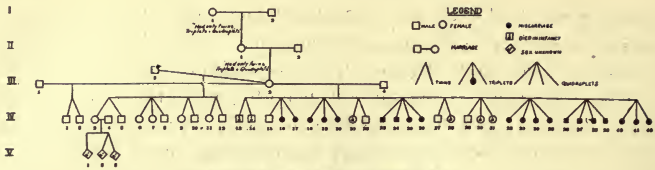
Another form of asymmetry, no less startling than hemi-hypertrophy is that of gynandromorphism. A gynandromorph is an animal that is male on one side and female on the other. This differentiation may include the reproductive organs, gonads and ducts. Usually it is longitudinally bilateral, but it may be antero-posterior. This curious phenomenon is most frequent in insects but has been reported in birds and in a few mammals. A beautiful case was described in a mutillid wasp in which the male half of the body was black and winged like the male while the female half was a rich red and wingless.

The problem of gynandromorphism has been extensively studied by T. H. Morgan and C. B. Bridges and reported in their contributions to the genetics of Drosophila Melanogaster. They found one gynandromorph among every 2,200 flies. The authors consider a gynandromorph to be a hybrid whose genes are carried by the sex chromosome; and they give definite evidence that the peculiar sex mosaic condition is due to an elimination of one X chromosome, usually at some early division of the segmenting nuclei.

The asymmetry embodied in hemi-hypertrophy and even in gyandromorphism is benevolent when compared with the deformities and monstrosities that may occur in the field of pre-natal pathology, where one twin becomes a mere parasite upon its normal cotwin. The germinal conditions may have determined an entirely normal pair of twins, of equal partnership in the rights of life. But in all single ovum (monozygotic) twins there is always a certain area of the placenta in which there is an anastomosis between the two vascular systems of the pair of embryos. If the balance of power between the two uterine inhabitants is equal; and if no marked positional or physiological preference is given to either one, this partial community of blood supply carries no penalty. But a stronger or favored embryo may appropriate an increasing monopoly of blood, so that the sibling foetus degenerates into an acephalic, acardiac, trunkless or amorphous parasite. Here, as Ballantyne remarks, nature ''attains to the extreme limit of teratological expression.'' One twin may be relatively normal, but the cotwin dwindles developmentally into a vegetative mass of malformed, or unformed tissues.

This glimpse into the teratology of the subject shows that twinning actually expresses itself in two apparently contradictory end results. It may produce perfect symmetry and mirror imagery; or it may produce gross disparity. Nowhere in the study of man do we find such complete duplication of individuality as among monozygotic twins; and nowhere do we find also such profound and monstrous degrees of individual difference as among twins of monozygotic origin. In this biological sense the range of individual difference is incomparably greater among monozygotic twins than among unselected pairs of individuals; for we must include among the former those aberrant foetuses which are so extraordinarily grotesque that they have lost all semblance even to the embryonic human form.

It must be recognized that dizygotic twins may undergo secondary fusions in the developmental period and be born as conjoined twins; but true double monsters are placed more readily in the monozygotic category. Wilder holds that there is a close relation between duplicate twins and double monsters; of the type in which one twin is a degenerate parasite upon the other, and also of the lightly conjoined type of twins, who can sometimes be severed successfully by a surgical operation. Newman agrees with Wilder in the view that these are all monozygotic in origin, and



PEDIGREE CHART FOR FIVE GENERATIONS

The diagram above illustrates a remarkable record of "a woman who, in three successive marriages, has never had a single child at a birth." A history of this case shows that there have been multiple births in each of four successive generations. The propositus who is indicated by No. 3 in the third generation (III-3) was married three times. (Fig. 15.)

From the Journal of Heredity. Vol. **10.** *p.* **383.**

FIGURE 16. A CASE OF HEREDITY TWINNING

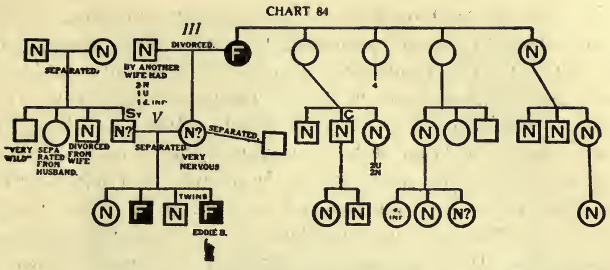
asks the question, "What more natural, therefor, than to infer that separate twins which are of the same sex and strikingly alike are also monozygotic?" Parenthetically it may be stated that Newman has definitely established the fact that armadillo twins are monozygotic in origin, and that twinning is a specific hereditary character in this species.

The problem of physical and mental resemblance in dizygotic twins is more simple. Dizygotic twins must be considered merely as two contemporaneous individuals. As a class such contemporaries doubtless show a higher degree of psycho-physical resemblance than non-contemporaneous siblings, but in any given pair we must be prepared to find ordinary fraternal individual differences. Such twins usually look no more alike than ordinary brothers and sisters, are easily distinguished by physical, mental and temperamental characteristics. (Figure 17.) Indeed one such

From Journal of Heredity. **Vol. 10. p. 402.**

FIGURE 17. FRATERNAL (DIZYGOTIC) TWINS

Their mother writes, "They are so utterly unlike in every way that it is hard for any one to realize that they are twins."



From Goddard's Feeblemindedness, its Causes and Consequences

FIGURE 18. FAMILY CHART OF TWINS, ONE MENTALLY NORMAL, ONE FEEBLE MINDED

twin may be mentally normal while the cotwin is backward or even feeble-minded. Goddard made a study of the family histories of 327 feeble-minded individuals. Fifty-one of his charts recorded the birth of twins. In four of these cases, one of the twins was mentally normal and the other feeble-minded (Figure 18). Surprising as this may seem to those who make the term "twin" snyonymous with resemblance, it is not difficult to explain. Two separate ova were in each case probably fertilized by separate spermatozoa. In one case both gametes were defective, in the other only one or neither. There is no reason to expect duplication or identity under such conditions of conception.

A few cases of twins have been reported in which one child was normal and the other of the mongolian type of mental deficiency (Figure 19). Mongolism is characterized by a small rounded

From Journal of Am. Medical Asso., Vol. 78. No. 1. (*Dr. Stafford McLean*).

FIGURE 19. MONGOLIAN IDIOT AND NORMAL TWIN SISTER AT 6½ MONTHS

skull, hypertrophied tongue with enlarged circumvallate papillæ, oblique almond eyes, and frequently lax joints, broad, flabby hands and feet, defective circulation, and nearly always imbecile mentality. Mongolians look so much alike, it has been remarked, that they appear to be members of the same family. However, Mongolians themselves do not beget children and the cause of the condition is very obscure. If the cases of one Mongolian in a pair of twins have been correctly diagnosed and reported, it suggests that the twins were dizygotic and the defect one of specific hereditary transmission. If it represents an endocrine disturbance, it may be that the endocrine defect itself was germinally determined. It is, however, necessary to be cautious in conclusions on this point. I have, myself, seen a pair of mentally subnormal, duplicate twins, pupils in a special class, who presented physical and mental features intermediate between true mongolism and the simple clinical variety of feeblemindedness. How shall we explain these semi-mongol or mongoloid types in presumably a genetically identical pair?

The necessity of caution in interpreting the rôle of chromosomes and hormones in asymmetric twins is well warranted by the confusion which associated itself with the rationalization of the freemartin. The freemartin is well known to cattle breeders as a sterile twin, born cotwin to a normal male. Professor Newman credits F. R. Lillie with having solved this baffling and controversial mystery. "Lillie's work has revealed the true nature of the freemartin; it is a sterile female whose gonads remain in the juvenile stage so that they resembles testes, and which has certain secondary sexual characters of the male due to the presence for a considerable period of male hormones in the blood borrowed from its male cotwin. The animal is hermaphrodite only in a very limited sense. The work leaves no question as to the dizygotic origin, not only of opposite-sexed, but also of same-sexed bovine twins."

If hormones play a regulative rôle in prenatal development, it might be argued that the interchange in blood supply made possible by the vascular anastomosis in the placenta of monozygotic twins, would tend to exert an equalizing influence upon the foetuses.

The term mongolian has just been used in a clinical and not an ethnological sense; but it indirectly recalls those instances in which twins actually present racial disparity rather than resemblance. This amazing possibility rests on the well recognized occurrence of super-fecundation, in which one impregnation is after a brief interval followed by another and the mother gives birth to dizygotic twins. Under illicit conditions there may be two fathers,

From Journal of Heredity, Vol. X, p. 428.

FIGURE 20. IDENTICAL TWINS FROM JAPAN. YEIICHI AND YUJI OGATA, OF TOKIO

of not necessarily similar race, for the pair of twins. Dr. John Archer, the first man to receive a medical degree in this country, reported a case in which a white woman was delivered of twins, one white and the other mulatto.

We are, therefore, confronted with an extraordinarily wide gamut of quantitative and qualitative diversities in the field of human twinning. The factors which bring about these diversities are not only germinal, but post-germinal, genetic and developmental. Their combined action may help to obscure the bi-modality of the distribution curve for twin resemblances, but leave unimpaired the validity of a classification into the two traditional groups.

It must be remembered that there are wide variations possible within either of these groups. Neither process works with iron clad rigidity or uniformity. For example, Williams recognizes that single ovum twins may be produced in one or all of as many as four different ways: 1. By fertilization of two polar bodies. 2. By premature separation of one or more blastomeres from a segmenting ovum. 3. By cleavage of the embryonic area. 4. By double gastrulization of the blastodermic vesicle. Moreover we must recognize the indisputable occurrence occasionally of an ovum with double germinal vesicle (two nuclei). Boveri has suggested the additional possibility,—actually demonstrated on eggs of sea-urchins and bees—that a sperm may occasionally unite with only one half of a precociously divided ovum, leaving the other half to develop parthenogenetically (Danforth). Recently Professor R. S. Lillie has suggested that the process of development is basically regulated by some physiological influence of a repressive or inhibitory kind comparable to chemical-distance action, which is indeed essentially a form of bio-electric control through potential-difference. We have already noted the existence of purely nutritional and hormone factors in the developmental period; and we have Newman's general observation that in human twins, "twinning is by no means a single fixed process, but is highly variable, evidently beginning earlier and being more complete in some cases than in others."

Now these various suggestion do not suddenly clarify the problem of correspondences in twins, but they do make more intelligible the distribution of correspondences and disparities which is actually found; and they do not necessitate the denial of a relatively frequent occurrence of monozygotic twinning.

From Journal of Heredity, Vol. X, p. 409.

FIGURE 21. TYPICAL DUPLICATES

Very pertinent to the whole question of resemblance of twins is Newman's theory of somatic segregation. The conception of specialization of resemblance is dependent, of course, upon some kind of unit character method of hereditary determination; but Newman holds that although every character has a genetic basis in the zygote, "the exact expression of character is dependent upon developmental or epigenetic factors that vary in each individual case."

For this reason there may be disparities between two sides of an individual, disparity even in the friction ridge patterns of his two hands; or a disparity in stature as we have noted in our case of hemi-hypertrophy. Such asymmetries are expressions of differentiation through somatic segregation.

"The unilateral appearance of an inherited unit character, such as a friction-skin pattern, almost certainly implies some unilaterality in the somatic distribution of the differentiating factor for this character. Whether the character appears in one or in both of a pair of twins (which are genetically equivalent to the right and left sides of a single individual), or, finally, whether it appears in one, two, three, or four of a set of armadillo quadruplets, depends on whether the differentiating factor is distributed during the earliest cleavage in a unilateral or bilateral fashion; in other words, whether, with respect to the differentiating factor in question, the earliest cleavages have been equational or differential."

In brief, the early somatic divisions in the genesis of twins may be fully as important agents in segregating unit characters, as are the germinal division which characterize the maturation of the gametes. Specialization of resemblance in twins is consistent with this view, but it is also quite consistent with a monozygotic interpretation of twins which reveal numerous fundamental correspondences.

The statistical facts concerning specialization of twin resemblance investigation will serve as a wholesome deterrent of rash generalization; but they should not prevent us from recognizing thoroughgoing similarity when it actually presents itself. After all, an accumulation of numerous specialized resemblances with a few exceptional disparities, in two paired individuals, amounts practically to duplication.

To a clinical psychologist who is so constantly impressed with the differences which obtain both among normal and abnormal individuals, it seems almost like a violation of the laws of nature to find in one afternoon two personalities which are practically indistinguishable. From the biological point of view, however, there is no reason why such instances of almost complete duplicity should not occasionally occur. The germinal and the somatic determinations of development may be so nicely balanced during the period of conception and cleavage, that we may have two persons who, psychologically as well as morphologically, stand for but one individual to the pair. Of the case of A and B, described in the foregoing pages, Shakespeare might again have said, "The apple cleft in two is not more twin than these two creatures."

AUTHOR'S NOTE: The reader of this article may be acquainted with an interesting pair of twins. The author will be grateful to receive any letters or photographs, bearing on the problem of physical and mental resemblances in twins. He is particularly interested in developmental correspondences observed in infancy and childhood. Address: Yale University, New Haven, Conn.

LATENT LIFE, OR, APPARENT DEATH

By Professor D. FRASER HARRIS
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TO the ordinary person nothing seems easier than to be able to distinguish between life and death, or to be less abstract, between a living animal and a dead one. A child can tell a dead tree in the woods when it sees one. A person naturally thinks of the entire organism as alive, the signs of its life being that it is warm, that it breathes, that its heart beats and that it is aware of its surroundings, all of which is in sharp contrast with the cold, still, unconscious corpse in which the beating of the heart has ceased for ever.

If asked to say whether an animal lying in the road was alive or dead, we should at once try to arouse it, stimulate it as it is technically called, and if, on its receiving the stimulus—a shout, a pin-prick, a touch with the boot—the animal jumped up or turned over, you would at once say it was alive; if it failed to so so, you would assume it was dead. In physiological language, an animal on being stimulated if alive will respond in some way or other, if dead it will not. Exactly the same reasoning applies to the isolated tissues, heart, muscle, etc., of the body; if they are alive they respond to stimulation, if dead they do not.

Response or reaction to the environment is then the great criterion of life; this property of being able to respond to a stimulus is called affectability or irritability. A dead organism having no affectability, fails to respond to stimulation; it is dead to the world. Response to stimulus is the chief test of livingness whether of individual, organ, tissue or cell.

Now we can state quite precisely the differences between a living animal and a dead one, for at present we are leaving plants out of account.

A living animal organism is characterized by the following capabilities or powers:

(1). It can feed, that is assimilate to itself material (food) chemically often quite unlike the composition of its own tissues, for cannibalism is not exactly a common custom. This digestion and incorporation involves excretion, or the getting rid of material useless or injurious to the organism. The one word "metabolism" covers all the changes wrought on matter by a living being.

(2). It can transform the potential energy of food into the kinetic energy of heat (animal heat), movement, nerve-energy and electric current. A living organism under this aspect is an energy-transforming machine.

(3). It is able to resist infection and, within limits, all agencies tending to compromise its integrity. It can manufacture anti-bodies, as they are called; they are biochemical responses to biochemical insults.

(4). The living body has a life history; it has birth, youth, prime, senescence. In other words, it goes through an orderly sequence of irreversible phases. Every living thing springs from an egg or ovum, which, being duly fertilized, enters on a course of evolution or progressive unfolding of its tissues from the simple to the complex, from the few to the many, from the immature to the mature. The living being is never stationary; it has time relations. It is interesting to note that amid this constant change of material, the personality or identity of the organism is maintained.

(5). Finally, it can reproduce itself: clearly all organisms that are to survive must be capable of reproducing their like. Except in the lowest forms, where buds can be cast off and thereafter attain to the likeness of the parent (asexual method), the method is the sexual, which requires the congress of two physiologically different individuals, the male and female parents from whom proceeds the new organism.

None of these things can a dead organism do; it can not feed, nor excrete nor produce heat; it passes through no sequence of events, it can not reproduce itself, and finally it putrefies. Death, then, is the permanent impossibility of exhibiting the characteristics of vitality; it is an irreversible state. In the author's terminology, death is a state of infinite physiological inertia, the biological antipodes of affectability.

Livingness is exhibited not only by entire organisms but by their constituent tissues and cells. For tissues and cells can feed, excrete, produce heat and electric current, give rise to anti-bodies, and, finally, produce new elements. The reason for the life of the entire individual is that each of its ultimate constituents is alive.

In judging of the livingness of isolated organs, tissues and cells we must have some convenient method capable of being followed out in the laboratory. The signs of life in the laboratory are, for instance, in the case of muscle—it absorbs oxygen, it gives out carbon dioxide, it produces heat, it twitches or contracts, and finally it can evolve an electric current.

Of all these signs of life, the one mentioned last is by far the most delicate, for tissues which have long since ceased to exchange gases with the atmosphere and even to produce detectable heat, can still give an electric current on being adequately stimulated. The isolated heart of the frog or tortoise, for long after its gaseous exchanges and heat-production are imperceptible, can yield distinct electric currents to that sensitive instrument, the galvanometer. Even after the heart has ceased to beat, as far as the unaided eye is concerned, it can still spontaneously evince electric disturbance; tissues other than the heart of course need first a stimulus. The evolution of electric current is, then, the most delicate sign of life, and it is also the last sign.

But it is also the first sign of life, for Professor A. D. Waller, the English physiologist, has shown that the hen's egg will give an electric current just as soon as the almost invisible speck representing the future chick is constituted on the surface of the yolk. Such widely different things as brain, liver, heart, muscle, eye, seeds, green leaves, fruits and sea-weed will, on being stimulated, produce an electric current. These currents are of course of very feeble voltage; only in electric eels and other fishes are they so powerful as to cause the death of other animals. The electric current, since it is producible as soon as a being can be said to be alive at all, and since it can be recorded long after every other sign of life is gone, has been picturesquely called the alpha and omega of animate existence.

Now it is clear that there must be *degrees* of livingness in tissues, for, whereas some like liver and heart are intensely alive, others such as the upper layers of the skin have little vitality and yet others—enamel of teeth and horn of nail and hair—are absolutely dead. Thus when Horace said "non omnis moriar" he was not even altogether alive.

It is similar with entire organisms; we can construct a scale of all degrees of livingness from the great physical and mental vitality of a Helmholtz, a Gladstone or a Kelvin at one end, down to the somnolent stupidity of the country yokel at the other. Furthermore, vitality undergoes diurnal variations, being at its maximum at about ten o'clock in the forenoon and at its minimum between 3 and 4 o'clock a. m., a time when it is well known those who are moribund usually die. Napoleon, whose saying that an army marched on its stomach is based on sound physiology, used to say that what concerned him was the state of a man's courage at 4 a. m.

Compare the degree of vitality enjoyed by a eupeptic young man just returned from a holiday with the depression of the hopeless sufferer from melancholia. In melancholia all the tissues are demonstrably less alive, less oxygen is absorbed, less carbon dioxide excreted and less heat evolved.

Dr. Waller has shown that a green apple gives on stimulation a more intense electric response than a ripe one, for the excellent reason that it is younger, less mature. But that it not all: if the green apple and the ripe one be very nearly killed by having had sent through them a very violent electric stimulus (shock), both apples for a time will be unable to show electric current but the young apple will revive sooner than the the older one. The analogy with human beings is surprisingly close.

Medical thought at the present time is greatly interested in that other sign of vitality, namely, resistance to infection, the power of making anti-bodies of which the class called anti-toxins is the best known.

New vegetables and animals can enter into a certain state in which, although they are not showing any of the ordinary signs of life, they are nevertheless not dead: this state is called latent life. The only sign of livingness exhibited in latent life is the electric current of Waller: in all other respects the organisms or tissues may be regarded as dead. They are taking in no oxygen, giving out no carbon dioxide, evolving no heat and are performing no movements, so that the condition is also called apparent death. A dried seed is a good example of this condition; it seems dead, but the ordinary person can ascertain whether or not it is dead by planting it in the ground and waiting until it has or has not produced a plant. If it produces a plant it was alive, but we have lost our seed, although we have gained a plant. Similarly, to know whether an egg is alive(impregnated) or not, "wait and see" if it hatches; if it does it was alive, but again we have lost our egg if we have gained a chick. Waller's method with seeds or an egg is to send a strong (electric) shock through it; if it produces an electric response it is alive. Not only has Waller used the electric response as a sign of life, he has also made it a quantitative measure of the degree of vitality. He selected a number of seeds of Phaseolus from one to five years old and tested one of each age for the production of electric current. The responses in fractions of a volt were for the five years respectively—0.0170; 0.0052; 0.0043; 0.0036; and 0.0014—a very remarkable demonstration of the statistical aspect of livingness. The older the seed the less the response; it is what one would have supposed, but it could not be taken for granted.

These seeds were dry, they were to all intents and purposes dead; they were lying in a pill-box doing nothing vital, but they were not dead, they were in latent life; they could germinate and they could produce electric current. Drying is an excellent method for sending many living things into la vie latente. It used to be asserted that wheat found in mummy cases could germinate. Mariette, the Egyptologist, definitely denies that this wheat can do so; placed in water it becomes a clayey pulp. It is true, however, that seeds of the gorse have germinated after being 30 years in latent life; seeds, after 87 years in a herbarium have sprouted, and seeds kept for 200 years have actually produced plants. Becquerel, the French naturalist, submitted the seeds of wheat, mustard and lucerne to the following drastic treatment—having perforated the seed-coats, he dried the seeds in a vacuum at 40° C. and sealed up the seeds in a tube almost exhausted of air for one year, submitted them to the temperature of liquid air (minus 198° C.) for three weeks and of liquid hydrogen (minus 250° C.) for three days and then placed them on moist cotton wool, when they germinated! Some fairy tales are not so interesting as this.

But it seems that even animal organisms can enter into latent life. Ever since 1719 we have known this, for the Dutch naturalist, Leeuwenhoek, found minute animals called Rotifers dried up in mud apparently dead but able to live again when moistened with water.

This rising as it were from the dead is called Anabiosis. Besides the Rotifera, or wheel-animalcules, other minute animals the Tardigrada, or bear animalcules, the Anguillulidæ, or paste-eels, and some kinds of thread worms are all known to be able to survive extreme degrees of desiccation for as long as twelve years. These animals are in a state very closely resembling death, but it is not death for it can be recovered from. Death is the permanent impossibility of living again; it is an irreversible state which latent life is not. From death Science knows no recall, no resurrection, but from latent life it does. From it an organism can either go back to full life or on to death. Latent life rather than sleep is the image of death.

Obviously, only simple or lowly animals can live after being dried up; and yet the wheel-animalcules are not so extremely simple seeing that they have a nervous system.

A much more widely applicable method of sending organisms into latent life is that of cooling them. By abstracting their heat, a large number of very different sorts of plants and animals can be so devitalized as to become apparently dead; that they are not dead is known only from the fact that on being thawed they can evince the usual signs of life.

The bacteria, the simplest of all plants, show extraordinary resistance to refrigeration, for it has been proved that they can be frozen down to the temperature of liquid air and yet retain their vitality. The late Professor MacFadyen chilled certain disease-producing organisms down to the temperature of liquid air and made them so brittle that they could be powdered up in a mortar, but after all this severe treatment it was found that on being thawed, they had retained all their disease-producing properties. The bacteria of putrefaction have been frozen at the temperature of solid alcohol and have yet on thawing retained their full capacity to cause putrefaction. These frozen bacteria were evidently not dead but only in latent life. The fact that the "germs" of decomposition of meat can be sent into latent life by being frozen is taken advantage of in the commercial process of cold storage. The beef is dead and, as we all know, liable to putrefy unless it is frozen. Were there no germs of putrefaction on the meat it would not putrefy; but it does not "go bad" on its journey from the Antipodes because the germs of putrefaction on it are by the refrigeration sent into latent life. That they are merely in suspended animation and not dead is proved by the familiar fact that as soon as the meat is thawed out, it will "go bad" with great rapidity which means that the bacteria on it and in it have returned to their active vital condition of fermenting or decomposing the meat.

Recent research on the preservation of fruit in refrigerators has shown that the spores of the Black Spot fungus can be kept for six months at minus five degrees centigrade and yet germinate at ordinary temperatures. It is a curious fungus, for its optimum temperature is as low as zero centigrade. The whole problem of the storage of fruit is being studied in the light of recent work in Biology. Fruits—apples and pears—pulled off the tree and kept for some time are still alive; in fact they are still breathing, that is taking in oxygen and giving out carbon dioxide; they are not dead, they are not even in latent life. They are not dead because, for one thing, they are not putrefying, and in fact their tissues and ferments are still too active to permit of them being described as in latent life. They are, as everyone knows, ripening, and this consists in their ferments forming sugar out of un-sweet materials. By being chilled, however, fruits can be brought into latent life which is evidently the condition to have them in if storage for a long time is desired.

Apples keep best at one degree centigrade; freezing the fruit destroys it because it breaks up the structure of the living cells and kills them and so prepares them for active decomposition. Of course, to freeze a solid mass like an apple requires a temperature lower than the freezing point of water (0° C.). Apples are found to live best, that is "keep" best in an atmosphere containing more oxygen and much more carbon dioxide than does the ordinary air.

Coming now to the animal kingdom, we find that by the application of cold many organisms can be sent into latent life. Sir Ernest Shackleton has reported that in the South Polar seas there are certain lowly marine organisms frozen motionless in the ice for ten months in the year, but able to swim about actively for the other two. They pass alternately from life to latent life, from apparent death to life; they have a yearly anabiosis. As one might expect, the cold-blooded animals survive degrees of refrigeration which would kill the warm-blooded. Physiologists know that snails, water-beetles, insects, frogs and fish can withstand temperatures so low that warm-blooded animals would be killed outright.

Sir John Franklin in his Polar Expedition of 1820 reported on carp fish frozen so hard that the intestines of some of them could be taken out en bloc, and yet that others of the same batch of fish revived and moved actively when thawed before a fire. Fishes frozen in a block of ice at minus 15° C. have been known to survive although the bodies of some of their companions were so hard they could be powdered up along with the ice. A fish has been frozen in a block of ice, then sawn in half along with the ice and each half has, on being melted, performed active movements.

The louse (Pediculus) has been known to be alive after no fewer than seven days submersion in freezing water. The frog is an animal that can withstand being frozen without being killed. It is possible to exhibit at the beginning of a lecture on physiology a frog frozen so stiff that it can be held out horizontally by the toes like a piece of board and yet, on allowing the frog to thaw, to show that it can skip about before the end of the hour like any other healthy animal.

On the approach of winter frogs descend into the mud at the bottom of the pond and there rest in latent life until next spring; this is their form of hibernation. In all probability they are not frozen stiff, but their life processes must be at an exceedingly low ebb. Snakes behave in a similar manner.

The French scientist Pictet has stated that frogs can endure a temperature of minus 28° C. This seemed to the writer so very low a temperature for frogs to live through that he made a number of experiments on the subject to gain further information.

He found that frogs could be frozen stiff as regards their skin and muscles and yet remain alive inasmuch as their hearts were still beating although probably not carrying on an efficient circulation of blood. It was found that if ice formed around the internal organs and especially around the heart, they could not survive. It was shown that, in the case of a frog whose mouth temperature had been minus 7.5° C. for three hours, and whose heart had stopped beating, that the muscles of the eyes and of the tongue would still respond by twitching when stimulated by powerful electric shocks. It was found that the duration of chilling had an important effect, a frog whose internal temperature was minus 10° C. was alive at the end of the first hour but not at the end of the second. Temperatures lower than minus 10° C., if the frogs survived them, could have been endured only for comparatively short periods.

When we come to the warm-blooded animals, we find that, as might be expected, they cannot withstand anything like the extreme degrees of drying and chilling which the more lowly and hardy animals are able to endure. Nevertheless tissue changes can become so depressed in some of the warm-blooded animals that a state of virtually latent life can be entered upon. Such a condition is seen in the hibernation or winter sleep of bears, tortoises, hedge-hogs, dormice and marmosets. On the approach of winter these animals, having already laid on a large store of fat, retire into some place of shelter, and, ceasing to breathe, go into a deep sleep until the spring. The amount of oxygen they consume is the irreducible minimum, the heat they evolve is very small; they live on their own body-fat and other tissues, for of course they eat no food at all. When they emerge next year they are extremely thin. We learn from these cases of hibernation that even after breathing ceases, the animal may yet live; but it may surprise some readers to learn that even after the heart has ceased beating the organism does not necessarily die all at once. The fact is, many of the tissues of the body live for a long time after the body as a whole is dead. In more technical language this is local life after somatic death. Thus some muscles live for hours, and the skin and hair-roots live for days after general or somatic death. It is well known that if the face be shaved *immediately* after death, that the hairs will have grown to a perceptible extent within the next day or two. In regard to the human being, we pronounce the person dead when breathing has ceased and the pulse is no longer perceptible. The breathing may be so slight that only by the moisture of the breath condensing on a mirror can it be known to be going on. Shakespeare alludes to this in King Lear:

> I know when one is dead and when one lives;
> She's dead as earth—lend me a looking glass.
> If that her breath will moist or stain the stone,
> Why then she lives. (Lear, Act V, sc. 2).

Though the pulse at the wrist be no longer felt, yet the heart may be alive, fluttering rather than beating in such a condition that if we could get at it and massage it, it would revive to some extent for a time at least. This possibility is now made use of by the surgeon whose patient's heart may stop during an abdominal operation. Without loss of time he inserts his hand into the wound and strikes the heart a few gentle blows through the diaphragm with the result that the heart sometimes recommences beating.

It may be now asked, can a human being enter into the state of latent life? The answer is "Yes;" but in so replying, we must recollect the kind of suspended animation which is compatible with the delicate protoplasmic structure and the complicated chemical behavior of human tissues. No mammal, no human being can be dried up or frozen stiff like some of the lowlier creatures and yet live. What we may admit is that life in man can be retained when all the vital processes have sunk to a minimum.

What is known as trance or narcolepsy is the form which latent life takes in the human being. Every now and again we hear of cases of persons, usually young women, going into profound and prolonged sleep from which they do not awake for weeks or months. During that time they take no food, they scarcely breathe, their heart's action is at a minimum. This is of course quite different from the hypnotic or mesmeric trance. Some people fear this state of trance very much; they are in dread of falling into it and being buried before they are really dead. Hence they insert explicit injunctions in their will that their physician is to open a vein or in some other way assure himself that they are dead before burial is permitted.

It is doubtless true that certain persons have been buried alive in the sense that while the heart's action was still at a minimum, they have been placed in a coffin. Stories of persons "laid out" for the undertaker, and reviving on his arrival are not unknown. Some persons have revived on the bier; but the number of persons buried while the body as a whole lived is in reality very small. Moribund persons have been buried at times of great confusion during plagues and epidemics.

Possibly the most famous case of narcolepsy is that of Colonel Townsend of Dublin which has been described by the well-known Dr. Cheyne:

> He could die or expire when he pleased, and yet . . . . by an effort he could come to life again. He composed himself on his back and lay in a still posture for some time . . . . I found his pulse sink gradually, till at last I could not feel any by the most exact and nice touch.
>
> Dr. Baynard could not feel the least motion in the breast nor Dr. Skrine perceive the least soil on the bright mirror he held to his mouth . . . . could not discover the least symptom of life in him. We began to conclude he had

carried the experiment too far, and at last we were satisfied he was actually dead . . . . By nine in the morning . . . . as we were going away we observed some motion about the body, and upon examination found his pulse and the motion of his heart gradually returning; he began to breathe heavily and speak softly.

Still more extraordinary are the narratives of the Fakirs of India who are said to allow themselves to be built up in sealed tombs for weeks without food and to be alive at the end of that time. Reports of these cases of human suspended animation are now too numerous and too well authenticated by European eye-witnesses of unimpeachable integrity to be set aside as either in themselves untrue or as due to collective hallucination.

Many people if asked to give an example of suspended animation would refer to the case of some one apparently dead through drowning. Strictly speaking a person rescued from drowning may be moribund, but not quite dead; there is, in physiological language, enough local tissue life present to ensure the living of the entire organism provided oxygen be got into the blood and so to the tissues before they utterly perish. Therefore, still speaking strictly, a drowned person is *not* in latent life, not in a condition which can be kept up indefinitely and which will pass into full life in due time. On the contrary, a drowned person is dying; but most fortunately, the several tissues do not die the moment the individual as a whole dies but can survive long enough to be revivable if only enough oxygen can reach them sufficiently soon. Of course, it all depends on the heart and nervous system; if the heart is dead the individual cannot live again; if the heart, though moribund, is capable of absorbing oxygen and of beating again, the individual will live provided also his central nervous system and particularly the center for breathing is still alive. In the actual practice of "first aid," it is well to assume that the person is alive and to persevere with artificial respiration while keeping the body warm for as long a time as two or three hours before pronouncing life extinct.

The tales of frogs being found alive in the midst of blocks of marble just broken open in the quarry have been the subject of much controversy but they are not now credited.

The latent life of isolated tissues is a remarkable phenomenon. Alexis Carrel of the Rockefeller Institute of Medical Research has actually been successful in causing tissues isolated from chick embryos to grow in glass vessels in a drop of blood-plasma for as long a time as two or three years at ordinary temperatures. When, however this "culture" was placed in a refrigerator all growth was stopped, and as long as it was chilled, it exhibited no growth, the isolated tissues having gone into latent life. Fragments of heart muscle can similarly be kept in vitro for two or three months; these beat spontaneously during all that period but ceased beating when sufficiently chilled.

In some few cases latent life seems to be capable of being entered upon after drastic treatment with certain chemicals. The insect, the louse, is a case in point. A recent writer from Russia thus describes its powers of resistance: "The louse is one of the hardiest and most prolific pests: the majority of disinfectants and insecticides he scorns; he can survive having drops of pure alcohol or chloroform dropped on him."

The state of latent life may be regarded as a condition of high resistance towards those conditions which make for death. Abstraction of water and of heat are both of them conditions tending towards death; they involve speedy death in many organisms. But such animals or plants as can reduce their metabolism (respiration and heat-production) to the irreducible minimum may escape death in the half-way house of latent life. It is apparent death, not real death which is a condition that can *not* be recovered from. In the author's terminology, the property of affectability has fallen to a minimum, that of physiological inertia has risen towards a maximum, the absolute maximum being reached in death itself.

All poisons tend to kill protoplasm, to immobilize it; death is the complete immobilization of living molecules; whereas latent life is a degree or stage towards this end. Any agencies like desiccation or refrigeration, or reagents like alcohol or chloroform which diminish molecular mobility, tend to render life latent and thereafter to extinguish it. Upon this partial immobilization depends the efficacy of a large number of our drugs and the action of many poisons. To abolish consciousness we administer chloroform, a substance which, by uniting for a time with certain of the chemically active radicles constituting protoplasm, immobilizes more or less completely the whole molecular complex. The immobilization of the molecules of the cells of the brain has as its psychical correlative the disappearance of consciousness. The anæsthetic really tends to immobilize the brain cells, the cells of the breathing center and the heart cells; what the surgeon wants is cerebral immobilization with its counterpart unconsciousness to pain without heart paralysis which would mean death.

The organism in latent life is not dead for it is capable of manifesting once more all the vital attributes which no dead thing can do. It is however very far from being fully alive, for it may be manifesting none of the attributes of livingness save the possibility of developing a feeble electric current which can be detected only by a delicate apparatus accessible to biological experts. It is not dead however much it looks it.

In living matter, the molecular whirl is at its intensest; in latent life the molecular whirl is for a time arrested; in death the molecular whirl has been stopped for ever. In life the dancers are in the mazes of an elaborate figure; in latent life each individual is standing stock still; in death every dancer has fallen over. In latent life the weights of the protoplasmic clock have been seized by a mysterious hand; in death they have descended to their full extent and can not be wound up again, for the cord is broken. In latent life there is only a stoppage, in death the end has been reached. In life "the sands of time" are running out rapidly; in latent life the stream has stopped; in death the sand is all in the lower globe.

In a sense very different from what the author of the lines meant it, yet in a sense profoundly true:

> 'Tis not the whole of life to live,
> Nor all of death to die.

THE HISTORY OF CHEMISTRY IN CHINA

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THE writer recollects in attending his first course in industrial chemistry that the lecturer introduced each subject with the statement, "This substance was first discovered by the Chinese." There were but one or two exceptions to this order of service. More recent studies have caused an expression of a shade of doubt as to the truth of all these claims made in behalf of the Chinese. The people of China did early develop a skill in dyeing, glass-making, manufacture of gunpowder and fire-works, preparation of cements, etc., and this implied a knowledge of some sort of chemistry. The early Chinese knew the distinction between green vitriol and blue vitriol; while Pliny as late as the first century A. D. confounded the two. They had indigo at a very early period and used it in dyeing. They are responsible for many things long before the European world had developed a need for them; but, on the other hand, the tendency has been to consider the hoary annals of Chinese history a convenient dumping ground for disposing of clouded beginnings.

In tracing the early sources of science, it should be noted that there were three distinct centers of almost independent developments—first, India; second, China, and third, the Egypt-Arabia-Europe area which is our own. The Hindus claim responsibility for being the teachers of both China and Europe in cultural matters, but there is doubt as to the validity of their claim, and there seems little ground for believing that in the development of chemical concepts these three areas were very closely related. It is of no small importance to discover that each of these three spheres developed a similar attitude of mind toward natural phenomena and went through the same steps of growth independently.

China likewise began with an age of alchemy; this was followed by the age of the iatro-chemists. These periods in each case were somewhat in advance, chronologically, of our own. An elaborate system of medicine was developed and mercuric chloride was used as an antiseptic in surgery, though there is no ground for believing that the Chinese had any idea of the principle of sepsis. This is but one of the many examples in China where practice far out-ran theory till theory was left hundreds of years behind. China's ancient bridge-building and canal construction are other examples. The period of the iatro-chemists held sway in China till the close of the nineteenth century, and the modern period has just begun. Two hundred years ago, China and the occident were probably at the same milestone in chemical science. It is just during the last two hundred years that we have forged ahead and the Chinese have stood still.

Age of Alchemy

The alchemists, as in Europe, began with an interest in the metals. The copper age came to China possibly a little earlier than to the occident, and the working of copper ores and the preparation of its alloys were well known at an early period. Alchemy received form as a distinct art about 1100 B. C. The important metals were five in number—gold, silver, copper, iron, tin. Lead was known but used only as an adulterant of tin so was not dignified by a place among these five. Mercury was likewise known; its common name was and is still *water silver*. These five metals for centuries and centuries were *the* metals. It is of note that in present day Chinese parlance the name for hardware store means when translated *five metals shop*.

With the five metals begins the evolution of the idea "element." The Chinese seem to have been desirous very early to reduce everything to a primary substance, to resolve all compounds into elements. Loa-dze, the Aristotle of China, dates at 700 B. C.; our Aristotle is usually dated 350 B. C. The terms "element," "original substance," etc., are frequently used, and scores of volumes in the literature of older China discourse upon the original primary substance, though with scant experimental support. The five metals were regarded as convertible one into the other; a variation of this idea makes lead a complex which may be changed under proper conditions into any one or all of these. This belief grew from the fact that the galenites of China invariably contain a good sprinkling of all these five metals.

Atomic Theory

The clearest atomic theory makes all compounds and substances reducible to a single substance which is a gas. This gas may recombine with itself and assume various forms and groupings. These are the secondary elements and one philosopher likens them to vortex rings. These now are of two kinds, either positive or negative principles. Combination between a negative and a positive may take place, and all the simple material substances are formed in this way. The theory has a flavor slightly like onr present-day ideas of the constitution of the atom. It is doubtful whether there was any more experimental evidence in the hands of the Chinese to support these ideas than was possessed by Heraclitus with his early fire-air-earth-water theory. It is quite certain, however, that the Chinese did have more actual experience with chemical substances and with what we now call chemical industries than had these sages of ours. This theory was put into its final shape in China about the tenth century.

Gunpowder was one of the substances which the Chinese had early discovered. It was typical of substances whose action was readily explained by this theory; a certain amount of one substance was mixed with a certain amount of another, and positive uniting with negative produced the explosion.

One of the commonly used American chemistry texts makes the statement that in the eighth century the Chinese recognized that air was composed of two gases, an active gas which was termed negative and which would combine with metals, sulphur and charcoal. Moreover, it is stated that they knew that a number of mineral substances evolved this gas on heating, among which was salt peter. The writer has been unable to locate the Chinese sources from which all this information is derived. While the idea of positive and negative principles in chemical combination was a well recognized one applied to all sorts of substances, still the above statement is probably couched in modern phrases which give it more of a chemical flavor than the original Chinese possessed.

No very clear distinction, if any, seems to have been observed between compounds and mixtures, and alloys were looked upon as genuine cases of combination. Much study and experiment was directed to the bronzes. In fact, the composition of the ancient bronzes is one of the interesting topics of chemical study in China to-day. The ancient Chinese seem to have gotten it into their heads that a law of simple ratios was required for the best combinations of copper and tin, and the following comprise the "Six Ratios" from a book dated about 1000 A. D.:

Cu:Sn Ratio	Variety of Bronze
5:1	bell metal
4:1	axes
3:1	spear heads
2:1	swords
3:2	knives
1:1	mirrors

This was probably an a priori set of ratios. There may have been some experiment attached, but the theoretical ratios for the manufacture of these different bronzes was not strictly adhered to in practice as recent analyses have shown.

It is of note that zinc and antimony—and China is the present day home of the antimony industry—were identified very late among the metals. Zinc was originally confounded with lead and afterwards became known as *secondary lead* which term it carries in the spoken language of to-day. No mention of antimony is found in the old literature.

The substances derived from the metals—like blue vitriol, the oxides, etc., were all recognized as definite compounds and the Chinese also evolved a "phlogiston theory" proposing a fire element to explain this relationship. This was several centuries before the labors of Becker and Stahl! It was a very obvious method of explaining their observations, since the Chinese possessed almost none of the chemical reagents, acids, etc., which our alchemists used, and heat was the universal agent used in most transformations.

It would be impossible to even touch upon the metallurgy of the ancient Chinese. This had been made a study for centuries and had been reduced to a well-polished art. The actual methods can still be observed in use in China to-day, moreover they are essentially the methods which were in use in Europe before modern industry appeared. A modern metallurgist has suggested that the Chinese discovered the pneumatic method for the manufacture of steel at an early date, and that this accounts for the phosphorus content of the famous Shansi steels.

Age of Iatro-chemistry

Iatro-chemistry reached its high-water mark in the fifteenth and sixteenth centuries. The study of medicine had been assiduously followed by the Chinese down the ages, and the original edition of the *Ben Tsao Gang Mu,* the materia medica used at the present day, was written by old Shen Nung at about 2800 B. C. He is the Chinese "father of medicine" who corresponds to our Hippocrates of about 450 B. C. The original of this materia medica contained mention of one hundred substances. Through later revisions, it has been enlarged to include about six hundred, of which one hundred and thirty-three are inorganic substances. It was put into its present form about 200 A. D.

Many of the inorganic compounds were made directly from the metal, and considerable stress was laid on the purification of the original metals. The methods of amalgamation and cupellation had been both used since ancient times. The important inorganic compounds included blue vitriol, copper carbonate, copperas, the iron salts, tin oxide, white lead, red lead, litharge, and all the common mercury compounds. The methods by which they were made are similar to those our own alchemists employed. All these methods in remarkable detail are to be found in this *Ben Tsao Gang Mu* which is the handbook in every Chinese drug shop.

White lead is manufactured from little lead plates by a method which is the Old Dutch process in its essential features. China and Holland did have some intercourse in ages back and the suggestion has been made that the Old Dutch process may have come from China.

Practical chemistry in China was held back considerably by the fact that the acids and alkalis, except soda and acetic acid were unknown. Sulphates were prepared by oxidation of the sulphides, and although they did not have sulphuric acid, they were able to bring about the same reactions by using blue vitriol and green vitriol at high temperatures.

Errors of Chinese Scientists

Characteristic of the Chinese "scientists" down the ages is that they lacked the inductive method. The philosophers constantly preferred a priori deduction and have reasoned everything by analogy. It seems that they truly had glimpses of the experimental method but deliberately chose the other. A group of natural philosophers arose in the eighth century, whose leader Cheng declares: "You must examine one thing to-day and another thing to-morrow, and when you have accumulated a store of facts your knowledge will burst its shell and come forth into fuller light, connecting all the particulars by general laws." If China had only taken seriously the thoughts of this school instead of deliberately discarding them, we, the occident, might be the student instead of the teacher in the modern school of science.

In addition to this, there is the spirit of inaccuracy which is one of the most real characteristics of Chinese life, which is not so much the cause as it is an attendant feature of China's backwardness in scientific matters. China has a fine system of decimal units, theoretically. But practically, while ten inches always make a foot, a foot may be one of fifty different standards, depending upon what it is that it is desired to measure, cloth, or silk, or timber, etc., and according to the standard used it may signify a length varying from 10 to 16 English inches. Distance along a road is not absolute, but depends on another factor:—is the road easy traveling,—is it through flat, or through mountainous country. A mile up hill is shorter than a mile downhill. There is a very nice practical philosophy behind some of these things, but they all point to an attitude of mind which has tended to retard a desire for accurate measurement and accurate thinking.

Conclusion

The above is but a rapid summary of some of the early accomplishments of the Chinese in the field of chemistry. The available Chinese literature has only been superficially touched. It is hoped an interest in more exhaustive studies will be roused.

It is evident that there were early minds at work in China on chemistry, and while difficult to assign dates to each of the important forward steps, it seems clear that previous to the seventeenth century China held her own, and in point of time was possibly a little ahead of Europe. It seems also true that early Chinese investigations were not more entangled with superstition and necromancy than were the European. Chemistry in China stopped growing about three hundred years ago, and admittedly the glory of past achievements fades because the Chinese failed to give their findings to the world.

THE LARGER HUMAN WORTH OF MATHEMATICS

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MATHEMATICAL thought has exercised over my spirit a fascination which is far-reaching in its effect upon my activity and happiness. It is not an easy matter to present the characteristics of this thought to one who has not been initiated into the remarkable secrets of the science; indeed the difficulty is so great that the task has seldom been attempted and not always with happy consequences. And yet I have felt that I could not fail of moderate success in this matter if I could reflect with any skill the enthusiasms of my own delight, since I believe that the fire of natural and spontaneous interest in one mind has the quality of producing a corresponding exaltation in another.

There are elements of mathematical thought which illuminate my spirit with a brilliant radiance whose after-images are pleasant to contemplate. Perhaps I can not bring to you now one of these moments of illumination of joy, for one can not produce them to order or easily recapture them but I can hope to present certain after-images which show some qualities of the original.

The impulse for the advancement of knowledge which is both most fundamental and most far-reaching in its practical and ideal effects is that which grows out of the pursuit of truth for truth's sake. What do we mean by this? What do we mean by mathematics for its own sake? It is clear that we do not intend to set up mathematics as a monster which must be worshipped, whom it is our duty to delight with the incense of human sacrifice. We mean rather to direct attention to the human values which are inherent in it apart from its use as a tool in any of the varied ways in which it may be so employed. Our purpose is to focus attention upon its primary values, those which it has in and of itself, those which are intimate to its own character and do not depend upon its uses outside of its own domain.

We are fundamentally so constituted that we delight in knowing for the sake of knowing. It is our most abstract and our most general motive in science. It actuates most powerfully our choicest spirits, moving them sometimes with a fervor akin to that of religion. A marvelous curiosity to know, insatiable and always demanding further satisfactions, creates a longing which can be relieved only by knowledge. It projects itself into the unknown and leads the researcher in ways yet untrodden to a goal which can not be foreseen. At the outer boundary line of knowledge, faint glimmerings may be detected in the darkness of ignorance beyond. What beckons us forth we do not know. Whether it can bring us any good we have no means of foretelling. It may lead us to a tragical something which will make it necessary for us, in much pain, to cast away some of our most cherished prejudices. But, whatever lies beyond in that which is concealed from our present vision,

> We work with this assurance clear,
> To cover up a truth for fear
> Can never be the wisest way;
> By every power of thoughtful mind
> We strive a proper means to find
> To bring it to the light of day.

Systematic and unsystematic thought. In its further reaches mathematics is perhaps the most abstruse of our mental disciplines; but in its first stages it is the simplest of those sciences which have attained permanence of result. Mathematics is the field of thought in which permanent progress is easiest. It has obtained this facility through abstraction. The problems of nature are complex beyond our ability to cope with or perceive. In the first attempt to make progress in the way of definite conquest, we must abstract from the complexity of the situation and attain to a new one relatively much simpler. In fact we may find it necessary to create a new situation having certain analogies with the actual one of nature but being so much simpler that we are able to grasp far more successfully the interrelations of its parts. It is precisely this procedure which has guided the development of mathematics.

It is not that the mathematician refuses to be interested in the immeasurable complexity of nature. It is rather that he seeks permanence of conquest, even though it be at the expense (in the first instance, at least) of a narrowed range of use. The way in which mathematics has interacted usefully with other elements in the progress of thought justifies her method of abstraction as profitable; it certainly conforms to the requirements of esthetic delight for the mathematician himself.

But the abstractions of mathematics leave us in a rarefied atmosphere too far removed from concrete experience to be a satisfactory resting-place for the mind of an inquisitive organism like man. He seeks to get closer to concrete phenomena. But, unless he is content to deal in vague and uncertain generalities, he finds the complexity of nature far too great for him even though he has forged a mathematical tool to assist in his labors. He must still confine attention to certain groups of phenomena abstracted from their surroundings. He must try, so to speak, to lift them from the matrix of their environment. Thus we arrive at the exact sciences of natural phenomena, as, for instance, the science of mechanics, through the use of abstraction as a necessary preliminary to exact and permanent intellectual conquest.

But it is clear that we do not understand even these restricted ranges of phenomena which we have separated in thought but not in reality from their environment until we have considered all the elements in that environment and have synthesized the disjoined knowledge of its parts into a comprehensive understanding of the whole. When we come to these questions of greater complexity we feel less certain of our results and far less confident of the permanence of our conclusions. The history of philosophy with its changing systems and the flux of its emphasis is a striking commentary on the difficulty of the general problem. And even here in the comprehensive problems of philosophy itself large abstraction has already been made from the complexity of phenomena and life and existence.

In definite contrast with the systematic thought of mathematics, the natural sciences, and certain parts at least of philosophical truth and speculation, stands the unsystematic thought of art and literature. Here one deals with the actual complexity of life and even with the character of individuals and their emotions. "It is the privilege of art to represent at a glance the whole of its object, and thus to produce at once a total effect on the mind of the beholder." Not infrequently men of science have seemed to overlook the importance of this body of unsystematic thought in art and especially in literature. But it appears that the development of unsystematic thought is necessary to sanity; not that its unsystematic character as such contributes to this end, but that through no efforts being made at systematic statement one can allow the whole flux of life to be reflected at once, at least so far as to have no purposed exclusions. If one is to have the systematic exactness of pure science it can be only after many relevant considerations are shorn off and attention is fixed on a part only (usually a small part) of the whole. This is necessary to definite conquest and the method is to be freely used. If one stops with this, however, a one-sided unbalanced view results which contributes forcibly to a lack of sanity in outlook and general judgment. With the continued development of systematic thought, let us encourage and support the free development of unsystematic thought in poetry and other forms of literature and art. The latter have abiding qualities of intrinsic human worth which science can never replace.

The domains of systematic and unsystematic thought have usually little effect the one upon the other; and yet between these two great arteries of our culture there must be somewhere a vital connection. The historians of general thought have not yet properly taken into account the vast body of unsystematic thought in the literatures of the world where for millenniums it has awaited their research. Nor on the other hand has the poetry of exact truth been written nor have its cultural elements in any representative case found their way into the general thought of mankind.

Literature not only takes the complex whole of life at a glance but it also internationalizes its local subjects and gives them a value which endures independently of time and place. Mathematics and poetry lie, if not on, at least not far from the extremes, the one of systematic and the other of unsystematic thought, and thus are about as far removed as possible one from the other. And yet they have a very striking common property, namely, the property of permanence. No other large domains of thought than mathematics and literature have acquired large bodies of truth retaining their values essentially unimpaired for two thousand years, not in a stagnant state, but in a state of vitality and effectiveness. It is a matter of great inspiration to see the Greek geometry and the Greek tragedy surviving through the ages and retaining the active power to excite our admiration and increase our happiness to-day.

The language of exact truth. Communication to others requires the previous construction of a language having the requisite flexibility. If we look into the remote origins of our culture we shall find reason for believing that it was language which initiated the marvelous release of the powers of man inherent and undeveloped in our primitive ancestors and coming to their fruition only after many ages of progress. It was and is a fundamental element in accumulating and retaining the heritage of the past so that each new generation, in periods of development, is able to begin a little further on than the preceding one.

There is something subtle in the way in which language makes it possible to pass the experience and thought of one generation along to the next. The phenomena of nature present themselves to us ordered in space and time, but without apparent logical connections to bind them together. As long as we meet them merely in the multiplicity of their separate existences we can not get far towards an understanding of them or of a mastery over them. It is necessary that they shall be ordered into groups or sets, each held together by some tie which serves in our mind either as a unifying or as a connecting element. The combination of distinct elements into a whole and the formation of these groups depends on a process which the mind constructs for itself slowly and only after much labor. Any means of giving a considerable measure of permanence to the constructions of one individual mind or of one age, will be of great value in maintaining mastery and effecting its further development.

Let us conceive, if possible, the condition of prehistoric man at a time when language was in the process of construction for the first time. When a tribe of men reach agreement concerning the common elements of a set of objects, as for instance the trees of the forest, and signalize a realization of their common features by giving to them some such name as tree, they crystallize into definite form a class of experiences felt by each of them in a more or less vague way. The idea denoted by the word becomes more distinct by constant recurrence and both word and idea take their places as part of the mental possessions of man.

This primitive process has been repeated in all ages of our history; it recurs often in the present day, notably in connection with the development of scientific thought. In youth we listen to the words of those of the previous generation, trace in their features some mark of the anxieties through which they have lived, and share remotely their enthusiasms and aspirations, their passions and their joys. But we receive through them in the language which they teach us a more living inheritance and a more eloquent testimonial to their ways of thought. "Unknowingly they have themselves altered the tongue, the words and sentences, which they received, depositing in these altered words and modes of speech the spirit, the ideas, the thought of their lifetime. These words and modes of speech they handed down to us in our infancy, as the mould wherein to shape our minds, . . . as the instrument with which to convey our ideas. In their language, in the phrases and catchwords peculiar to them, we learnt to distinguish what was important and interesting from what was trivial or indifferent, the subjects which should occupy our thoughts, the aims we should follow, the principles and methods which we should make use of."

A word or a way of thought into which so much experience of the race has been instilled can easily be taught to the children of a new generation and be made to serve for them as a nucleus about which they can gather experiences of their own similar to those first embodied in the language. Thus through the various words which they use and the various turns of phrase which they employ they have a subtle means of assistance in organizing their early experience so that they are able to make much more rapid acquisition of knowledge than their ancestors who first had the confusion of unorganized impressions out of which to construct the initial organization of truth.

To the individual who is brought up in a civilized and intellectual age words and their organization into sentences certainly come earlier than clear and conscious thought. Through the use of our parents' tongue we are introduced to the complex processes of highly abstract reasoning in a manner which is truly marvelous. The way of thinking of our ancestors, preserved in some measure in the constructions of their language and in the peculiar ways of expressing thought developed through ages of progress, becomes to us our most precious heritage from the past. A highly significant part of the development of mankind is summarized into the forms and words of language in such a way as to be capable of transmission and to be of unmeasured value in passing on to the children the acquisitions of their ancestors.

What the language of daily life does for the thought of usual intercourse the language of mathematics does for the thought of exact truth. Everything which I have said about language in general I can now transfer to the language of mathematics in respect to its use in connection with exact thought. It furnishes the essential means for the expression of the latter. It supplies the support without which the mind would be unable to carry through the processes necessary to attain the more profound or far-reaching results. There is a certain storing, as it were, of intellectual force in the mathematical symbols from which it can be released suddenly with almost explosive power. These become mighty engines through the aid of which we can rear intellectual structures quite inaccessible to our unsupported power.

The invention of number was the first step in the creation of the language of mathematics; and the choice of adequate and convenient symbols for the representation of integers is one of the chief triumphs of the intellect. A long and arduous mental struggle, in which some of the finest minds of antiquity had part, preceded the conception of zero and the introduction of a symbol to represent it in the way now familiar even to our children. The result of a long and important development of thought is embodied compactly in this remarkable sign. The introduction of a symbol like 4/5 marks a new stage in the development of mathematics. The general fact is repeated in many situations; but I can not go into a further analysis of this matter. It is sufficient to our purpose if we realize that the language of mathematics is an essential support to the mind in all its processes of exact thought and that the results emerging in this way can be expressed only in mathematical terms.

Being a lover both of mathematics and of poetry I enjoy finding certain general similarities between them. I have already alluded to one very striking common property of them, namely the property of permanence. I wish now to direct your attention to the historical fact that poetry was the primary and most important means by which the language of ordinary intercourse was brought to a stage of relative perfection just as mathematics was the essential means in creating the language of exact truth. Ordinary language having been brought to perfection by the labors of the poets was then appropriated by writers of prose; exact language having been developed by the mathematicians has been employed freely by the cultivators of every exact science.

Mathematics and philosophy. Philosophy and mathematics started life together. After a brief period of companionship they parted company and each went its own way. Mathematics was the first science to emancipate itself from the tutelage of philosophy; it gained its freedom at the dawn of Greek civilization. Mechanics next succeeded towards the close of the Grecian period, physics obtained its independent position at the opening of the modern era, biology about the beginning of the nineteenth century, and psychology in its latter half. Sociology as an independent science has hardly yet passed its period of infancy.

When men began consciously to cast about them to understand their universe, they found it possible in a relatively short time to procure and contemplate a large body of unsystematic thought, a wealth of philosophic explanation, and a rather large body of speculative proto-science of nature. But in respect of mathematical knowledge they had to begin much nearer the bottom. In the less exact disciplines there was an ebb and flow of movement with a general progress forward, accompanied often by a discarding of what at one time was considered well established. But in mathematics a conquest once made is almost never lost and there is a consequent unbroken enlargement of doctrine. Since it pushes its conquests out in many directions, is frequently annexing new domains, never yields up what it has once attained, and remains youthful in its spirit of conquest, mathematics is destined to become, if indeed it is not already, the most extensive scientific doctrine in the whole range of knowledge.

Early in the history of thought philosophy soared the heights on wings of speculative grandeur and soon reached an eminence which it has never surpassed. Mathematics took time to dig deep till it was in possession of secure foundations on which to build. Here it reared a magnificent structure of enduring beauty. In our generation this mathematics has reached forth a hand of conquest and has annexed certain restricted domains of philosophy. "The first real advance in logic since the time of the Greeks was made independently by Peano and Frege—both mathematicians" working with the tools and from the point of view of mathematics. In former days the nature of infinity and continuity belonged to philosophy, but now it belong to mathematics. An important part of the theory of classes has been annexed by this greedy conqueror.

But more than all this, it has injected its spirit into a large province of modern philosophy. Among the philosophies of the present day Bertrand Russell distinguishes three principal types, combined in varying proportions in single philosophers but in essence and tendency distinct, namely, the classical tradition, evolutionism, and the method of logical atomism. The last has crept into philosophy through the critical scrutiny of mathematics. According to Russell it represents "the same kind of advance as was introduced into physics by Galileo: the substitution of piecemeal, detailed, and verifiable results for large untested generalities recommended only by a certain appeal to the imagination."

A doctrine which lay quiescent in the domain of philosophy for many generations has recently been brought by mathematical methods into the activity of vigorous life. The modern theory of relativity is a precise physico-mathematical realization of the philosopher's speculation of relativity. The existence of the philosophical doctrine has been of profound value in the creation of the mathematical doctrine; but the latter is now so far in advance of the former that the philosopher is rare who is able to follow the train of thought by which the more exact theory is brought to fullness. This mathematical conquest of a domain of philosophy has in our generation yielded a penetrating insight into certain fundamental matters both of physics and of philosophy. A theory of gravitation, satisfying for the most part in its broad aspects, has come into being for the first time. Under the impulse of this theory our notions of force and mass have suffered considerable change and our conceptions of time and space have undergone a veritable revolution.

Without going into more detail in these matters, I may insist upon the fact that one of the profound intrinsic human worths of mathematics lies in its conquest over intellectual matters of perennial interest on which agreement cannot be reached until they are penetrated by the spirit and methods of mathematics and the invariant elements of truth are extracted and justified by a convincing array of precise evidence.

Mathematics and the foundations of science. Mathematics is autonomous. What is intimate to it, its nature and structure and laws of being, must be sought in itself. Logically the mathematical sciences can be developed in complete independence of all other sciences; and when pursued in this way to their goal they completely realize their object. Owing to its self-sufficiency, its abstract character, and its exclusion of complicating factors from the ideal considerations with which it is concerned, mathematics is essentially easier than the other branches of systematic truth. The appearance of greater difficulty, which has deceived most people, grows out of the fact that it is relatively further advanced than any other subject. It requires the learner longer in mathematics than in other sciences to attain an elevation from which he may enjoy the prospect of unexplored territory. Its wildernesses are further from the confines of civilization; and the ignorant picture them as filled with horrid monsters of indescribable physiognomy. But the hardy intellectual traveler who explores in this land of the far unknown finds nature gracious, there as well as here, in dispensing her beauties and joys and comforts.

As a discipline which is unique through its being more completely developed than any other it may be utilized as an object lesson of importance in the development of thought. The mind has not been able to chart unknown regions and to explore them systematically. Truth, when attained, often has an appearance quite unexpected. Its central characteristics can not be anticipated before it appears in thought. Consequently, the extended development of any discipline affords a means of analyzing the methods and foundations of successful thinking and of extracting by such analysis principles of guidance for all domains of exact thought. In certain important respects mathematics affords just such a support to the mind in finding its way to truth; it has continuously rendered a service of this character since the days of the early Greek philosophers. This contribution has varied in detail from age to age, ranging from marvelous uses in interpreting physical phenomena to marked support in speculative philosophy and the theory of knowledge.

During the last half century or so mathematics has come definitely to a stage of self-consciousness with respect to its processes and presuppositions; and these have been analyzed and subjected to critical logical scrutiny. The foundations on which the subject is built are understood with a completeness foreign to any other domain of thought. From this fact it may well serve as a matter of instruction to point the way to a suitable and needed analysis of the presuppositions on which any given discipline is founded.

The importance of such an analysis seems not always to be apprehended. The sciences of nature are shot through with presuppositions not recognized. Even in the more precise reasoning of mathematics there was much to be elucidated by a critical scrutiny; and certain presuppositions had to be brought into the focus of attention before it could be properly said that we understood the foundations of the science. Elsewhere such analysis has been made only very imperfectly; the success achieved by mathematics in this work has not yet borne its proper fruit. It has been made clear that no science has been brought to a truly objective stage in its development until the presuppositions lying back of it are perceived as such and the grounds for making them are clearly realized. In the sciences of nature this process is more difficult than in mathematics; this, indeed, accounts for the fact of earlier success in mathematics than elsewhere. But when the result is once achieved in one science no other should rest satisfied until the same end is reached in an appropriate way.

Mathematics and the method of thought. Perhaps it will be agreed that we can nowhere study the processes of thought, by which the intellect reaches appropriate decisions, more effectively than in that domain where it has been most successful in attaining enduring results of significant value. If this principle is agreed upon, it is a corollary that mathematics is a field of thought which will yield us some of our most definite information as to the essential elements in the methods of clear and accurate thinking. Unfortunately, mathematicians themselves have generally been but little interested in the broad principles of method which their achievements are capable of bringing to light; they have usually been disposed to stand apart from the broader questions of a theory of knowledge, satisfied apparently with the self-sufficiency of their own discipline. Outside of their fold there has never been a group of thinkers with the requisite information and training to elicit from the body of mathematics the instruction which it is thus capable of affording. This field of promising possibility lies uncultivated while we lack those advantages which its fruitage well may yield.

It is important to ascertain the character of those regions of thought in which new methods have most frequently arisen into clear consciousness. Owing to precision of ideas and processes in mathematics we can answer that question definitely and with considerable confidence for that discipline. New methods have usually come to light in connection with well-defined and well-restricted problems. Experience has forced upon us a realization of the profound importance of deep penetration into even the simplest matters. When a new means of illuminating them has been discovered its radiance spreads to adjacent fields and often overleaps great barriers to shed new light in most unexpected places. The connections between different elements of thought can not be anticipated successfully; it requires the event to exhibit them. The presuppositions which underlie truth become apparent gradually as we derive the remotest consequences of what is already known. For the researcher everywhere the character of the success in mathematics emphasizes the importance of detailed and penetrating and carefully analyzed investigations of basic matters.

The continuous advance in the understanding of the presuppositions of our science; the axioms or postulates on which it rests, and the resulting modifications in our views of its significance impress us constantly with the supreme necessity of the logical coherence of knowledge. No principle is thoroughly understood until all of its consequences are developed and their ramifications are ascertained. This process can be carried out only through the most searching logical scrutiny; it is desirable that the intuition shall be present in discovery, but the logical faculties should dominate exposition completely. "To supersede the employment of common reason, or to subject it to the rigor of technical forms, would be the last desire of one who knows the value of that intellectual toil and warfare which imparts to the mind an athletic vigor, and teaches it to contend with difficulties and to rely upon itself in emergencies." But when its results are once attained and they are to be put to the test of a systematic organization for determining the coherence and consistency of the parts, no glow should be permitted except that which comes from the cold light of logic.

A more deep-lying problem of the method of exact thought is brought out by the question as to the fundamental character of that mental process by which scientific truth is discovered. Natural science always proceeds in one of three ways: mathematically, experimentally, or by hypothesis. Have all these methods fundamental matters in common one with another and with the processes of mathematics itself? And, if so, are they of such sort that it is useful to the progress of science or to our delight in it to have them brought to attention? Owing again to the relatively more advanced state of mathematics as compared with the natural sciences we can consider for it, in a more objective way than for them, this question as to the basic characteristics of the process of discovery.

Not a few mathematicians are agreed that these characteristics are summed up in considerable measure in the word invention. Some of the things in mathematics one may think of as being discovered; but others, and the more fundamental things, seem to have been created by the mind. The positive integers, for instance, were not found in nature but were created by the human spirit. After their creation many of their properties have been discovered. This relation between invention and discovery pervades most of the mathematical literature. Mathematical space has been created, not found in nature, as is shown by the fact that the mathematician has several kinds of three-dimensional space as well as numerous spaces of higher dimensions. It is true that his creative power was released through observation of the environment; but it can not be maintained that the environment dictated the geometry since in that case only one geometry could have resulted. A full analysis of the matter would carry us much too far afield, but we may assert that the process of discovery in mathematics is primarily that of invention.

This leads the mathematician to suspect that the method of exact thought everywhere is largely dependent upon invention, that the hypotheses of science are not extracted from nature but are invented by the mind through a release of its powers brought about by natural phenomena. Since one's procedure in forming hypotheses is doubtless much affected by his conception of the nature of the process it is important that the laborers in each science shall ascertain the corresponding fundamental characteristics of their processes of discovery.

If we should suppose that the advance of knowledge among the most cultivated people is in the direction of making life not worth while this would operate to destroy the part of society so affected with pessimism and the whole earth would ultimately be left to the less advanced. Thus a philosophy which makes life not worth while will have a natural tendency to destroy itself, so that it can not become permanent. That philosophy of the method of thought which results from a contemplation of mathematical progress leads to a doctrine which dignifies the process of thinking, exalting it to a place of veritable creative grandeur. It proceeds in the direction of making life worth living. It is optimistic in outlook and thus has one of the first qualities which are essential to permanence.

The invariants of human nature. Another value of mathematics is in its creation or clarification for its own use of various concepts which are afterward seen to serve as a unifying element about which other large domains of truth may be systematically organized and the relations of fact thus be brought to clearer understanding. Everywhere we are confronted by change; nature seems to be in an eternal flux. The complexity of particular phenomena is bewildering and we should be lost in their maze if we could not find some means of ascertaining the elements of permanence in the midst of the flux. In mathematics we have the same situation freed of distracting elements and idealized in a way which makes it possible to give a rather complete analysis of the whole matter. The flux and change of nature is replaced, in the ideal situations of mathematics, by what we call a group of transformations. The elements in consideration are subject to transformation according to the laws prescribed by the group which governs the phenomena; and our problem is to determine the things which are unchanged in the midst of the general flux allowed by the controlling group; in other words, we are seeking what we call the invariants, or the invariant combinations, of the elements subject to the flux permitted by the group. This conception, vaguely present in much of scientific speculation, has been recreated by mathematics into precise form, has been clarified, and has been utilized so fully that we now find it to be true that a large portion of the whole of mathematics has to do consciously or unconsciously with the theory of invariants. The essential elements of the logical characteristics of a situation of this sort are brought out clearly by the mathematical theory. The resulting body of truth furnishes us with a model by which we may be guided in the contemplation of the elements of permanence in any changing situation.

Whatever the subject of inquiry in any domain of exact thought there are certain entities whose mutual relations we desire to ascertain. The combinations which have an unalterable value under the changes to which the entities are subjected are their invariants. It is the purpose of the theory of invariants to determine these combinations, elucidate their properties, and express in terms of them the laws which are involved in the given situation. The "laws of nature" are expressions of invariant relations under the changes occurring in nature or brought about by directive agency. Two problems concerning natural phenomena demand attention. If we know the group of changes we may demand the determination of the invariants; if we know the invariants we may demand the determination of certain (if not all) possible groups under which these invariants persist. To enforce the judgment that invariants are a fundamental guide in present day science we have only to cite the fact that the theory of relativity has been developed in intimate dependence upon and under the guidance of the theory of invariants.

To pursue this matter further would carry us too far in the direction of a study of the usefulness of mathematics in the development of natural science, a matter which we are purposely excluding from present consideration. It has been said by them of old time that the proper study of mankind is man. Our purpose keeps us closer to this problem than to the study of nature. It is a fair question to ask what mathematics has to teach us concerning human nature. What do we mean by human nature except those characteristics of individual people which are unchanged from one to another, and from age to age? Those elements which are invariant through the whole group of human beings as far as they may be brought under observation? And how shall we determine the characteristics of this human nature other than by an analysis of the invariant elements in human experience and thought?

It can not be maintained that mathematics affords the best means for pursuing this study. In fact, it is probably generally supposed that mathematics makes no contribution at all to the problem of human nature, of the invariants among the qualities of individuals; we shall attempt to show that this judgment is incorrect.

The best means of studying human nature of course arises from the usual relations of life. But these in themselves are quite insufficient for a complete analysis. The continued acceptance of a large body of vital mathematical truth through some millenniums suggests the invariant character of certain elements of human thought in its logical aspects, just as the continued appeal of ancient poetry (for instance) to people of cultivated taste bespeaks an unchanging element of human nature in its finer emotional aspects. The presence of such invariant elements, wherever they may be found, is an instructive matter for the historian of culture and civilization.

Where can one find a systematic analysis of literature, that great storehouse of material for the understanding of human nature and the progress of unsystematic thought, having for one of its primary objects the ascertainment of the invariant elements of human nature in its emotional aspects? A study of the changes in taste and their cause contributes indirectly to this end; but both literature and mathematics, in different ways and with reference to different parts of our nature, can be made to yield important values towards an understanding of its invariant elements.

Since the historian of thought and civilization is seeking to bring his analysis of the progress of culture into systematic form it is perhaps no great surprise that he has found it difficult, and so far has not found it possible, to utilize successfully the truth which is half-concealed and half-revealed in the unsystematic thought of literature. But it is rather astonishing that such historians of thought have not been able to utilize the systematic work of mathematics in their expositions. I know of only a single instance where a general analysis of the progress of thought has taken an adequate account of the domain of mathematics, and that is in the work of J. T. Merz on "The History of European Thought in the Nineteenth Century."[1] This excellent general analysis has not had for one of its purposes to bring out the invariant qualities of human thought, and hence of human nature, as they are made manifest by the abiding truths of mathematics. The contribution which mathematics has to make to the study of human nature has not yet been considered in a systematic way.

And still it is certain to those who contemplate the nature of mathematical truth that many characteristic qualities of human thought are to be determined from such an analysis. It is a significant fact for the understanding of ourselves that the demonstrations in Euclid's *Elements* gain the same adherence to-day as in his time and in all the intervening ages; an invariant quality in the processes of reasoning and the ground for conviction through demonstration abides through the ages. There is absolute agreement in all times and all places that the number of prime integers is infinite, bespeaking a unity of the whole race in its understanding of the properties of elements conceived in the first place with exactness. The properties of a Euclidean triangle are in harmonious agreement even though they have been discovered by numerous thinkers of many generations. A sphere did nothing for the Greeks contrary to what it does for us to-day. The properties of a cube are invariant, whoever derives them and in whatever age he lives. It is an eternal truth that every integer is the sum of squares of four integers, and there is unanimity as to this fact and as to its demonstration. The persistence of mathematical theorems and the continued agreement as to their proof indicates a profound unity in the characteristic thought processes of those who contemplate them, exhibiting one fundamental phase of human nature.

Artistic delight in mathematical truth. Truth serves many ends. When a science has reached a certain stage of development,

[1] To this magistral work and to many articles in the *Encyclopædia Brittannica* I am under deep obligations in connection with this address. I have also profited by reading C. J. Keyser's *The Human Worth of Rigorous Thinking,* Columbia University Press, 1916.

varying greatly with the character of its material, it begins to throw off into the body of society great practical or even esthetic values which could not be realized without it. Astronomy has enabled us to have some conception of the vastness of space and the hugeness of the mass of matter, perhaps infinite in its totality, distributed through this space. Geology has released the imagination to contemplate enormous periods of time and, through its influence on biology, has rendered marked service in making possible our conception of the long progress of life on the planet, culminating in man. Mathematics, by exhibiting a body of truth which can live through millenniums without needed corrections, and at the same time can grow in magnitude and range and interest, has given the human spirit new ground for believing in itself and for rejoicing in its power of consistent thought.

It is not enough to accumulate the elements of knowledge or even by means of them to control nature for our use; we must appropriate them by idealizing them into things of beauty and motives to conduct. Truth may be made to yield the highest delights of contemplation in the spirit of artistic performance. This is generally realized in the case of the unsystematic truth afforded by literature and the other fine arts. It is less in evidence in the greater body of systematic truth. But when the latter is brought to its highest order of perfection, as it is in the domain of mathematics, it becomes capable of yielding the purest and most intense delights in artistic excellence. They are of a sort to be enjoyed in large measure only after an adequate training; and in that respect there is a certain exclusiveness about them. But to those who are willing to pay the price of adequate knowledge mathematics yields a gratification of the artistic sense surpassed by that arising from no other source. "The musician plays and the artist paints simply for the pure love of creation." The mathematician creates abstract and ideal truth for the pure love of discovery and of contemplation of the beauty of his mental handiwork.

In pursuing esthetic satisfactions we create a beautiful theory for the sake of our delight in it, as in the case of the theory of numbers or of abstract groups. Working in such fields with the simpler elements of mathematical thought we make progress of a sort not at first possible with the more complex materials. We bring the theory to a higher state of perfection; there are fewer lacunæ; the connections of the various parts are exhibited with clarity; we have a sense of having seen to the root of the matter and having understood it in its basic characteristics. The theory thus developed becomes an ideal in the light of which we get a new conception of what should be attained in other fields where the labor and the difficulty are greater. Results in one field of mathematics may thus become of great value in a totally different range of mathematical ideas or even in other disciplines altogether. Moreover, when such progress is attained we often find that the tools employed in bringing it about are sufficient for dealing with more difficult matters, so that the one completed theory furnishes us not only the ideal, but also the means, for further valuable progress.

A characteristic delight in mathematical truth is that which arises from economy of thought realized through the creation of general theories. When we develop the consequences of a set of broad hypotheses we find that our results, which are attained by a single effort, have applications at once in many directions. Thus we see the common elements of diverse matters and are able to contemplate them as parts of a single general theory pleasing for its elegance and comprehensiveness.

Fundamentally mathematics is a free science. The range of its possible topics appears to be unlimited; and the choice from these of those actually to be studied depends solely on considerations of interest and beauty. It is true that interest has often been, and is to-day as much as ever, prompted in a considerable measure by the problems actually arising in natural science, and to the latter mathematics owes a debt to be paid only by essential contributions to the interpretation of phenomena. But, after all, the fundamental motive to its activity is in itself and must remain there if its progress is to continue.

"The desire for the one just form which always inspires the literary artist visits most men sometimes" and is ever present to the mathematician in his hours of creative activity. The one just form which the mathematician seeks is more ideal and perhaps more delightfully artistic than that sought by any other thinker; for it is primarily a form of abstract thought in which he is interested, a form which remains the same as ages come and go, as languages are developed and die away, as the canvas of the painter rots to fragments and the material of the sculptured image is resolved by decomposition into its elemental dust. It is a thing of beauty which is indeed a joy forever.

For many people the numerous practical applications of mathematics have obscured its artistic elegance. But it is not the only fine art which in another aspect is also of the greatest practical utility. This quality it shares with the noble art of architecture. The two equally satisfy the following informal definition given by Sidney Colvin: "The fine arts are those among the arts of man which spring from his impulse to do or make certain things in certain ways for the sake, first, of a special kind of pleasure, independent of direct utility, which it gives him so to do or make them, and next for the sake of the kindred pleasure which he derives from witnessing or contemplating them when they are so done or made by others." Both mathematics and architecture possess all the qualities here enumerated. Each is of essential practical utility, contributing necessary elements to the material comforts of man. And, more than this, each delights the artistic sense through beauties peculiar to itself and furnishing the ideal reason for its existence.

From a certain point of view the four main divisions of thought—mathematics, natural science, philosophy, that unnamed one ruling without definite system in the domain of art and literature—are the stones and brick and mortar from which is builded the culture of the time, into which are wrought the values received from the past, and through which our development shall proceed to the acquisition of new power for further conquest. We break the environment into parts in thought and from these we fashion new objects such as never before existed in the universe—objects both concrete and ideal—and these we put together in ways well pleasing to ourselves to serve the ends we propose or erect the constructs we conceive.

But this is too mechanical to be the whole truth. The more profound values lie deeper and have their fruition only in the fullness of the character of man. If science did not touch a more profound matter than mere motion or reach to constructs which can not be adequately pictured by material symbols, it would fall far short of the glory of Living Thought. But it does forcibly react in a profound way with all our activities, particularly through the emotions excited by the play of the artistic sense. In fact, the elements of all Thought are parts of one body, living and organized, inspired by the breath of the Universe itself and pulsating with the life of truth in its deeper manifestations.

The problem of consistent thinking. The leading characteristic of man is the power to think. There is nothing of higher esthetic interest than to determine whether we can think consistently. This fundamental question can be answered in the affirmative only by exhibiting the results of consistent thinking. The existence of mathematics affords the best conceivable proof of its possibility and gives the spirit of man leave to believe in itself, since here admittedly is a body of consistent thought maintaining itself for generations and even for millenniums, able to sustain all the attacks of logic and all the tests of the practical life.

There was a time when this confidence in the permanence and consistency of mathematics was absolute. The fundamental methods of argumentation men conceived to belong to a class of innate or inherent ideas which had been put in the mind of man by the Creator. The initial hypotheses and basic notions of a mathematical discipline they thought of as belonging to the same category. If these innate ideas did not have all the elements of absolute certainty, there could be only one conclusion: the Creator had deliberately deceived man. Since they considered this to be absolutely impossible, they had complete confidence in the certainty of mathematical results.

Nowadays we seek a more earthly reason for confidence in our constructions in science. Our agreement that mathematics is possible as a consistent body of truth we now understand to rest on postulates for which admittedly we have no logical demonstration. Perhaps these postulates may be framed in the following way: Reasoning is possible and does not lead to wrong results when employed according to the universally accepted rules; mathematical objects can be created or discovered by the mind; we can actually formulate consistent axioms or postulates concerning these objects. With each of these three statements there are grave logical difficulties. We can not assert that we have an immediate perception of them as true; we can not, by direct illumination, see their validity. We must examine each of them in the cold light of experience and accept it only in so far as it meets the most exacting demands. Our confidence can never be absolute. As J. B. Shaw has said in his "Philosophy of Mathematics:" "We may found our deductions on what premises we please, use whatever rules of logic we fancy, and can only know that we have played a fruitless game when the whole system collapses—and there is no certainty that any system will not some day collapse!"

Let us proceed further with the difficulties of the situation. In all preceding generations conceptions in mathematics have been used with confidence which, in the experience of a later day, were found to be not sufficiently well defined; they have been discarded or essentially modified, sometimes after generations of confident use. It is not likely that men have heretofore always made mistakes of this kind and that we have suddenly come upon an age in which mathematical conceptions are refined to the last point of analysis.

We are then forced to the conclusion, however unwelcome it may be, that the certainty of mathematics after all is not absolute, but relative. To be sure, it is the most profound certainty which the mind has been able to achieve in any of its processes; but it is not absolute. The mathematician starts from exact data; he reasons by methods which have never been known to lead to error; and his conclusions are necessary in the sense, and only in the sense, that no one now living can point to a flaw in the processes by which he has derived them.

Let us make as concrete as possible the difficulties and the immense values which are at stake. Let us suppose that the Euclidian geometry should become untenable under the weight of constant accretions and should go crashing down to helpless ruin; in that day man's hope of reaching tolerable certainty anywhere in his thinking would be destroyed and even the world of mind would become a dark confusion of irrational elements. The character of such a loss suggests the magnitude of the present value.

What certainty have we that such loss does not impend? We have no logical demonstration of its impossibility; and in the nature of things can not have such a demonstration. The same uncertainty attends all other truth, and in even more marked degree. There is no logical certainty of the consistency or the permanence of truth; at most there is a moral certainty. From mathematics we have the strongest grounds for the latter. When thousands of persons through thousands of years examine thousands of theorems proved by numerous methods and in numerous connections and there is always absolute unanimity in the compelling character of the demonstration and the consistency of results, we have a ground of moral confidence so great that we can dispense with the proof of logical certainty and comfortably lay out our lives on the hypothesis of the permanence, consistency and accuracy of mathematical truth. The existence of mathematics gives the mind the best reason yet advanced for believing in its powers and the essential accuracy of its careful processes.

Emotional exaltation arising from the contemplation of mathematical truth. A profound emotional exaltation arises from the contemplation of mathematical truth either in the static aspect of accomplished results or in the dynamic aspect of a science with an everlasting urge to further development. By the ideal values which it constructs and by the permanence of its results mathematics gives to the spirit of man the right and the courage to believe in itself and to trust its controlled flights. Here it justifies its claims to preeminence more completely and more profoundly than in any other part of its broad domain. It exhibits a body of truth which is permanently pleasing and which exacts confidence at all times and among all thinkers who examine it.

By building first on its narrow and exactly conceived foundations and by adding bit by bit to its possessions of permanent truth, mathematics has made possible a release of the imagination of man such as can be completely realized to-day by only a relatively few individuals, a release however which will allow an expanse of the general human mind to-morrow or the next day. Vast new domains of contemplation are opened up by the non-Euclidean geometries, theories of hyperspace and space of an infinite number of dimensions, functions of an infinite number of variables and functions of lines. Such conquests give a new sense of power and mastery and increase the dignity of man. In the presence of so many beautiful creations of his thought "the mathematician lives long and lives young; the wings of his soul do not early drop off;" he rejoices in the grandeur of the heights to which his controlled imagination attains.

If one is to realize the intenser delights afforded by the contemplation of mathematics he must of course be a deep student of its secrets. It is only when he is able to devote a large share of his energy to research and is successful in the creation or discovery of important new truth that he may rejoice in the fullest glow of delight through a realization of himself in such ideal conquests. However important the work of preserving past discoveries and handing down to the future the accumulated tradition and however far-reaching such a stream of influence flowing in hidden ways in the minds of cultivated people, it can not be placed in the same category with that creative work which guides instructor and student alike and teaches generations what to think. It is the great glory of mathematics in our time that its achievements are being immensely enriched and extended by the researches of the present; so that this, the oldest of the sciences, has the vigor and the spring and the growth of the youngest of them. He who discovers a fact or makes known a new law or adds a novel beauty to truth in any way makes every one of us his debtor. How beautiful upon the highway are the feet of him who comes bringing in his hands the gift of a new truth to mankind!

Alone before the wild and restless force
Of nature we have seen man's active soul
Stand forth in awe without a sure resource
Of power to overcome or to control
The salient things submerged beneath the whole.
And we have seen in vision some new power
Spring up from hidden depths of mind and roll
With bounding joy to conquest, hour by hour
Increasing till the strength of man reached fullest flower.

What stage of progress have we now attained
In this process of far-unfolding thought?
What ground to think that it shall be maintained?
Have we the fullness of our conquest brought
And reached the depths where nature works and caught
From her the deepest blessing she can yield?
Or fathomed her profounder secrets fraught
With good, no major truth remaining sealed
From sight, with only minor things to be revealed?

If so, no glow of zeal could move our thought;
Our life would lose its meaning and its zest;
No vision of the future could be caught
By mind's prophetic penetration, blest
With prospect large; in pessimistic rest
And deep stagnation then must mind abide
Without a great compelling interest
To bring its power to action and to guide
Its strength to ways of joy or largest use provide.

But crescent science such a view as this
Dispels; for largest things with keen insight
We feel; the growth of knowledge must dismiss
From thought such pessimism; its darkening blight
Of shadow is illumed by sure foresight.
We joy to see new worth to be attained
And know the present conquest is but slight
Compared with wider truth that shall be gained
For thought's dominions, now by science unexplained.

We need the willing mind to consecrate
Its strength to finding truth, the zeal to bring
From nature's storehouse values good and great
And lay them at the feet of man. To wring
From restive nature some unwilling thing
Were joy supreme. The means for our release
To greater power we seek. The bounding spring
To growth shall move in us and never cease
To bring to us new joy and truth's renowned increase.

ON FOUNDER'S DAY

By Professor EDWARD L. NICHOLS
CORNELL UNIVERSITY

ON Founder's Day it is well that we should remember the founder. Even after the lapse of half a century his personality is still vivid.

To the undergraduate of the early seventies, Ezra Cornell was a familiar figure. We saw him often on the campus or in the work-shops of Sibley—a tall spare man, of shrewd but kindly countenance. Then in 1874 occurred his death. We all marched with the cadet corps at his funeral. A few of us had the privilege of standing at his bier as members of the guard of honor.

If you would get a definite picture of the personality of the founder, read those pages in the autobiography of Andrew D. White which treat of the beginnings of the university. You will be impressed in that account with two great qualities, *breadth* and *insight.*

Consider the far sightedness evinced in that incident of the choice of site for the new institution. It is a matter of record that Ezra Cornell insisted on the present spacious campus, now world-famed for its natural beauty, first among American university sites in that regard. When his first board of trustees favored a location lower down and more convenient to the village in the valley, a location ample for any school which they could imagine as likely ever to grow up on this hillside, he made his prophetic retort since become famous: "Gentlemen, some of you will see five thousand students on this hill."

Not one of them, it is safe to say, had the slightest expectation of the fulfilment of so extravagant a claim; but as we all know it has literally come to pass long since.

To us in these days when five thousand has become a sort of standard or average size for the enrollment of the larger universities in this country, there is nothing wild or improbable about Mr. Cornell's remark. But in 1868 there was no university in the land with half that number of students. Moreover, even to-day, five thousand at Cornell is a very different thing from five thousand in any town of a million people, where the local demand would fill several universities of that size.

What kind of a school did the founder have in his mind when he saw in his vision "five thousand students on this hill?" To me his well-known motto tells the story.

"I would found an institution where any person can find instruction in any study."

Here we have two great attributes specified, *Democracy* and *Breadth*. It was not the definition of a college, for the American college, then as now, was neither broad nor democratic.

Something quite different was clearly in the founder's mind—a place having at least two of the great qualities of a *university*.

With the wise and liberal cooperation of Andrew D. White, the founder succeeded in getting something quite different actually started—a place free from sectarian bias or control, where all subjects were on an equal basis; where women were on equal terms with men; where eminent scholars from abroad—men such as Agassiz, Lowell Curtis, Froude, Freeman, Bayard Taylor, Boyesen and Adler—added their influence to that of the resident faculty.

These accepted commonplaces of to-day were so far from accepted half a century ago that the new Cornell was launched amidst a hurricane of mingled abuse, derision and applause. Now, after more than fifty years, we find a growth of college and university population here and elsewhere out of all proportion to the growth of the country and a growth of material equipment even greater than the growth of the student body. Never in the history of the world have such large amounts of property been set aside for education as in American endowments within the last half century.

Comparing Cornell with other American universities, we note the almost complete disappearance of the gulf which once separated us from our sister institutions, and we can not but ask ourselves whether we have indeed abandoned the ideals and purposes of the founder or whether those great principles have commended themselves elsewhere, and the movement has been towards our position. That the movement has been this way I believe we may claim, and be proud of it, but of course we have all developed and are approaching a common standard.

Comparing American students with those of the rest of the world we notice one striking difference.

University students abroad have been identified with every forward movement—their radicalism has frequently been a source of alarm to those who stand for "things as they are."

A hundred years ago and a little more, when Napoleon felt strong enough to announce the empire, all France was subservient but the students of Paris. They in a body refused to sign the oath of allegiance to the emperor.

In 1848 when Prussia was in revolt and the throne was very near to overthrow, the revolutionary camps were full of students. A foolish, ill-judged movement it proved to be, and a very expensive one to some of them personally. But if it had carried and Germany had become a republic, there would have been no German Empire in 1870 and no world war in 1914!

Again in 1878 the situation was so serious in Berlin that mounted police patroled the streets all night in platoons. In those days the students hired public halls in the city and crowded them evening after evening to listen to orators who urged the abolition of autocracy and the conversion of Germany into a social democratic state.

Again in Russia in the early years of this century—at what terrible cost did students work for the overthrow of czardom! Russian prisons were filled with them and it seemed as though Siberian convict camps would soon contain all the intelligence of Russia. And they failed, and we all agreed that it was a foolish, futile demonstration; but again, in view of the suddenness with which the Russian government crumbled a few years later it may not have been so forlorn a hope.

Finally, consider how every now and then the student body at Tokio breaks out into protest against the government; recall that highly dramatic episode in Shanghai when a handful of students captured a gunboat in the harbor and proceeded to bombard the arsenal; also the very recent Chinese student strikes—seemingly the most harmless and footless of all forms of protest, but which are said to have brought about the resignation of at least two high officials in Peking nevertheless!

At home what do we find? Student bodies infected with radicalism? Never! On the contrary, if we are to go by what opinions are most loudly voiced and which are taken as typical; opinions by which we are judged; the American undergraduate is a tory and a reactionary. Take his attitude on any of the great questions of the day, from the status of women in the university, on which subject his view is medieval, to the league of nations.

We have just been through one of the greatest of revolutions and have dethroned a king, but I have heard of no great student outcry against King Barleycorn.

Now nobody wants a university full of anarchists. They are certainly a nuisance, harmless but still a nuisance—but since everywhere else in the world students are progressive, why not here also? "It's natural for boys to be liberals" they say in England "they turn tory fast enough as they get older."

The answer I find in one word: *tradition.*

Our vast growth in American educational institutions is after all largely social—literally millions for fraternity houses, dormitories, stadiums, etc., as against thousands (and this means a thousand to one) for the advancement of knowledge. The fraternity houses at Cornell have cost more than all the buildings on the campus (west of Bailey Hall). The student body spent on one football game this year more than the entire annual income of our new Heckscher fund for research.

Now social institutions are governed by tradition, not reason, and tradition is bad. It is tribal in nature.

In the Solomon Islands they have the canoe tradition. Before a new canoe can be put in the water, a ceremony must be performed involving a human head—an enemy's head if possible, or if not the head of a member of a neighboring village found straying from home, or the head of a slave of the tribe, or even the head of some useless member of the tribe itself. Incidentally the owner of the head is eaten, and by strict adherence to such traditions the natives had pretty well eaten each other out of existence by the time the Europeans came along and offered them more modern means of destruction.

Now most of our traditions are much like that in spirit. Such maxims as: "The king can do no wrong," "We fight it out first and talk about it afterwards," "Might makes right" are as old as the human race. All the traditions of caste, of the vendetta and feud, of lynching, of racial antipathy and above all the great tradition of war, are of savage origin.

As to the better so called traditions of fair-play, of sportsmanship and the like—they are modern and artificial. They are not native to us, but have to be acquired and are all too readily relinquished. Note the constant effort necessary to maintain a high standard of sportsmanship even in college sport; how hard to accord applause and consideration to an adversary; how easy to lapse into a primitive boorish muckerism! Are we in American student circles, and especially here at Cornell, governed by tradition rather than reason?

If what they say of us is true: That there is no scholarly interest among students; that undergraduates read nothing; that they do not think, then have we indeed departed from the great ideals of the founder. For tradition is aristocratic not democratic, reactionary not liberal, feudal or tribal in spirit, based on custom, on mere superstition, anti-rational, anti-intellectual.

Let us admit sorrowfully that the world is so near to its primitive savage state that it must still be governed by tradition, not by reason.

Of a *university* the opposite is true:

There *principles* have supplanted *tradition*. A university is essentially democratic; it lives to think and by thought; it is ever progressive not reactionary. Its chief function is the advancement of knowledge. Are we then a university, as the founder intended us to be, or not?

We are, or I should not be speaking to you to-day on this subject!

Here on East Hill in Ithaca, where Ezra Cornell planned to have it, there is a university.

"I do not speak of this great group of buildings, nor of their contents, nor of any college or group of colleges. These colleges are useful establishments but collectively they do not constitute the Cornell of which I am thinking.

Here and there upon the campus in laboratories and seminary rooms and libraries you may have become aware of individuals and groups—old and young, men and women, at work at something which does not appear in undergraduate schedules or curricula.

Theirs is the most fascinating and most important work in the world: the discovery of new truths and principles. They are adding to the world's stock of knowledge, and it is by means of this knowledge that the world is slowly—oh so slowly—getting away from its tribal traditions.

They are the university—the kind of university we may well believe the founder would delight in were he alive now.

Such work is creative and therefore immortal. He who adds a single real fact to our knowledge of the universe has won a place in the hall of fame. His recognition may not be immediate nor local, but whenever in the course of time that fact is made use of the discoverer will be remembered.

A Scottish schoolmaster a century ago made just one contribution to the science of optics. His name is a familiar one to-day to every school boy in the world who studies physics, and will be for centuries to come. He doubtless devoted a life time to teaching; but fine and beautiful and important as teaching is it is ephemeral, like newspaper work. Its influence lasts, but the source is soon forgotten.

If Cornell University should be wiped out by some great scourge or cataclysm—even as some of the European universities may yet be by the great war—it would be utterly forgotten in a single generation in spite of its great services in the teaching of tens of thousands of students. But it will not be forgotten whether it live or die, for it will have contributed something to the world's knowledge. These investigators—they are of the immortals. Neither they nor their work will die. They are the soul of the university and the soul lives on. Nor will the memory of the founder die, for he made his contribution in that motto of his and though his ideal were to fail of realization and be forgotten, we can easily imagine scholars of the far future finding his saying and acclaiming:

So here was one who in the darkness of the nineteenth century had the modern idea, for he said:

"I would found an institution where any person can find instruction in any study."

To those of my hearers who are undergraduates I would say, strive to get in touch with the real university which I have described, for until you do you will not be of the university. You may be enrolled in this or that college and after four years go out with our label on you, but, unless you have taken some part, be it only that of a breathless, eager, looker-on at some one of the creative activities of our researchers and scholars, you will never get the best—the only really worth-while thing that Cornell has to offer you.

UNUSUAL HUMAN FOODS

By Professor ALBERT M. REESE
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IN that interesting book by Simmons, "Animal Food," published many years ago, is described almost every imaginable kind of animal food used by civilized and savage races of man, from man himself, in the interesting, if gruesome, chapters on cannibalism, down to the lower invertebrates.

It is my purpose, in this short article, to call attention only to those types of animal food not commonly eaten by Americans that I have actually eaten and proved to be palatable. Many others might, of course, be mentioned on good authority, but only those which I have myself eaten will be described. Some of these obviously could have no economic importance in the United States; others might be added to our menus, and a few are already on the market in some localities.

Let us begin with the highest group of animals, the Mammalia.

Monkeys. Owing to the strong anatomical resemblances between man and some of the monkeys, it is possible that some of the reported cases of cannibalism have been due to mistaking monkeys, which are quite generally used for food in some countries, for human infants or children. This resemblance would probably be sufficient to deter most people from eating monkey meat, if the animal were cooked entire, but if the hands, head and feet be removed and the body be dismembered, the human resemblance is lost and, unless told, the average person would not know what animal he was eating. Monkey stew or minced monkey meat would probably be eaten and enjoyed by anyone who did not know what animal was before him. As in all animals, the flesh may be tough or tender, probably depending upon the age of the monkey and on how it is prepared. Just what familiar flesh it resembles in taste it is hard to say, but it is certainly a very agreeable food.

Peccary or bush-hog is another animal that makes a very acceptable dish, though, of course, not one of any importance outside the countries where these animals occur. The flesh may sometimes be tough, but is excellent, resembling, as might perhaps be expected, pork more than anything else.

Opossum. This animal is familiar to most people in this country, but, except among the negroes of the South, is not fully appreciated as an article of food. While not numerous enough in most sections to be of much importance it might be raised in captivity. Its flesh is quite pleasant to the taste, possibly resembling fresh pork as much as anything.

Woodchuck or ground-hog is a very familiar rodent in many parts of the country, being so numerous in some places as to be quite a serious pest. Why the ground-hog is not more generally eaten is hard to understand, for, when properly cooked, it can scarcely be told from rabbit. Its legs being small it does not have the fine hams of the rabbit, but there is sufficient flesh on a good sized animal to be well worth cooking. It is customary to soak the flesh in water to remove the "gamy" taste, though the necessity for this is doubtful.

Muskrats are sold in the eastern markets under the name of marsh hares, at about the same price, per pound, as rabbits. They may be cooked in the same way that rabbits and squirrels are prepared, and possibly would not be distinguished in taste, by the average person, from the more familiar animals.

Considering the enormous numbers of muskrats that are killed for their fur, this animal should be more generally used for food. The flesh is darker, before cooking, and is not so attractive as that of the rabbit, but its taste when well prepared is certainly excellent.

We Americans have many silly ideas and prejudices in regard to what is fit to eat, and it is one of these prejudices that keeps many people from eating woodchuck, perhaps because of its relation to rats and other disagreeable rodents; people do not seem to realize that rabbits and squirrels, which they do not hesitate to eat, are also rodents.

Whale meat has been used for food by the Japanese and others for generations, but it is only within a few years that we Americans have begun to realize the possibilities of these huge mammals as a source of food. It is said that there are no "choice cuts" on a whale; all the flesh is equally good. Imagine an animal from which Porterhouse steaks may be cut in half-ton chunks!

On our Pacific Coast and, perhaps, in the largest cities of the east, fresh whale meat may be bought in the markets. The writer has never tasted the fresh meat. In certain western cities whale meat is canned, and in this form may be obtained almost anywhere. This canned meat looks like canned beef, and when made into stews or cooked in other ways would probably not be distinguished by the average person from excellent canned beef. Why it is not more generally used it is difficult to understand, unless the popular idea that whales are fishes has something to do with it.

Birds, unfortunately, are nearly all suitable for human food. The writer is opposed, on principle, to the use, under ordinary circumstances, of birds as food, with the exception, of course, of domestic breeds and perhaps certain of the water fowl.

However, there is one bird, only too well known in almost every corner of the United States, that might well be an article of diet; it is the house or *English sparrow.* There is very little difference of opinion in regard to this species; it is a pest—in some places a serious nuisance—against which a nationwide war of extermination has been declared. In destroying these birds by traps or guns, why not make use of them as food? To be sure they are small, but they are nearly as large as the bobolink that was formerly so extensively used for food under the name of reed-bird. They are easily prepared, and when properly roasted taste just as good, so it seems to the writer, as the famous reed-birds. The bones are so tiny that most of them can be eaten along with the flesh. At certain seasons of the year when they congregate in large flocks it is not difficult to shoot, with fine shot, or to trap in various ways, these birds in considerable numbers. If the use of English sparrows as food could be encouraged it might help in the war to reduce their numbers.

Edible birds' nests, while of no importance in this country, form quite an important article of commerce in some parts of the Orient. In China, which is apparently the chief market, they bring fancy prices. These nests are, as is well known, formed of the dried saliva-like secretion of birds, and are of about the size and shape of the nests of cemented twigs built by our chimney swifts. The material resembles gelatine and when treated with water swells in about the same way. Properly cooked the edible bird's nest is supposed to be a remarkable delicacy. The writer prepared, according to the only recipe available, a nest obtained near the Island of Palawan of the Philippine group. The result was a gelatinous mass without a particle of taste. Either the nest was stale or there was something wrong with the method of preparation, since none of those who tasted it was enthusiastically anxious for more.

The writer once ordered bird's nest soup at a Chinese restaurant. While the taste was excellent, there was nothing but the name on the menu to indicate that the dish was not ordinary chicken soup. Besides the fine particles of chicken there were small, tasteless lumps of gelatine that *may* have been bird's nest or may have been ordinary gelatine. There was absolutely no taste other than what would be expected in chicken soup. Perhaps the soup has been Americanized to satisfy the present demand.

Reptiles. There is scarcely a group of animals against which there is such a general and unreasoning prejudice as the Reptilia, and this applies as much to their use as food as it does in other respects.

Almost anyone will eat turtles, nearly all species of which may be used for food; yet when alligators or lizards are suggested they are usually declined with disgust, often with the statement "because they are reptiles." An illustration of this was once seen in South America. The writer had expressed the desire to taste the flesh of the iguana, which lizard was said by the English gentleman, whose guest he was, to be commonly used for food. The Englishman spoke enthusiastically of the flavor of the big lizard; but when a few hours later, the writer, after skinning a freshly killed caiman or South American alligator, suggested cooking some of the flesh, this same Englishman declined, with vigorous expressions of disgust, to consider eating the crocodilian. Another illustration was seen years ago in central Florida. The individual, in this case, instead of being an educated English gentleman, was a very ignorant and crude youth, who had said that he would not be caught eating a dirty "varmint" like a 'gator. Shortly afterwards, during his absence from camp, we cooked some alligator steaks, and on his return, had them served as "fish." We all partook; the youth in question eating with evident enjoyment the despised "varmint" under the name of "fish."

The writer has described in a previous issue of this journal[1] an alligator dinner given at a boarding house in a college town, where some thirty people, of both sexes and of various occupations, ate alligator meat every individual declaring the meat to be unusually palatable. In this case the meat was cut into pieces and cooked in cracker crumbs, like a breaded veal cutlet, which it resembled somewhat in taste and texture. It is probably the silly prejudice, illustrated above, that keeps the alligator from being used extensively as a source of fresh meat in the regions where the species is found.

The use of *turtles* as food, from the lowly snapper to the aristocratic diamond-back, is too familiar to need mention here. The use of the eggs of these animals is less common, especially in this country, though in some tropical regions they are extensively used. While scarcely comparable to the fresh eggs of domestic fowls, some turtle eggs are decidedly palatable.

Amphibia. As among the reptiles, so among the amphibia, there is an unjustifiable prejudice against certain forms by people who do not hesitate to eat other species. Almost anyone will eat

[1] December, 1917.

frog legs (for some reason only the hind legs are commonly eaten, though the rest of the muscular parts are equally good), while very few people would dream of using the larger salamanders, closely related to the frogs, as food. Of course these salamanders can not be obtained in such large numbers as frogs, and, their legs being small, most of the meat would have to be obtained from their tails; but some of them are quite large, and are more or less of a pest in streams where they abound, so that it would seem a waste of good food to destroy them instead of eating them.

The *axolotl* and other moderate sized salamanders are said to be used as food in Mexico and to be exposed for sale in the Mexican markets. Perhaps the most common of these large salamanders is *Necturus,* popularly known as the *mud-puppy* or *water-dog,* though these names are also applied to Cryptobranchus or the hellbender. As necturus is rather thick-bodied and may reach a length of 12 to 18 inches there is considerable meat upon it, which in flavor is very similar to that of frogs. The animal is harder to skin than the frog, but it may be cooked in the same way, and it is doubtful if the average person would distinguish between the taste of its flesh and that of a similarly prepared frog.

Cryptobranchus alleghenienesis, the American giant salamander or hellbender, popularly known as *alligator* or *water-dog* is the largest of American salamanders, reaching a length of two feet and a weight of nearly two pounds. It is found in the waters tributary to the Ohio River, in some places being quite abundant. As in Necturus the legs are too small to be of use as food, and as in Necturus the skin is rather hard to remove; but the flesh is equally agreeable and during the breeding season the eggs, of which a considerable mass may be found in a single animal, are also of a very pleasant flavor.

An illustration of the persistence of the taste of ether in an animal killed with that reagent was seen in a hellbender which after being etherized, was skinned, cleaned, washed and, after several hours, was fried in egg and cracker crumbs. In spite of the washing, the intervening hours, and the heat of cooking the flesh still retained a distinct flavor of ether, though the eggs had no such taint.

Fishes. Since nearly all of the common fishes are used for food, and there is but little popular prejudice against members of the class, attention will be called to but one group that should be more generally made use of as food: this is the *Elasmobranchs,* or sharks and skates. In the markets of China these forms are commonly displayed for sale. The fins, especially of certain species, are in demand as a source of gelatine.

Certain of our sharks are now canned and put on the market under the trade names "gray fish," "deep-water swordfish" and perhaps other names. While not of such a desirable flavor as canned salmon these canned sharks are excellent substitutes for fresh fish and should be more generally used. The addition which their use would make to our food supply may be seen from a statement made by Kellogg in his "The Shellfish Industries" that "It has been estimated that thirty-seven million dogfish, equal in weight to half the total catch of the Massachusetts fishermen, were taken by them in 1905."

Of invertebrates but one or two will be mentioned. Nearly everyone likes lobster, either fresh or canned, but its near relative of fresh waters, the *crayfish,* is unknown as an article of food in many regions where it is quite abundant. In certain sections of the west and south crayfish are used as food and are extensively canned, but, as has been said, they are unknown as an article of food in many places where, if not sufficiently abundant to sell commercially, they could be easily collected in sufficient numbers for family use. When prepared in about the same way that fresh lobster is cooked the crayfish makes a decidedly pleasant dish, and the mass of abdominal muscle in the "tail" of a large crayfish is considerable.

Fresh water mussels. In many of the rivers and other bodies of fresh water in various parts of the country are found several species of fresh water mussels. In some localities where they are of certain species and are of sufficient abundance they are collected and their shells are used for making pearl buttons. It may be possible that these mussels are used for food at times, but I have never heard that this is done. Owing to the frequent pollution by sewage of the streams in which they live, it would probably be unwise to eat them raw, but there is no reason why they should not be eaten after being properly cooked. They are, to be sure, sometimes very tough, but this might be remedied by special methods of cooking, and the flavor, while not so delicious as that of some of the salt water bivalves, is decidedly agreeable.

Squid and perhaps other cephalopod molluscs are sometimes displayed for sale under the name of devil-fish, by Italian stores, even at a distance from the coast. They are used in making soup and possibly in other ways.

The writer had a soup or stew made from an eviscerated specimen, using milk, seasoning with salt and pepper, and adding a lump of butter. The flesh, while not so delicate as that of an oyster, was not especially tough, and the soup was very much like that made from oysters, but with an additional taste that was not very agreeable. Possibly the addition of celery or some other flavoring substance might counteract this undesirable taste.

This devilfish soup was given to a domestic science class of about twenty young women; about half of these young women voted that they liked the preparation, and all were interested in trying a new dish.

At thirty cents a pound it is not likely that squid will become especially popular on American tables.

The reluctance of people towards eating untried articles of food is mentioned by V. Stefansson in an article in THE SCIENTIFIC MONTHLY for December, 1920. He says: "Similarly we found that 'well brought-up' men, used in their homes to a large variety of foods, both domestic and imported, take very readily to any new thing (such, for instance, as seal meat). But men 'poorly brought-up' and used to only half a dozen or so articles of food in their regular diets are generally very reluctant to try a new food unless it has been represented to them in advance as an expensive or specially delicious thing." . . . "For one thing, the man of the laboring type has a feeling of being degraded when he is compelled to eat the food of 'savages,' while the man of the intellectual type is appealed to by the mild flavor of adventure in experimenting with 'native food.'" Stefansson found that Eskimo women were much slower to try new kinds of food than were the men.

REGARDING THE HABITS OF TARANTULAS[1] AND THE EFFECTS OF THEIR POISON

By W. J. BAERG
UNIVERSITY OF ARKANSAS

As one who has grown up north of the Mason and Dixon Line and had seen tarantulas only in collections, I had never given these big hairy spiders any serious thought. However, when I came to the Ozarks of this region and heard some of the weird stories telling how these tarantulas would jump on a person from a distance of 15-25 feet, and how their bite proved almost always fatal, I developed considerable curiosity in regard to these terror-inspiring objects. Upon learning that these spiders are fairly common on the stony hillsides near the college campus, I immediately set to work and in a short time assembled a small collection. It seemed

HOLE OCCUPIED BY TARANTULA, SHOWING THE WEB OVER THE HOLE. NEARLY NATURAL SIZE

[1] *Eurypelma steindachneri* Ausserer, determined by Professor C. R. Crosby, Cornell University.

desirable to me, since so little is known about their habits, that I keep a few alive for daily observations.

In the Ozark region the tarantulas are commonly found living in holes. These holes vary from 1½ to 2 inches in diameter and from 8 to 12 inches in depth. They are apparently not made by the spiders themselves, but are appropriated from gophers, ground squirrels and other small rodents. Most of the holes when the spiders are "at home" are covered with a thin webbing, some are merely lined around the edge.

It would seem that flooding these holes with water might be an easy way to get the spiders; but here, as elsewhere, inference is misleading. The simplest way that I have so far found is to insert a slender stick into the hole and gently tease the spider, whereupon it usually proceeds to leave the hole at once.

Having found that a large grasshopper once a week or ten days and a small dish of water solved all the problems of feeding, I encountered no further difficulties in keeping the tarantulas under bell jars on the laboratory table. During the winter the feeding problem is still further simplified, for, although these spiders remain active all through the year; yet they refuse all food from some time in October till about the middle of April, and require nothing but water for their sustenance and well-being.

HOLE OCCUPIED BY TARANTULA SHOWING WEB AROUND THE EDGE OF HOLE. NEARLY NATURAL SIZE

VIEW OF UNDERSIDE OF TARANTULA SHOWING THE BROKEN FANG. NEARLY NATURAL SIZE

One female tarantula, about $2\frac{1}{4}$ inches long, has now been under observation for more than two years, and is apparently doing very well under the simple diet outlined above.

The process of molting, or shedding the skin, seems sufficiently interesting to be briefly described here. The skin splits around the upper edge of the main body (cephalothorax) in such a way that the entire top from the base of the cheliceræ (the arms that operate the fangs) to the base of the abdomen comes off like a lid. The skin of the abdomen may or may not split along the middle of the back.

A year ago the molting took place on August 15, this year on August 20. The latter molt occurred from 8 to 11 in the morning and I was able to observe the entire process. The first conspicuous evidence of molting is the lifting of the upper surface of the cephalothorax. This remains attached over only a short distance near the base of the right chelicera.

A significant feature in the process of molting is that it proceeds practically without any visible effort on the part of the tarantula. About all that one is able to observe is that the body by rather faint pulsations gradually oozes out of the old skin, rising up and moving to the left in such a manner that by the time that all the appendages and the abdomen have been extricated from the skin the tarantula is seen lying on its side and facing in the opposite direction of the skin. At this stage the spider turns on its back and begins to exercise its legs in a more or less leisurely manner for about one hour when it gets back on its feet and behaves in the normal way.

Some time this year during the month of May I obtained a large female which was apparently heavy with eggs. Instead of placing her under a bell jar, like the others, I put her into a large battery jar half filled with dirt, thinking that she would probably make some sort of a hole preparatory to egg-laying; but she made no such an attempt.

On the morning of June 28 the spider constructed a large silken bag all around herself and kept busy on the inside of it for some time. On the next day she was on the outside of the bag which had now shrunken to the size of a black walnut without the hull. From now on the tarantula spent practically all her time sitting over the bag.

On July 20 I made a small opening in the bag and took out a

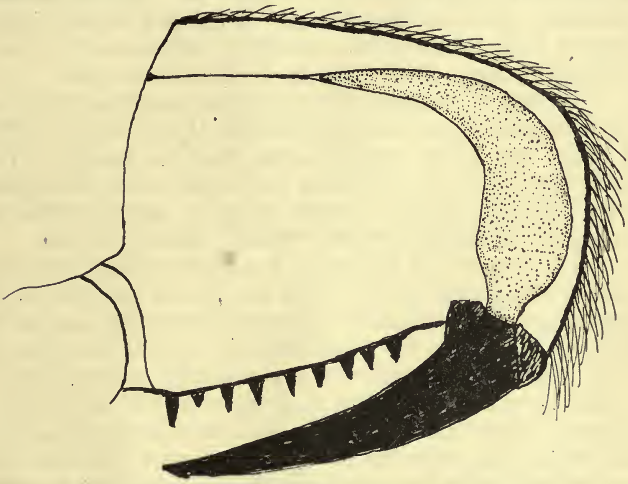
TARANTULA AND EGG SAC. NEARLY NATURAL SIZE few eggs and young spiders. The eggs are white in color, globular and about two millimeters in diameter. The young spiders match the color of the eggs so well that they are quite difficult to see when small. The young were at this time feeding on the eggs still unhatched. A few days later, July 24, I decided to take out all the eggs and young for further study. The bag contained at this time 460 eggs in apparently good condition, 113 young spiders, and 90 eggs which were shrivelled up. This makes a total of 663 eggs as originally laid. The shrivelled eggs had obviously furnished the food for the young spiders. Hoping that I might get some information on the final result of this struggle for existence, I replaced the eggs and the young spiders in the bag and closed the slit that I had made with some glue. Unfortunately my efforts interferred with the instincts of the spider for on the following morning I found her enjoying a breakfast consisting of her own eggs and young spiders.

It is well known that tarantulas, in fact all spiders in general, are cannibals. Thinking that I might get some more detailed information on this particular habit, I placed two large females, that had just been brought in from their natural homes, under a large bell jar. Contrary to what might be expected, they were quite peaceable. One sitting quietly on one side of the jar, the other opposite her, behaving much like two persons not on speaking terms. This attitude they steadfastly maintained in spite of my efforts to bring them together. Thus they remained from nine o'clock in the morning till noon, when I left the laboratory. However during my absence, at least one of them must have realized that it was lunch time. On my return at about one o'clock P. M. I found one of the females sitting comfortably on the abdomen of the other and busily feeding on its contents. There was no evidence of any struggle. The dead tarantula was badly torn on the upper surface of the abdomen, but showed no other injury. The victor showed no evidence whatsoever of having been attacked.

It we may judge from these observations, there seems to be no definite fighting spirit. Several individuals apparently tolerate each other till one develops a desire for food.

Recently when an intelligent young man told me that his brother had been bitten by a tarantula and had died as a result a few days later, I decided to make some sort of a study of the effects of the much-dreaded venom.

Accordingly a guinea pig, seven months old and weighing about 635 grams was secured and the experiment was carried out in the following manner. The hair on the inside of the right hind leg was cut off close to the skin, and then having fastened the leg and holding the pig firmly an attempt was made to have the tarantula implant her fangs on the prepared spot. The spider used in these tests was a large female, whose body measured 2½ inches in length and 1 inch across the thorax. After several attempt it became obvious that she was unable to penetrate the skin of the pig. Consequently in an effort to obtain some evidence on the nature of the poison, the chosen spot on the leg was disinfected with alcohol and treated so as to remove the difficulty in penetration. Hereupon after a little agitation the tarantula proceeded to implant both fangs well into the flesh of the guinea pig's leg. A second trial was made and in this, one of the fangs entered the flesh. Both times when the tarantula struck the guinea pig gave evidence of more or less pain. A number of observations on temperature,



CROSS SECTION OF CHELICERA SHOWING FANG, AND ROW OF TEETH, POSITION AND RELATIVE SIZE OF POISON GLAND. ENLARGED ABOUT TEN TIMES

respiration, etc., were made; but as all of these proved to be of obviously little value, they are omitted here. There developed a slight swelling in the leg which possibly was due mainly to the preparatory treatment. At no time did the guinea pig refuse to use the leg in walking around.

For the next subject I selected a white rat, about one month old. The tender skin of this animal was an advantage, for the tarantula was easily induced to implant her fangs deeply into the flesh of the inside of the right hind leg, and without any difficulty repeated the act. The four spots where the fangs had penetrated assumed a reddish appearance; but the blood did not gather in a drop. When the tarantula struck, the rat struggled and gave other evidence of more or less pain.

Since the rat gave apparently a definite response to the effects of the poison, the observations are given here in condensed form. At first, immediately after the tarantula had struck, the rat seemed bewildered. With eyes closed it ran about in the cage holding up the wounded leg. After about 15 minutes it ceased to run and for a half an hour it jumped around in a jerky way. Then it seemed to go into a state of coma. For a half an hour it remained rather quiet with only a sudden movement of the legs now and then. During the two hours following the rat moved about restlessly, holding the wounded leg close to the body. Later it became quiet again and soon began using the wounded leg. Four hours from the time it was bitten the rat opened its eyes and an hour later it behaved as if it had entirely recovered. After several hours it partook of a hearty meal consisting of milk and corn meal.

According to a theory held by nutrition chemists a full-grown rat represents in many ways one thirtieth of a grown man. That is to say that a man requires thirty times the amount of food needed for a rat, etc. Assuming that a man would also require thirty times the amount of spider venom in order to suffer the same agony; I decided to try the "deadly" poison on myself.

On the morning of August 10, I induced the large tarantula, used in the previous tests, to strike me twice on the inside of the small finger of the left hand. In the first attempt the fangs barely penetrated the skin. The second was more successful, at least one of the fangs went well under the skin just below the first joint.

The blood gathered a little in the openings but did not collect in drops. A small amount of the poison, a clear, colorless, and tasteless liquid, was present in all four places where the fangs had struck. The sensation produced by the strike was that of a stab of a pin. This pain, if I may call it a pain, decreased gradually so that two hours after the biting took place no trace of the pain remained. At no time was the finger at all stiff.

On the following day the experiment was repeated. An effort to use another tarantula than the big one used in the previous tests failed, she could not be induced to strike, in spite of all teasing and with fangs conveniently placed on the tender portion of the small finger. So the large female was again brought out and she did not disappoint me. After but little teasing she struck violently twice. At the first strike I felt a strong desire to groan, at the second, in which the spider seemed even more desperate, she broke her left fang off at the middle. The poison was used more generously than on the day before, two large drops collected and ran down on both sides of the finger. In one of the punctures a small drop of blood collected, the others merely assumed a reddish color.

The pain was very much as has been noted for the previous test, at first fairly sharp and then becoming gradually dull till in about two hours all trace of pain had disappeared.

It should be added that I did not resort to the use of any disinfectants, in fact the punctures were not tampered with in any way. With regard to relative susceptibility to insect poisons, I should probably be considered an average individual. The sting of a bee causes moderate swelling and a pain that lasts for ten or fifteen minutes.

NORMAN BRIDGE LABORATORY OF PHYSICS

California Institute of Technology, Pasadena, California, which was recently dedicated. It is here that Professor R. A. Millikan and his associates are carrying on their important work on the constitution of matter. Professor Millikan is working in close cooperation with Professor Noyes of the Gates chemical laboratory and the astronomers of the Mt. Wilson Observatory. Professor H. A. Lorenz said at the dedication: "If some effect cannot be found on the earth the astronomers will look for it in the sun and if there is some new and not wholly understood phenomenon in solar physics, it will be reproduced and investigated in the Norman Bridge Laboratory."

THE PROGRESS OF SCIENCE[1]

STARS AND MOLECULES

THE range of research has been expanded in opposite directions and has opened up two hitherto unattainable regions, the minutest and greatest, the constitution of the atom and the constitution of the stellar universe. The two extremes meet in the method of investigation for the laboratory and the observatory have gone into partnership. The variations in the movement of the electrons in their orbits about the nucleus reveal the chemical relationships and reactions of the elements as well as the age and motions of the stars.

The laws that have proved useful in explaining the properties of gases are now found useful in interpreting the sidereal system. Dr. F. H. Seares, in a recent address at the Carnegie Institution of Washington, showed that the gas law of the equipartition of energy applied in general to the stars. The massive stars have the lowest velocities, while the smaller stars move more rapidly. Professor Seares says: "This equal distribution of the energy of motion can scarcely hold rigorously for the stars, since such a state can exist only when the motions are completely at random, which is not the case with the stars. Some of them move as groups, having motions which are parallel and equal. That it holds even approximately is surprising, for in a gas the state of equipartition is brought about by the collisions and close encounters of the molecules. But the stars do not collide, or at least so rarely that in practice we may consider that their motions take place without mutual interference. How then has the equal distribution of energy among the stars come about? We do not know; but obviously its existence is a circumstance that must be considered in any theory which pretends to account for the development of the stellar universe."

This peculiar behavior of the stars results from an extensive investigation of the masses, densities, and diameters of stars of all classes by Professor Seares, combined with recent measures of stellar velocity by Dr. W. S. Adams and his associates at Mount Wilson Observatory. When the stars are classified according to their intrinsic brightness or candle power and their temperature, it is found, as first shown by Hertzsprung and Russell, that the hottest stars do not differ widely in intrinsic brightness, but that among the cooler stars —those which are red—there are enormous differences in luminosity, amounting to 10,000 fold or more. And, what is more extraordinary, there is a gap between the two extremes of brightness, within which we find no red stars at all. We thus have the so-called giant and dwarf subdivisions of stars, a grouping which shows most clearly among the stars of lowest temperature, but persists to some degree through all the intermediate temperatures and disappears only in the case of the bluish white stars of high temperature.

The classification according to intrinsic brightness and temperature thus reveals two great divisions of stars, both of which run through the entire scale of temperatures: the giants which, roughly, are of the same order of brightness, all very luminous; and the dwarfs which merge with the giants among the very hot stars, but become fainter and fainter as we run down the temperature scale. Our sun is a typical

[1] Edited by Watson Davis, Science Service.

dwarf star of intermediate temperature, whose brightness is about 1/100 that of an average giant.

The study of astronomical processes in terrestrial laboratories has been made possible by the use of heavy currents of electricity. Dr. Gerald L. Wendt has by this means heated thin tungsten wires to the temperature of the hottest stars, some 50,000° F. and reports to the Chicago Section of the American Chemical Society and to the National Academy of Sciences that the metal is decomposed almost completely into helium. This, if true, would be a more complete and extensive disruption of the atoms than has been attained by Sir Ernest Rutherford, of the Cavendish Laboratory, Cambridge, who has obtained traces of hydrogen by bombarding the nucleus of nitrogen and other elements of low atomic weight with alpha particles.

Professor R. A. Millikan, of the California Institute of Technology, is also studying the constitution of atoms by bombarding with alpha particles, using his oil-drop detector to catch and count the ejected electrons. His method is to suspend in such a field a minute oil-drop, of diameter about one hundred thousandth of an inch, giving it just enough charge to neutralize the force of gravity upon it and therefore to keep it just suspended in midair tending to move neither up nor down. He then shoots alpha rays immediately underneath the drop and when one of these rays goes through a helium atom which is also underneath the drop and detaches from it an electron, the residue of this atom becomes thereby electrically charged and is thrown instantly upward by the field into the oil drop to which it sticks, thereby communicating its charge to that of the drop and changing the balance of the forces which had theretofore acted upon the drop. The result is that the drop begins to move upward at a speed which is proportional to the amount of charge communicated to it by the advent of the atom of helium upon it, so that if the alpha particle knocked out just one electron from the helium atom, the oil drop which instantly caught that ionized atom would begin to move upward with a speed which would be proportional to the value of this single electronic charge. But if the alpha particle had the good fortune to pick off both electrons from the helium atom as it shot through it, the charge communicated to the oil drop by the capture of the residue of the helium atom would then be twice as large as before and the motion would therefore be twice as rapid. By catching in this way the residues of ionized helium atoms at practically the instant at which they become ionized, it is possible to tell without the slightest uncertainty whether the alpha particle in shooting through the atom has knocked off just one of its electrons or both of them.

The results of Dr. Millikan's experiment are very interesting. He found that his alpha particles, which, it will be remembered, are moving with a speed very much faster than that of an ordinary bullet, *got both electrons every sixth shot*. That is to say, five shots out of six which got anything knocked only one of the two electrons out of the helium atom, but *on an average every sixth* successful shot knocked them both out. These facts throw some light on the structure of the helium atom, for they show that the two electrons in their revolutions around the nucleus of the helium atom must get into the same region of the atom a considerable portion of the time, otherwise they could not both get into the way of the alpha particle bullets as frequently as they are found to do. It is also interesting that Dr. Millikan has not yet found any atom save the helium atom, which loses more than one single electronic charge when an alpha particle is shot through it.

AN INTERNATIONAL LANGUAGE

There is a conflict between the political and scientific tendencies of the times and it will be curious to watch which influence prevails. In the political field nationalism is the order of the day. The war gave birth to a dozen new nations. International intercourse is hampered by tariff barriers, postal impediments and the revival of obsolescent languages.

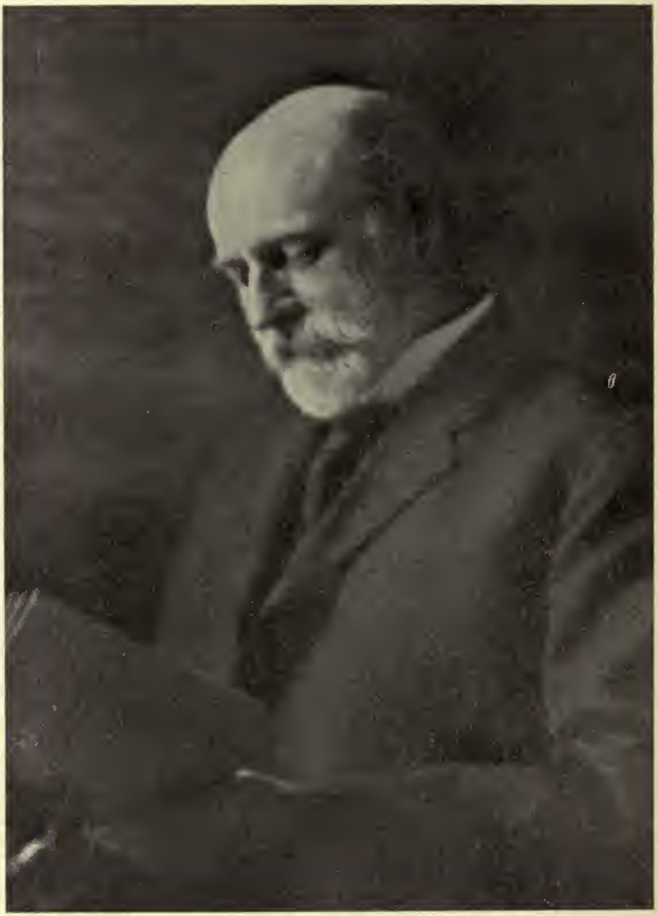
But now comes the radio which knows no nationality and which may put a girdle round the earth seven times a second. It is impossible to partition the ether. Its waves spread impartially in all directions and anybody may listen in without the consent or knowledge of the sender. The Eiffel tower talks to people of thirty tongues. So long as intercommunication was confined to print, mail and telegraph, it was possible to get along with the aid of interpreters, but when millions are receiving messages without intermediaries they must have a common language. Whether this will be gradually and capriciously evolved out of the current commercial and maritime codes; whether the nations may set aside their mutual jealousy so far as to adopt one of the modern languages; whether Latin, the old international language, will be brought into use in its classical, ecclesiastical or a simplified form; or whether an artificial language, such as Esperanto or Ido, will find acceptance, remains to be seen. It is no longer an academic question, but has suddenly become of pressing practical importance. It should receive serious attention by competent philologists. It is of peculiar importance to the scientist who formerly could get along fairly well with a reading knowledge of English, French and German but who now must master not only Italian, Russian, Dutch and the Scandinavian languages, but also Polish, Czech, Japanese, Chinese, Irish and Hebrew if he wants to read the reports of research in the original. Patriotic pride is strong in the newer nations and demands the publication of their scientific achievements in the vernacular. But the more powerful the impulse for the multiplication of languages and the wider the fields in which science is cultivated, the more necessary will become an international medium of communication.

The whole progress of civilization during the past century and a half has been toward making the world a smaller place to live in. Railroad, electric line, automobile, airplane and airship have all made transportation of concrete things easier and faster. The wire telegraph and telephone and the radio telegraph and telephone have taken information instantaneously to the whole world.

There is a missing link in this great time-contraction of the globe. The Japanese trans-Pacific radio operator can, in international code, tell the American operator that atmospheric disturbances are interfering with communication; they can hold a rather extended technical conversation in code. But difference in language prevents the simplest kind of exchange of ordinary information between many peoples of different countries, in spite of the fact that mechanical means of communication are highly developed.

International language will soon become an acknowledged world necessity. Like all the other great developments of modern times, it must first undergo development and scientific study. An international auxiliary language that will bring people of alien tongues together is not a remote possibility. If it existed to-day, if the generation that is growing up to-day were being taught an accepted international language, there is little question but that the next generation of the world would be able to easily "listen in" on radio broadcasting from any nation.

Pioneer work in the scientific con-



JOHN CASPER BRANNER
Formerly professor of geology at Stanford University and at the time of his death president emeritus.

sideration of the international auxiliary language problem is being done by the Committee on an International Auxiliary Language of the International Research Council, headed by Dr. F. G. Cottrell. Much progress is being made as those who attended the symposium on the subject at the Toronto meeting of the American Association for the Advancement of Science know.

INTERNATIONAL MEETINGS AT ROME

THE International Research Council, organized in 1919 at Brussels, will meet again in that city on July 18 of this year. Meanwhile the International Astronomical Union and the International Geodetic and Geophysical Union will meet at Rome on May 2. The United States will be represented at the astronomical meeting by Professor Frank Schlesinger, Yale University, chairman of the American delegates; Dr. R. G. Aitken, Lick Observatory; Dr. C. E. St. John and Professor F. H. Seares, Mount Wilson Observatory; Dr. H. D. Curtis, director of the Allegheny Observatory; Dr. O. J. Lee, Yerkes Observatory; Professor H. N. Russell, Princeton University; Professor John A. Miller, Swarthmore College; Professor Edward Kasner, Columbia University; Dr. Harlow Shapley, director of the Harvard College Observatory, and Dr. Frank B. Littell, of the U. S. Naval Observatory.

Dr. William Bowie, chief of the division of geodesy of the U. S. Coast and Geodetic Survey, will head the American delegation to the geodetic and geophysical meeting, and will be delegate to the section on geodesy. Other delegates are: Section on terrestrial magnetism, Dr. L. A. Bauer, director of the department of terrestrial magnetism of the Carnegie Institution of Washington; section of seismology, Professor H. F. Reid, of the Johns Hopkins University; section on meteorology, Dr. H. H. Kimball, of the U. S. Weather Bureau; section on physical oceanography, Dr. G. W. Littlehales, of the hydrographic office of the Navy Department; section on volcanology, Dr. H. S. Washington, of the geophysical laboratory of the Carnegie Institution of Washington.

American astronomers met in Washington just before the American astronomical delegates left for Rome and considered many of the subjects that will come up for international consideration.

One of the questions on the agenda of the Rome meeting that will interest and affect the ordinary person most directly is the reform of the calendar. The American section did not instruct its delegates on this matter but it is expected that some action will be taken by the International Astronomical Union meeting. Much of the discussion by astronomers at Rome will relate to the unification of nomenclature and plans for international cooperation in various projects. A new system of spectrum classification of stars will be recommended by the American delegates, and plans for the determination of terrestrial longitude by wireless telegraphy will be laid. Another important question that will arise is the variation of latitude, or the "wabbling" of the earth. About twenty years ago, the Ukiah, Calif., Observatory was established as one of five latitude stations, and valuable data have been obtained. But the astronomers realize the need of further knowledge of the factors that affect the accuracy of their measurements and will urge additional stations.

Each one of the sections of the International Geodetic and Geophysical Unions has full agendas. The scientists of Europe will discuss the triangulation nets of many of their countries and Africa, as well as the establishment of a fundamental longitude net of the world. Europeans will have as an example of international cooperation the United States, Mexico and Canada which are using the same triangulation net with effective results. Isostasy, or the distribution of densities of the earth, will also be considered. Volcanologists will lay plans for getting to the eruptions in the least possible time and they will also arrange to chart the volcanoes that discharge their lava into the sea instead of the air and for this reason are seldom discovered. They will consider tapping the volcanic energy of the earth by holes leading down into the hot portions, as is now being done in Italy. Equally interesting questions will be discussed by those who study the earth's magnetism, earthquakes and the oceans.

The International Union of Pure and Applied Chemistry meets at Lyons, France, from June 28 to July 2. From August 10 to 19 there will be an International Geological Congress at Brussels, Belgium. In June there will be an International Chemical Conference at Utrecht, Holland, to which distinguished chemists of all nations, including Germany and Russia, have been invited. Professor W. A. Noyes is acting as chairman of the committee to select American members of the conference, the other members being Professor Stieglitz, Professor Lewis and Dr. Whitney.

SCIENTIFIC ITEMS

We record with regret the death of Benjamin Moore, Whitney professor of biochemistry at the University of Oxford and formerly professor of physiology at Yale University; of Augustus D. Waller, professor of physiology at the University of London; of Theodor Liebisch, professor of mineralogy at Berlin; and of Camille Jordan, professor of mathematics at Paris and editor of the *Journal de Mathématiques.*

Sir Ernest Rutherford, Cavendish professor of experimental physics in the University of Cambridge, has been named as president of the British Association for the Advancement of Science for the annual meeting to be held at Liverpool next year.—Sir Frank Dyson was elected president of the British Optical Society at the annual meeting. At the same meeting Professor A. A. Michelson, of the University of Chicago, and Dr. M. von Rohr, of Messrs. Carl Zeiss, Jena, were elected honorary fellows of the society.

Professor Albert Einstein, of the University of Berlin, has delivered a series of four lectures in Paris on the "Theory of Relativity," under the auspices of the Collège de France.—After Vilhjalmur Stefansson had delivered a lecture before the National Geographic Society, the society made the announcement that its Research Council had awarded him the Grant Squires prize "in recognition of the unique interest and importance of his book, 'The Friendly Arctic,' the outstanding geographic publication of 1921."

Establishment of fellowships in medicine to increase the supply of qualified teachers and investigators is announced by the National Research Council. The fellowships, supported by appropriations of the Rockefeller Foundation and the General Education Board, will be open to Americans or Canadians of either sex holding or qualified to hold degrees of doctor of medicine or doctor of philosophy from approved universities. The appropriations are $100,000 a year for five years. Successful candidates, to be known as fellows in medicine of the National Research Council, will be at liberty to choose the institutions or universities in which they will work. The fellowships in medicine are similar to the fellowships in physics and chemistry established under the same auspices.

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SOCIAL LIFE AMONG THE INSECTS[1]

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LECTURE I

GENERAL REMARKS ON INSECT SOCIETIES. THE SOCIAL BEETLES

DURING the past fifty years, the science of living organisms has itself, like a living organism, developed so rapidly that it has more than once changed its aspect and induced its votaries to change their points of view. The future historian of the science will probably emphasize the difference of attitude towards the living world exhibited by Darwin and his contemporaries and that of the present generation of twentieth century biologists. He will notice that the works of the Victorians abound in such phrases as the "struggle for existence," "survival of the fittest," "Nature, red in tooth and claw," and disquisitions on the unrelenting competition in the development, growth and behavior of all animals and plants. This struggle, as you know, was supposed to constitute the very basis for the survival of favored forms through natural selection. There can be no doubt that even to-day we must admit that there is much truth in all this writing, but we would insist that it depicts not more than half of the whole truth. To us it is clear that an equally pervasive and fundamental innate peculiarity of organisms is their tendency to cooperation, or "mutual aid," as it was called by Prince Kropotkin. Even to the great Victorian naturalists the fact was familiar—though they failed to dwell on its great social significance—that all living things are genetically related as members of one great family, one vast, living symplasm, which, though fragmented into individuals in space, is nevertheless absolutely continuous in time, that in the great majority of organic forms each generation arises from the cooperation of two individuals, that most animals and plants live in associations, herds, col-

[1] Lowell Lectures.

onies or societies of the same species and that even the so-called "solitary" species are obligatory, more or less cooperative members of groups or associations of individuals of different species, the biocœnoses. Living beings not only struggle and compete with one another for food, mates and safety, but they also work together to insure to one another these same indispensable conditions for development and survival. The phenomena of mutualism and cooperation are, indeed, so prevalent among plants and animals and affect their structure and behavior so profoundly that there has arisen within very recent years a new school of biologists, who might be called "symbiotists," because they devote themselves to the investigation of a whole world of microorganisms which live in the most intimate symbiosis within the very cells of many if not most of the higher animals and plants.

If asked why it seems advisable to devote six lectures to social life among the insects, I might say that these creatures exhibit many of the most extraordinary manifestations of that general organic cooperativeness which I have just mentioned, and that these manifestations have not only an academic but also a practical interest at the present time. For if there is a world-wide impulse that more than any other is animating and shaping all our individual lives since the world war, it is that towards ever greater solidarity, of general disarmament, of a drawing together not only of men to men but of nations to nations throughout the world, of a recasting and refinement of all our economic, political, social, educational and religious activities for the purposes of greater mutual helpfulness. As Edward Carpenter says:

> The sense of organic unity, of the common welfare, the instinct of Humanity, or of general helpfulness, are things which run in all directions through the very fibre of our individual and social life—just as they do through that of gregarious animals. In a thousand ways: through heredity and the fact that common ancestral blood flows in our veins—though we be only strangers that pass in the street; through psychology, and the similarity of structure and concatenation in our minds; through social linkage, and the necessity of each and all to the other's economic welfare; through personal affection and the ties of the heart; and through the mystic and religious sense which, diving deep below personalities, perceives the vast flood of universal being—in these and many other ways does this Common Life compel us to recognize itself as a fact—perhaps the most fundamental fact of existence.

The social insects may also be singled out for special treatment for the following more particular reasons: first, because they represent Nature's most startling efforts in communal organization and have therefore been held up to us since the days of Solomon as eminently worth imitating, or to be avoided as an "abschreckendes Beispiel"; second, because these organizations are simpler and more perspicuous than our own and we can study their origin, development and decay and subject them to experimentation; third, because many of them represent clean-cut products of comparatively simple evolutionary tendencies and hence final and relatively stable accomplishments; fourth, because they show us the extent to which social organization can be developed and integrated on a purely physiological and instinctive basis, and by contrast therefore throw into sharper relief some of the defects and virtues of our own more intellectual type of society; and fifth, because they are so remote from us that we should be able to study them in an unbiased and truly scientific spirit.

I wish to dwell somewhat on the third of these reasons for the purpose of placing in clearer perspective the great antiquity and completeness of the social organization of insects. Some years ago the museums of Königsberg and Berlin sent me for study an extraordinary collection of ants in lumps of Baltic amber. There were 9,560 specimens, representing 92 species and 43 genera. As you know, the Baltic amber is merely the fossil resin of pines which flourished during Lower Oligocene Tertiary times in the region which is now Sweden. The liquid resin exuded from the tree- trunks precisely as it does to-day, and great numbers of small insects, especially ants, were trapped in the transparent, viscid masses which hardened, fell from the trees or remained after the rotting of the wood and were carried down by the streams and embedded in what is to-day the floor of the Baltic Sea and the soil of Eastern Prussia. The lumps are now brought to the surface either by mining or by the action of the waves which cast them up on the beaches. So beautiful and lifelike are the insects preserved in the amber that by comparison all other fossils have a singularly dull and inert appearance. Many of the specimens which I was able to examine were as exquisitely preserved as living ants embedded in Canada balsam by some expert microscopist. My study showed conclusively that the ants have undergone no important structural modifications since the Lower Oligocene, that they had at that time developed all their various castes just as we see them to-day, that their larvæ and pupæ were the same, that they attended plant-lice, kept guest-beetles in their nests and had parasitic mites attached to their legs in the very same peculiar positions as in our living species, and that at least six of the seven existing subfamilies and many of the existing genera were fully established. Some of the species in the amber were even found to be practically indistinguishable from those now living in Northern Europe and North America. The Baltic amber also contains social bees, wasps and termites, and though these are not so well known, what I have said of the ants will also *mutatis mutandis* prove to be true of them. Since my work was published Cockerell and

Donisthorpe have described a number of ants from the Bagshot Beds of the Isle of Wight, also of Oligocene age, and very recently Cockerell has described a typical ant, *Eoformica eocenica,* from even earlier strata, the Green River Eocene of Wyoming. We must conclude, therefore, that these insects—and the same is very probably true also of the wasps, bees and termites—had their origin in the Cretaceous, if not earlier. What I wish to emphasize is the fact that all the main structural and social peculiarities of these insects were completed by the beginning of the Tertiary and that they have since been merely marking time or developing only the slight modifications which serve to distinguish genera, species, subspecies and varieties.

Now how many years have elapsed since the beginning of the Tertiary? Geologists have, of course, made many and diverse estimates. I shall take the most recent, which are much in excess of earlier computations. Barrell gives the time since the beginning of the Tertiary as 55 to 65 million years. But the social insects are the most recent—the mere newly rich, so to speak—in the great class Insecta, which has a fossil record extending back to the Upper Carboniferous. And as our earliest known fossils are perfectly typical insects, it is probable that the earliest Hexapods made their appearance in the Silurian, if not earlier. This would make the period during which these wonderful creatures have been living and multiplying on our planet about 300 million years!

In order that we and the impatient reformers in our midst may experience the proper feeling of humility let us now compare the age of man and his society with that of the ants. During the Oligocene and early Miocene, while these insects, together with the uncouth primitive mammals, represented the dominant animal life of the plains and forests of the globe, the early Primates were just splitting into two tribes, one of which was destined to produce the modern apes, the other the Hominidæ, or humans. Our ancestors were probably just forsaking that life among the tree-tops which, as Woods Jones has shown, has left its ineffaceable impress on all the details of our anatomy. A large part of the diet of these early Hominids and their immediate ancestors probably consisted of those same ants which had already developed a cooperative communism so complete that in comparison the most radical of our bolsheviks are ultra-conservative capitalists. By a hundred thousand years ago our ancestors had reached the stage of the Neanderthal man, whose society was probably somewhat more primitive than that of the Australian savage of to-day. And so far as the actual, fundamental, biological structure of our society is concerned and notwithstanding its stupendous growth in size and all the tinkering to which it has been subjected, we are still in much the same infantile stage. But if the ants are not despondent because they have failed to produce a new social invention or convention in 65 million years, why should we be discouraged because some of our institutions and castes have not been able to evolve a new idea in the past fifty centuries?

I find that social habits have arisen no less than 24 different times in as many different groups of solitary insects. Careful investigation of the life-histories of tropical species will probably increase this number. These 24 societies, which I propose to consider in more or less detail in this and the following lectures, represent very different stages in the evolution of the social habit. Some of them are small and depauperate, mere rudiments of societies, some are extremely populous and present great differentiation and specialization of their members, whereas others show intermediate conditions. And while each of the 24 different societies has its own peculiar features, we nevertheless observe that all of them have arisen in the same manner and have the same fundamental structure. Each is a family consisting of two parent insects and their offspring or at least of the fecundated mother and her offspring, and the members of the two generations live together in more or less intimate, cooperative affiliation. During the long history of the Insecta this situation has developed time and time again and quite naturally out of the very general propensity of female insects to lay their eggs on food suitable to the hatching larvæ or to make protective structures or burrows, to store them with food and to oviposit on it. As a rule, the mother insect then dies and never sees her offspring, but all such parental care, which is also very prevalent among many other animals and even among plants, is nevertheless a potential or implicit nursing or fostering, which readily become actual or explicit in such species as manage to survive the hatching of their young and can therefore continue to feed and protect them. It is difficult, nevertheless, to draw a hard and fast line between certain solitary forms and some of the societies or families I have selected, for there is a finely graded series of cases of parental care between complete indifference to the offspring and the families of what may be called the incipiently social or subsocial forms. As the societies grow in size and complexity they naturally change from associations in which the progeny depend on their parents to associations in which the parents come to depend on their progeny.

John Fiske and others have claimed that human society has been rendered possible by a lengthening of infancy and childhood, since this obviously involves more elaborate care of the young by the parents and a greatly increased opportunity of learning on the part of the child. This is true, but it is equally true that the adult life of the parents must also be prolonged to cover the retarded juvenile development, and the insects show us that the lengthening of the adult stage comes first and makes social life possible. In solitary insects, of course, it is just the brevity of adult life that prevents the development of the social habit, no matter how long the larval period may be. This period may, in fact, extend over months or even years in certain insects which have an adult stage of only a few days or hours.

Momentous consequences necessarily follow from the lengthening of the adult life of the parent insect and the development of the family, for the relations between parents and offspring tend to become so increasingly intimate and interdependent that we are confronted with a new organic unit, or biological entity—a super-organism, in fact, in which through physiological division of labor the component individuals specialize in diverse ways and become necessary to one another's welfare or very existence. Since this integration necessarily leads to an important modification of the activities of the originally solitary insects composing the society it will be advisable to dwell for a few moments on the basic behavior of insects.

The activities of insects, like those of other animals, are an expression of three fundamental appetites or appetencies. Two of these—hunger and sex—are positive and possessive, the other—fear or avoidance—is negative and avertive. These appetites appear as the needs for food, progeny and protection.. So far as I am able to see, they manifest themselves in insects in essentially the same manner as in the higher animals, such as birds, mammals and man. The appetites of hunger and sex arise from internal stimuli which compel the organism to make random or trial and error movements till appropriate, specific external stimuli are encountered. Then a sudden, consummatory reaction occurs and the relieved organism lapses into quiescence till the internal stimuli again make themselves felt. In the case of fear or aversion, harmful or disagreeable stimuli, usually of external origin, cause random movements till the organism escapes or succeeds in ridding itself of the noxious or discomfort-producing situation, when it becomes quiescent. And the behavior of insects, like that of other animals, seems to be made up of successions of such appetitive or avertive cycles, which may be repeated during the life-cycle, or—and this is particularly true of insects—the whole life-cycle may consist of a few appetitive cycles of very elaborate patterns—the so-called "instincts."

Now when insects or other animals, for that matter, take to living in societies these fundamental appetites, which as solitary individuals they have been exercising for millions of years, are by no means lost or suppressed but become peculiarly modified. Since the environment of the social is from the outset much more complex than that of the solitary insect, it must respond not only to all the stimuli to which it reacted in its presocial stage but also to a great number of additional stimuli emanating from the other members of the society in which it is living. Even man, as Berman says, "with the growth of his imagination and the increase in number and density of his surrounding herd, has become the subject of continuous stimulation." The result seems to be a greatly increased responsiveness of the organism. It becomes, so to speak, socially sensitized, and all its appetites and emotions become hypertrophied or even perverted. This will be clear for the insects from the following very summary considerations:

(1.) Social life encounters serious and urgent difficulties in the matter of food, for the colony must have access to a supply which is abundant, nutritious and easily and continuously available in order that all the adult members as well as the young may be adequately nourished. Such an ideal food-supply is rare so that social insects are, as a rule, chronically hungry and in the presence of food positively greedy. Whenever possible both bees and ants gorge themselves to the utmost. While an ant is feeding on nectar or syrup her abdomen may be snipped off with a pair of scissors, without interrupting her repast. We shall see, however, that she appropriates only a very small portion of the swallowed food and that she distributes most of it among her nestmates. Hence, though she behaves like a glutton, we must refrain from regarding her as such. When we see a man importuning everybody for food or money we naturally regard him as avaricious or greedy, but when we learn that he is turning in all his collections to the Red Cross, he is transformed in our estimation. Not only does the social insect thus develop an unusual appetite for food but it also develops elaborate methods of apportioning the food among the adults and brood of the colony according to their various needs. Furthermore, the greatest economy in the use of food, which is of course energy, must be practiced and various methods of preserving and storing it for consumption during seasons of scarcity must be devised. And since insect societies must compete with many other hungry animals they tend to specialize in their diet and to take to foods that can not be readily utilized by other organisms. All this specialization leads eventually to the development of a caste peculiarly adapted to provisioning the colony. As we shall see, this caste comprises the so-called "workers."

(2.) The reproductive gives rise to even more serious difficulties than the nutritive appetite. If all the individuals in the colony are permitted to reproduce without restraint, the population will very soon outrun the food-supply and all its members will suffer from malnutrition or starvation, or it will have to resolve itself into smaller and feebler communities, and spread over a larger territory. The higher social insects have overcome this difficulty by rigidly restricting reproduction, except when food happens to be unusually abundant, to a few individuals and suppressing it in all the others. Hence the fecundity of certain females, the queens, and of the males, or drones, becomes greatly enhanced or hypertrophied, while the remaining females, the workers, are reduced to physiological sterility. But it was found most convenient, while thus developing the queens and males as a reproductive and the workers as a nutritive caste, and depriving the latter under normal conditions of the capacity for reproduction, to leave them in possession of their primitive parental instincts, that is, an ardent propensity for nursing the brood.

(3.) In the higher social insects fear is very readily aroused and can be easily studied in all its manifestations from abject cowardice and "death-feigning" in small and feeble species to panic rage in very populous communities. It is certainly of great biological significance, because these insects and their helpless brood are sedentary, or fixed to a particular environment and are therefore exposed to the unforeseen attacks of enemies, inundations of great changes of temperature. Hence, we find that they not only make elaborate nests and fortifications but have developed powerful jaws, hard skulls, pungent or nauseating secretions and deadly stings. The workers originally assumed the protective rôle in addition to their other functions, but in many ants and most termites a special warrior or soldier caste has been evolved. Then, precisely as in man, many wasps, bees and ants found that the best method of defence is offence and their enemies were attacked before they could reach the nest. From this it was, of course, only a step to the organization of marauding and plundering expeditions and the development of aggressive warfare.

All the very complicated manifestations of the hunger, sex and fear appetites are so inextricably interwoven and interdependent that it is impossible adequately to study any one of them in isolation. I shall therefore have to refer to all of them again and again, but I wish to put the main emphasis in these lectures on the hunger appetite, because it is the most fundamental, exhibits the most astonishing developments and is found to have an even greater influence on the reproductive and protective appetites than we had supposed. The recent work of the biochemists and physiologists on the vitamines and internal or endocrine secretions, or "encretions" as some German investigators call them, has shown that extremely minute quantities of certain substances may have very profound and far-reaching effects on the metabolism, structure and functioning of living animals, and there has long been a suspicion that the differentiation of the fertile and sterile castes among social insects may be due to very delicate chemical stimuli. I shall endeavor to show that such stimuli may also play a determining rôle in maintaining the integrity or solidarity of many insect societies.

Before describing the various societies in greater detail I wish briefly to compare them with human society. I use this word in the singular, because at the present time, owing to the greatly increased facilities of transportation and intercommunication, what were once numerous independent human societies have practically fused or are about to fuse to form one immense, world-wide society. Human and insect societies are so similar that it is difficult to detect really fundamental biological differences between them. This assertion may be supported by the following considerations:

(1.) It is sometimes said or implied that human society is a rational association, due to intelligent cooperation, or contract among its members, whereas insect societies are merely physiological or instinctive associations. The second part of this statement is correct, but he who would seek support for the first part in the works of present day sociologists, psychologists and philosophers will be disappointed. The whole trend of modern thought is towards a greater recognition of the very important and determining rôle of the irrational and the instinctive, not only in our social but also in our individual lives. The best proof of this statement is to be found in the family which by common consent constitutes the primitive basis of our society, just as it does among the insects, and the bonds which unite the human family are and will always be physiological and instinctive.

(2.) It may be said that insect societies are discrete entities, each of which arises as a single family, increases in population for some time and then dies away, whereas human society—the Great Society of Graham Wallas—is a mixtures of families and groups which grow and continue indefinitely. This is an important distinction but not absolute, since human society must have arisen from a single family or a few families, such as we find among the anthropoids. The difference would therefore seem to lie in the fact that our society no longer repeats its earliest phylogenetic stage as does that of the social insects. But there are some insects, such as the honey-bee and some South American bees and wasps, that no longer repeat this incipient stage but from time to time send off new colonies, or societies by swarming, much as did the

Phoenicians and early Greeks and the nations of western Europe in more recent times.

(3.) Korzybski, in an interesting book entitled "The Manhood of Humanity," has recently endeavored to emphasize another difference, the existence of social heredity, or what he calls "time-binding," in human society and its absence among animals. Certainly no one can overestimate the importance of tradition and social heredity. We should still be in the anthropoid stage if we had failed to preserve and add to the capital of culture and mores transmitted to us by former generations or ceased to transmit them and the fruits of our own activities to our descendants. It is clear also that the social insects do not bequeath libraries, institutions and bank accounts to their posterity, and that each colony or society begins anew with the structural and instinctive equipment acquired by true, or organic heredity. This explains why we see so little change in these insects during the past 50 million years. Nevertheless, the distinction is not absolute. There are, as I shall show, ants, termites and beetles that cultivate fungi and bequeath them to succeeding generations. Social insects may also be said to bequeath real estate, that is, their nests, pastures and hunting grounds; and since the young queens of ants and termites often live for some time in the parental nests before they establish colonies of their own, there is reason to believe that they may acquire a very slight amount of experience by consorting with their sisters and parent queen.

(4.) It may be said that the social insects differ from man in not having learned the use of tools, but there are species of ants that use their larvæ as shuttles in weaving the silken walls of their nests, and the marvelous engineering feats of many social insects show that they are our close rivals in controlling the inorganic environment.

(5.) That they have acquired an equally astonishing control of their organic environment is shown by the fact that they are the only animals besides ourselves that have succeeded in domesticating other animals and enslaving their kind. In fact, the ants and termites may be said to have domesticated a greater number of animals than we have, and the same statement may prove to be true of their food-plants, when they have been more carefully studied.

(6.) It may be maintained that we have developed language and this, of course, is a true distinction, if we mean by language articulate speech, but the members of an insect society undoubtedly communicate with one another by means of peculiar movements of the body and antennæ, by shrill sounds (stridulation) and by odors.

The wonder has always been, not that there are so many differences in structure between such disparate organisms as insects and man, but that there are so many striking similarities in behavior. And the wonder grows when we find that social organization at least incipiently analogous to our own has arisen *de novo* on at least 24 different occasions in nearly as many natural families or subfamilies belonging to five very different orders of insects. A list of the groups that form these various societies is given in the accompanying table.

Coleoptera (Gynandrarchic)	1. Scarabæidæ (Copris, Minotaurus)
	2. Passalidæ (Passalus)
	3. Tenebrionidæ (Phrenapates)
	4. Silvanidæ (Tachigalia Beetles)
	5. Ipidæ (Ambrosia Beetles)
	6. Platypodidæ (Ambrosia Beetles)
Hymenoptera (Gynarchic)	*Sphecoidea*
	7. Sphecidæ (Sphex)
	8. Bembicidæ (Digger Wasps)
	Vespoidea
	9. Eumeninæ (Synagris)
	10. Zethinæ (Zethus)
	*11. Stenogastrinæ (Stenogaster)
	*12. Epiponinæ (Chartergus, Belonogaster, etc.)
	*13. Rhopalidiinæ (Rhopalidia, etc.)
	*14. Polistinæ (Polistes)
	*15. Vespinæ (Vespa)
	Apidæ
	16. Halictinæ (Halictus)
	17. Ceratininæ (Allodape)
	*18. Bombinæ (Bumble-bees)
	*19. Meliponinæ (Stingless Bees)
	*20. Apinæ (Honeybees)
	*21. Formicidæ (Ants)
Dermaptera (Gynarchic)	22. Forficulidæ (Earwigs)
Embidaria (Gynarchic)	23. Embiidæ (Embia)
Isoptera (Gynandrarchic)	*24. Termitidæ (Termites, or "White Ants")

In this list the first to tenth, the sixteenth and seventeenth, and the twenty-second and twenty-third are incipiently social or subsocial; the remaining ten, marked with asterisks, are definitely social. In the termites and all the beetle groups the colony consists of a male and female parent and their offspring of both sexes; in all the Hymenoptera, Dermaptera and Embidaria the female alone founds the colony, which is developed by her daughters. The former groups are therefore gynandrarchic, the latter gynarchic. These differences will become clearer as we proceed.

Let us examine first the six beetle societies which have been developed by species belonging to as many different natural families.

(1.) *Scarabæidæ*—For our knowledge of the habits of the dung-beetles we are indebted to one of the greatest entomologists, J. H. Fabre. His observations are recorded in parts of four of the ten volumes of his "Souvenirs Entomologiques," and comprise some of their most remarkable chapters. Some notion of the difficulties which he encountered while working out the life-histories of these insects may be gleaned from his statement that he did not succeed in completely elucidating the habits of one of them, the sacred Scarabæus, till he had had it under observation for nearly forty years. He studied quite a number of species and found startling diversity in their behavior. Some of them, the Aphodii, e. g., merely lay their eggs in fresh dung and the hatching larvæ feed on the substance. Among the others, which resort to much more elaborate methods of caring for their progeny, three different types of behavior may be distinguished:

(A.) The Sacred Scarabæus (Fig. 1) above mentioned and many allied forms are fond of the open sunlight and are often seen making perfect spheres of fresh cattle manure and trundling them away to cavities in the soil or under stones. These pellets are devoured by the beetles. Fabre found that a single beetle will not only eat but digest a mass of dung equal to its own body-weight in 12 hours. When the female beetle is ready to lay she makes a very similar pellet, but this time of sheep's dung and rolls it into an elliptical chamber which she has previously excavated in the

FIG. 1
Sacred scarabæi (Scarabæus sacer) trundling their pellet of dung. After E. J. Detmold.

soil. This chamber is about as large as one's fist. She then makes a crater-shaped depression surrounded by a circular flange at one pole of the pellet, lays a large egg in it and draws the material of the flange over it till it is completely enclosed. The pellet is now pear-shaped. Thereupon the mother beetle leaves the chamber and proceeds to dig another and provision it in the same manner. The hatching larva consumes the inside of the pellet, pupates

FIG. 2
Male Sisyphus beetle (*Sisyphus schœfferi*) holding the dung pellet while the female digs the burrow to receive it. After E. J. Detmold.

within it and emerges as a beetle in due season. There is, of course, nothing social about this insect. But in a smaller, allied form, *Sisyphus schœfferi* (Fig. 2), Fabre found that the male helps the female trundle her pellet to a convenient spot, guards it while she excavates a cavity, assists her in lowering the pellet, waits for her till she has oviposited in it in the same manner as the Scarabæus, and then departs with her to repeat the performance.

(B.) In Copris, of which Fabre studied two species, *C. hispanus* and *C. lunaris*, we have a closer approach to a social condition. These insects are crepuscular and dig a chamber as large as a large apple immediately under the pile of dung. This is then carried down in masses and leisurely devoured. During the breeding season, however, the beetles associate in pairs and the male and female not only cooperate in excavating a chamber but also in nearly filling it with dung, which they then proceed to knead into the form of a smooth ellipsoid as large as a turkey's egg (Fig. 3). In the case of *C. hispanus* the male then deserts the female and the latter proceeds to cut the ellipsoid up into four spherical pellets, each of which is treated like the pellet of the

FIG. 3
Spanish Copris (*Copris hispanus*) fashioning her large ellipsoid of dung in her subterranean chamber. After J. H. Fabre.

sacred Scarabæus, provided with an egg and converted into a regular ovoid (Fig. 4). The mother remains in the chamber, guarding the pellets and keeping them free from fungus growth for four months, while the larvæ are developing within them. After the young beetles hatch the mother accompanies them to the surface of the soil and the family disperses. In the case of *C. lunaris* the male remains in the chamber with the female and helps her manufacture the ovoids, which owing to his assistance are twice as numerous as they are in *hispanus.* When the young beetles emerge they are escorted to the surface by both parents.

(C.) Other beetles, like Geotrypes, Onthophagus and Minotaurus, dig long tubular tunnels into the soil immediately under the dung. As a rule, they do not make spherical pellets but pack the deeper, blind end of the burrow with layers of dung till it forms

FIG. 4
Spanish Copris (*Copris hispanus*) guarding her ovoids of dung in the subterranean chamber. After E. J. Detmold.

a sausage shaped mass above the egg or enclosing it at one end. The behavior of *Minotaurus typhœus* (Fig. 5) is even more astonishing than that of Copris. The male and female beetles mate in March and together dig a tubular gallery straight down into the soil to the remarkable depth of five feet. The male remains above, works the dung up into elliptical pellets and lowers them down the shaft, while the female, after laying an egg in the sand at the bottom of the burrow, receives the pellets, tears them apart and packs the fragments down, as if she were working in a silo, till they form a mass as big as one's finger. Then she digs in succession a few branch galleries off from the main shaft, furnishes each of them with an egg and provisions it in the same manner. By constructing an ingenious apparatus and providing the beetles with an unlimited supply of manure, Fabre induced one male to make

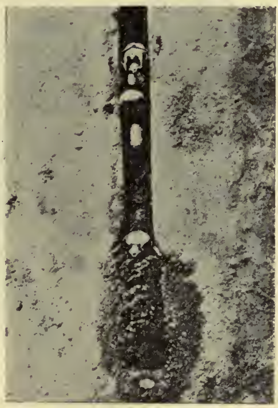

FIG. 5
Lowermost portion of burrow of the Minotaur (*Minotaurus typhœus*) showing the male bettle lowering the dung in pellets and the female storing it in layers above her egg. After J. H. Fabre.

239 pellets and hand them down to the female, but unfortunately the latter had died at the bottom of the gallery, so that there were no eggs and the pellets had not been torn apart and stored. The development of the young requires five months and the female very probably remains in the burrow till the brood hatches and crawls up to the surface.

(2.) *Passalidœ*—These large, active, jet-black, flattened and parallel-sided beetles (Fig. 6) are common throughout the tropics of both hemispheres. A single species, *Passalus cornutus,* occurs in the United States as far north as Michigan and Massachusetts. Ohaus, who first studied the habits of several species in the forests of Brazil, has shown that they form colonies consisting of a male and female and their progeny and make large, rough galleries in rather damp, rotten logs. The broadly elliptical yellowish green or greenish black eggs, to the number of a dozen or more, are laid in a loose cluster and guarded by the parents. The larvæ are drab-colored and cylindrical, with the hind pair of legs reduced to peculiar short paw-like appendages which can be rubbed back and forth on striated plates at the bases of the middle legs (Fig. 7), thus producing a shrill note. On the dorsal surface of the abdomen of the adult beetle there is also a stridulatory organ in the form of patches of minute denticles which may be rubbed against similar structures on the lower surfaces of the wings. Ohaus found that the parent beetles triturate the rotten wood and apparently

FIG. 6
Passalus sp. Adult beetle and rather young larva, about twice natural size.

treat it with some digestive secretion which makes it a proper food for the larvæ, since their mouth-parts are too feebly developed to enable them to attack the wood directly. They are therefore compelled to follow along after their tunnelling parents and pick up the prepared food. All the members of the colony are kept together by stridulatory signals. The noise made by the beetles is so loud that it is possible to detect the presence of a Passalus colony in a log by merely giving it a few sharp raps. I have been startled on more than one occasion in Central America by the shrill response thus elicited from large Passali that were burrowing deep in the wood. When the larvæ are mature they pupate in the burrows and the emerging beetles are guarded and fed by the parents till they are fully mature. Observations that I have made in Australia,

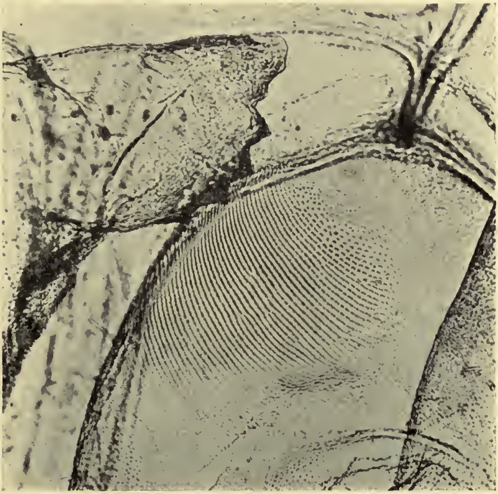

FIG. 7
Microphotograph showing abbreviated, paw-like hind leg of Passalus larva and the striated surface over which its toothed edge is rubbed during stridulation.

Central America, Trinidad and British Guiana confirm Ohaus's statements.

(3.) *Phrenapates*—Nearly a century ago Kirby described a

FIG. 8
Phrenapates Bennetti, a social Tenebrionid beetle, from a specimen in the Museum of Comparative Zoology. Photograph by Mr. Leland H. Taylor.

peculiar beetle from Colombia as *Phrenapates bennetti* (Fig. 8). It is about an inch long, jet-black and shining and superficially resembles Passalus, but belongs to a very different family, the Tenebrionidæ. G. C. Champion records it from Central America (Panama to Guatemala), and states that he "met it in plenty in decaying timber in the humid forest region of Chiriqui and frequently dug it out of cylindrical burrows, probably made by the larvæ, in the solid wood." Some years later Ohaus encountered the insect in Ecuador and gave a more detailed account of its habits. The male and female gnaw in the wood of the silk-cotton tree (Bombax) a narrow, cylindrical gallery about a foot and a half long and make roomy niches on each side of it at definite intervals. All the work is neat and smooth, unlike the burrow of Passalus. In each of the niches Ohaus found an egg or one or two larvæ, the latter feeding on fine, elongate shaving which filled the niches and had evidently been provided by the parent beetles. The eggs are laid at rather long intervals so that the larvæ, unlike those of Passalus, vary considerably in size. They resemble our common meal-worms (*Tenebrio molitor*), but are milk-white. No stridulatory organs could be detected in the beetles, but like some other Tenebrionids (Blaps) they emit a penetrating odor.

(4.) *Tachigalia Beetles*—During the summer of 1920 I discovered in the jungles of British Guiana a couple of Silvanid beetles which lead a more spectacular existence than some of the preceding. These beetles, which Messrs. Schwarz and Barber have named *Coccidotrophus socialis* and *Eunausibius wheeleri* (Fig. 9) are less than a quarter of an inch in length and have long, slender, subcylindrical, red or chestnut brown bodies, with short legs and club-shaped antennæ. They occur only in the hollow leaf-petioles (Fig. 10) of a very interesting tree, *Tachigalia paniculata*, and only in young specimens 1½ to 7 ft. high while they are growing in the shade under the higher trees of the jungle. The older trees, which

FIG. 9
Tachigalia beetles, the larger *Coccidotrophus socialis*, the smaller *Eunausibius wheeleri*.

may attain a height of 40 feet or more, have all their petioles inhabited by viciously stinging or biting ants. Each beetle colony is started by a male and female which bore through the wall of the petiole, clean out any pith or remains of previous occupants it may contain and commence feeding on a peculiar tissue rich in proteins, which is developed in parallel, longitudinal strands in the wall of the petiole (Figs. 11 and 12). As they keep gnawing out this tissue they gradually make grooves and pile their feces on the ungnawed intervening areas, so that the interior of the petiole assumes a peculiar appearance (Figs. 13 and 14). While the beetles are thus engaged numbers of small mealy-bugs of the genus

FIG. 10
Bases of leaf-petiole of *Tachigalia paniculata* (*a*) of young, shade tree; (*b*) of large, sun tree, both nearly one-half natural size. Pieces of the older petiole and adjacent trunk have been cut out to show the cavity.

Pseudococcus (*Ps. bromeliæ*) (Fig. 15), covered with snow-white wax, wander into the petiole through the opening made by the beetles, settle in the grooves, sink their delicate sucking mouth-parts into the nutritive tissue and imbibe its juices. The beetles soon begin to lay their small, elliptical, white eggs along the edges of the grooves (Fig. 14) and the hatching larvæ, which are beautifully translucent, run about in the cavity and feed on the same tissue as the parents. But incredible as it may seem both the adult beetles and the larvæ in all stages have learned to stroke the mealy-bugs with their antennæ, just as our common ants stroke similar mealy-bugs and plant-lice, and feed on the droplets of honey dew,

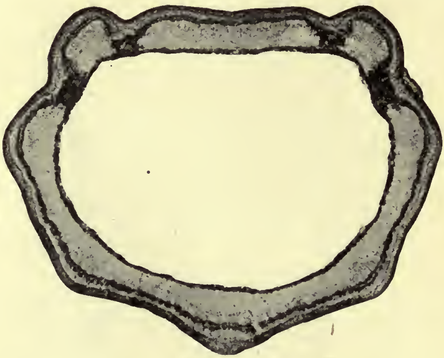

FIG. 11

Cross-section of base of a young, uninhabited petiole of *Tachigalia paniculata* showing the bands of protein-containing nutritive tissue (dark). Photograph by Professor I. W. Bailey.

or saccharine excrement which they give off when their backs are properly titillated. So greedy are the Silvanids for this nectar that I have seen a beetle or a larva stroke a mealy-bug for an hour or longer and receive and swallow a drink every few minutes. When two or more beetles or two or more larvæ or a group of beetles and larvæ happen to be engaged in stroking the same mealy-bug, they stand around it, like so many pigs around a trough, and the larger or stronger individual keeps butting the others away with its head. The butted individuals, however, keep returning and resuming their stroking till the knocks become too severe or the stronger individual leaves and begins to stroke another mealy-bug. Thus the beetles and their progeny have discovered a rich food supply, consisting in part of the proteid-containing tissues of the Tachigalia and in part of the sugar and water discharged by the mealy-bugs, which in turn imbibe the sap of the tree. The beetles lay their eggs at intervals so that larvæ in all stages are

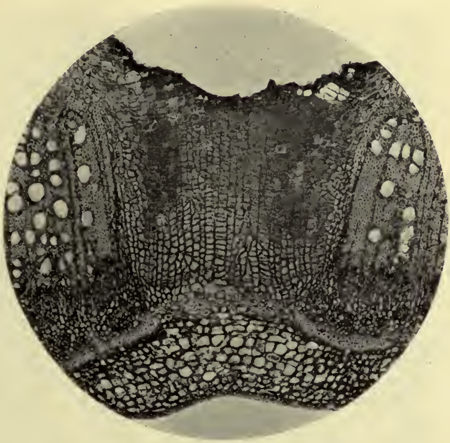

FIG. 12
Enlargement of one of the bands of nutritive tissue of the preceding figure, showing the rather homogeneous protein-containing cells. Microphotograph by Professor I. W. Bailey.

found in the same colony. When mature each larva constructs a cocoon of minute particles bitten out of the plant tissues (Fig. 16), creeps into it, closes the opening from the inside and pupates. When the young beetles hatch they remain with their parents and

FIG. 13
Cross-section of Tachigalia petiole inhabited by a flourishing colony of *Coccidotrophus socialis*. The gnawed out areas of nutritive tissue are seen above, with the frass piled on the intermediate areas; below three cocoons have been sectioned. Photograph by Professor I. W. Bailey.

soon begin to lay eggs, so that eventually the colony consists of several dozen beetles, larvæ, pupæ and mealy-bugs in all stages and all living peacefully together, except for the little family bickerings of the beetles and larvæ over the milking of their patient, snow-white cattle. When the petiole becomes too crowded, pairs of young beetles leave it, enter other petioles of the same

FIG. 14

Enlarged drawing of a part of the wall of a *Tachigalia* petiole inhabited by *Coccidotrophus socialis;* showing the food grooves and frass ridges, the entrance with its wall, the eggs, an intact and broken cocoon of the *Coccidotrophus* and two cocoons of the Coccid parasite, *Blepyrus tachigaliæ,* one of them after the eclosion of the parasite.

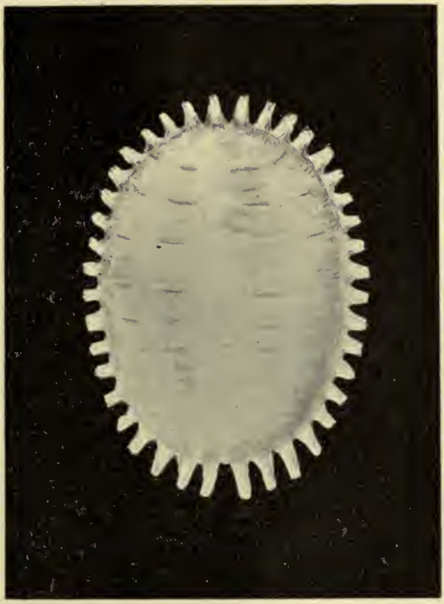

FIG. 15
Pseudococcus bromeliæ Bouché. Sketch of an adult living female with intact covering and peripheral pencils of wax.

or other Tachigália trees and start new colonies. As the tree grows and emerges from the undergrowth into the sunlight, the ants which then take complete possession of it oust the beetles from the petiolar cavities but adopt their mealy-bugs, just as the invading German army appropriated the French cattle. There are many other extraordinary insects associated with the Tachigalia, its beetles and mealy-bugs, but I must omit an account of them because they are irrelevant to the present discussion.

(5.) *Ipid Ambrosia Beetles*—The family Ipidæ comprise small, cylindrical, red-brown or black beetles which live in the trunks and branches of trees. The group is now divided into two sections, one of which includes the bark-beetles, which are nonsocial and make the beautiful, radiating burrows so commonly seen on the inner surface of the bark of sickly trees, the other includes the ambrosia beetles (Fig. 17), which are social and run their burrows right into the wood of healthy or recently felled trees. The name ''ambrosia beetles'' is derived from a term applied by Schmidberger to the fungi which the beetles cultivate as food for themselves and their larvæ. Structurally the two sections of the family Ipidæ can be readily distinguished by the mouthparts, the bark-beetles having their maxillæ armed with a row of 12 to 20 strong tooth-like bristles adapted to gnawing bark, whereas the maxillæ of the ambrosia beetles are fringed with 30 to 40 delicate, curved bristles, evidently suited to cropping the soft hyphæ of their food-fungus. Fourteen genera and nearly four hundred species of ambrosia beetles have been described. One genus alone, Xyleborus, which is cosmopolitan, contains 246 species. The fungi that grow in the galleries often

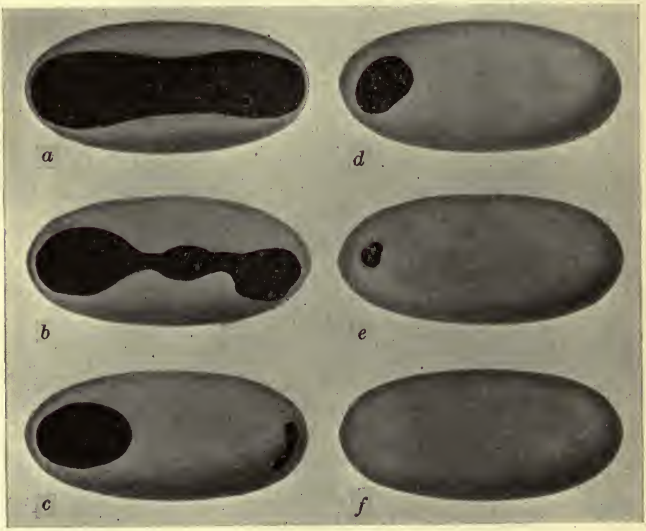

FIG. 16
Six successive stages in the construction of the cocoon by the full-grown larva of *Coccidotrophus socialis*.

give their walls a black stain, so that the value of the wood thus affected is greatly impaired. One species, *Xyleborus perforans*, has a bad reputation in the tropics, where it goes by the name of "tippling Tommy," because it has a strong predilection for boring in the staves of wine, beer and rum casks and thus causing much leakage. It might be adopted by our prohibitionists as their totem-animal.

The ambrosia beetles were first carefully studied in this country by H. G. Hubbard, whose untimely death deprived us of one of our most talented entomologists. I can not do better than quote his concise account of two of our species of Pterocyclon (*mali* and *fasciatum*): "The sexes are alike, and the males assist the females in forming new colonies. The young are raised in separate pits or cradles which they never leave until they reach the adult stage. The galleries, constructed by the mature female beetles, extend rather deeply into the wood, with their branches mostly in a horizontal plane. The mother beetle deposits her eggs singly in circular pits which she excavates in the gallery in two opposite series, parallel with the grain of the wood. The eggs are loosely packed in the pits with chips and material taken from the fungus bed which she has previously prepared in the vicinity and upon which the ambrosia has begun to grow. The young larvæ, as soon as they hatch out, eat the fungus from these chips and eject the refuse from their cradles. At first they lie curled up in the pit

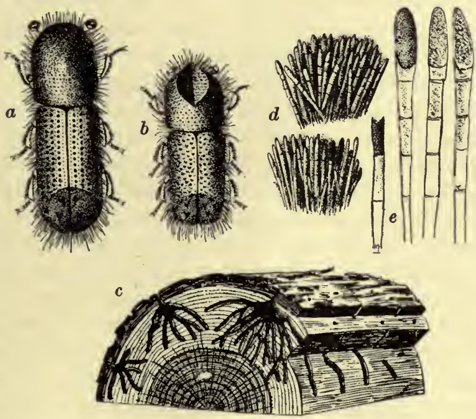

FIG. 17

Ambrosia beetle, *Xyleborus celsus* Eichh., of the hickory (after Hubbard); *a*, female beetle; *b*, male; *c*, piece of hickory, showing burrows of *X. celsus* in the sap-wood; *d*, ambrosia grown by *X. celsus* on the walls of of the burrows; *e*, same more enlarged.

made by the mother, but as they grow larger, with their own jaws they deepen their cradles, until, at full growth, they slightly exceed the length of the larvæ when fully extended. The larvæ swallow the wood which they excavate, but do not digest it. It passes through the intestines unchanged in cellular texture, but cemented by the excrement into pellets and stained a yellowish color. The pellets of excrement are not allowed by the larvæ to accumulate in their cradles, but are frequently ejected by them and are removed and cast out of the mouth of the borings by the mother beetles. A portion of the excrement is evidently utilized to form the fungus bed. The mother beetle is constantly in attendance upon her young during the period of their development, and guards them with jealous care. The mouth of each cradle is closed with a plug of the food fungus, and as fast as this is consumed it is renewed with fresh material. The larvæ from time to time perforate this plug and clean out their cells, pushing out the pellets of excrement through the opening. This debris is promptly removed by the mother and the opening again sealed with ambrosia. The young transform to perfect beetles before leaving their cradles and emerging into the galleries." The ambrosia of Pterocyclon "is moniliform and resembles a mass of pearly beads. In its incipient stages a formative stem is seen, which has short joints that become globular conidia and break apart. Short chains of cells, sometimes showing branches, may often be separated from the mass. The base of the fungous mass is stained with a tinge of green, but the stain of the wood is almost black.

(6.) *Platypodid Ambrosia Beetles*—These were formerly included among the Ipidæ but are now regarded as an independent family. They can be easily distinguished by their much broader head and longer feet, the first joint of the tarsi being as long as all the remaining joints together. The great majority of the species are tropical, so that their habits have not as yet been very thoroughly studied. So far as known, the Platypodids all bore in the wood of dying or recently felled trees, live in societies and feed on fungi which they grow on the walls of their burrows. Hubbard and Swaine have studied some of our North American and Strohmeyer has published some observations on one of the few European forms. The following description of *Platypus compositus* is quoted from Hubbard: "They are powerful excavators, generally selecting the trunks of large trees and driving their galleries deep into the heart-wood. They do not attack healthy trees but are attracted only by the fermenting of the sap of dying or very badly injured trees. The death rattle is not more ominous of dissolution in animals than the presence of these beetles in standing timber. . . . The female is frequently accompanied by several males and as they are savage fighters, fierce sexual contests take place, as a result of which the galleries are often strewn with fragments of the vanquished. The projecting spines at the ends of the wing-cases are very effective weapons in these fights. With their aid a beetle attacked in the rear can make a good defense and frequently by a lucky strike is able to dislocate the outstretched neck of his enemy. The females produce from 100 to 200 elongate-oval pearl-white eggs, which they deposit, in clusters of 10 or 12, loosely in the galleries. The young require five or six weeks for their development. They wander about in the passages and feed in company upon the ambrosia which grows here and there upon the walls. . . . The older larvæ assist in excavating the galleries, but they do not eat or swallow the wood. The larvæ of all stages are surprisingly alert, active and intelligent. They exhibit curiosity equally with the adults, and show evident regard for the eggs and very tender young, which are scattered at random about the passages, and might easily be destroyed by them in their movements. If thrown into a panic the young scurry away with an undulatory movement of their bodies, but the older larvæ will frequently stop at the nearest intersecting passage and show fight to cover their retreat.'' The ambrosia of *P. compositus* consists of hemispherical conidia growing in clusters on branching stems. The long continued growth of this fungus blackens the walls of the older galleries.

Each species of ambrosia beetle—and this is true of both the Ipidæ and the Platypodidæ—grows its own peculiar fungus in a pure culture, irrespective of the tree it may select for its burrows. Strohmeyer seems to have shown how in the case of certain Platypodids the mother beetle manages to obtain the spores of the particular fungus which she cultivates. He finds that she carries them from the burrows in which she passed her larval and pupal stages to the new burrows which she makes for her own progeny in a kind of crate or basket consisting of one or several dense tufts of long, curved hairs on the top of her head or on her mouth-parts; and Schneider-Orelli has found that the females of the Ipid ambrosia beetles carry the fungus in the fore part of the stomach and are thus able to infect the walls of the new burrows which they establish. These are only two of the instances among the social insects of the actual transmission of a food-plant from generation to generation.

We may now summarize very briefly the main points of interest in connection with the social beetles:

(1.) The six unrelated families are all very ancient. Species of four of them (Silvanidæ, Tenebrionidæ, Ipidæ and Platypodidæ) are, in fact, known from the Baltic Amber. The absence of the dung-beetles from that formation is easily explained, since these insects are not arboreal, nor are they attracted by liquid resins. Several of the living genera (Scarabæus, Copris, Onthophagus, Sisyphus, and Gymnopleurus), however, are known from the Upper Miocene shales of Oeningen, and Hagedorn mentions several species of ambrosia beetles as occurring in the African and Malagasy copal, a fossil resin of comparatively recent formation. There can be little doubt that all the six families which I have been considering are much older than these records would seem to indicate. Most of them, in fact, are cited by Handlirsch as probably having arisen at the beginning of the Cretaceous or even earlier.

(2.) The substances on which the six groups of social beetles feed are remarkably diverse, ranging from dung and wood in various stages of decay to the living tissues of plants, the honey-dew of mealy-bugs and delicate fungi. These are all abundant and ubiquitous substances of vegetable origin, and all the social beetles manage to store or find their food in such peculiar places that they can avoid intense competition with most other organisms.

(3.) This abundant but in many cases not very nutritious food-supply which the adult beetles seek and exploit primarily for their own consumption enables them to acquire a considerable longevity, and this in turn, of course, enables them to survive the hatching and development of their young.

(4.) In all the groups the parent beetles show a very pronounced interest in their offspring, and feed them directly or, at any rate, place them in close contact with the food and guard them.

(5.) The father beetle cooperates to a greater or less extent with the mother beetle in providing for the young, although his cooperation may be slight. Probably it is really *nil* in most of the Ipid ambrosia beetles, the males of which are in many species wingless and very rare, so that mating must take place in the maternal colony.

(6.) There are neither structural nor physiological differences between the fully developed young and the adult parents of the social beetles. In other words, nothing like a development of castes has made its appearance among them.

HOMING POWERS OF THE CAT

By Professor FRANCIS H. HERRICK

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NO animal has been so highly extolled on the one hand as a paragon of virtue, and on the other so roundly condemned as an unmitigated nuisance as the domestic cat, which has been associated with man for upwards of three thousand years. Southey once declared that no home was complete unless it had "in it a child rising six years and a kitten rising six months." Friends of the cat never tire of lauding its domesticity, its neatness, its useful services as a destroyer of rodents, the natural grace and beauty of its movements, its affection and even its surpassing intelligence; while its detractors denounce it as an independent, unsocial ingrate, attached to the hearth for the comfort it affords, but seldom wasting any affection on the person who lays the fire or supplies it with food, as incapable of any unselfish devotion and service, a carrier of vermin and disease, and the most cruel and remorseless enemy of bird-life everywhere.

Viewed impartially the cat is a carnivorous animal of rather moderate intelligence; courageous and resourceful when put to the test, it only follows at all times the bent of its strongest instincts; like every feline it has keen tactual, visual and auditory senses, but its nose is small and rather weak; its endurance in relation to its bodily strength is phenomenal, and we can not but admire its marvellous powers of muscular coordination and control; fecund, and endowed with a vitality which in the popular mind extends far beyond life's usual limits, the cat is unsurpassed as mother and nurse, and in this field her instinct is never-failing.

In his excellent economic study of the cat, Forbush[1] reminds us that while partly tamed this animal has not been fully domesticated: "It has not been subdued, confined or controlled, except in rare cases, but is to all intents and purposes a wild animal. In most cases it stays in the home of man, mainly because of the warmth of his fire, the food that it eats and its affection for the location where it was reared. If, by accident or design, anything

[1] Forbush, Edward Howe: "The Domestic Cat," *Economic Biology Bulletin*, No. 2. Boston, 1916.

occurs to interrupt its association with man, it readily returns to the wild;" and Shaler,[2] who is also quoted by this writer, says: "As a consequence of the affection which cats have for particular places, they often return to the wilderness when by chance the homes in which they have been reared are abandoned. Thus in New England, in those sections of the district where many farmsteads have of late years been deserted, the cats have remained about their ancient haunts and have become entirely wild. In this state they are bred in such numbers that their presence is now a serious menace to the birds and other weaker creatures of the country. The behavior of these feralized animals differs somewhat from that of creatures which have never been tamed. They have not the same immediate fear of a man, but the least effort to approach them leads to their hasty flight."

Every one will admit that the cat varies no less in its individual ways and disposition than does its inveterate enemy, the dog, yet its attachment is mainly directed to its home and neighborhood, and while vagabondage may be rarely adopted by choice it is more commonly enforced. "Thousands of families, says Forbush, "go into the country or to the seaside in summer, taking cats and kittens with them, and leave their pets on their return to the city, not knowing, perhaps, that such cruelty is forbidden by law."

Varied and voluminous as the literature of the cat is found to be, especially in the fields of anecdote, general natural history and anatomy, its homing ability has never been previously tested under experimental conditions, though accounts of this notorious power abound in many languages; from time immemorial it has been said that the cat, like the bad penny, always comes back. Probably all cats possess this homing power in varying degrees, and all with fixed abodes might possibly be induced to exercise it under certain conditions; yet in every case the possession of a power, and the tendency to use it should be clearly distinguished; though possession, in this case, be under the firm grasp of heredity, the *use* is determined by experience and the physiological state of the animal at the moment. Thus it is obvious that an animal with dependent young would have a double inducement to return to its home provided local attachments had already taken root; on the other hand, it is equally clear that, whenever an animal is forcibly removed from its abode, the diversions or accidents which are likely to attend it may be of such character as to block or defeat any impulse to return. In every such case the only facts likely to be either known or knowable are that the animal on that occasion did or did not return; we are usually left in complete ignorance of the animal's

[2] Shaler, Nathaniel Southgate: *Domesticated Animals*, New York, 1895.

inherent abilities, of its struggling impulses or even of its efforts, should any be made.

The account of experiments to follow is offered mainly as a sample of this animal's power under certain conditions; they do not admit of the usual methods of control; they can be multiplied indefinitely, but they can not be exactly repeated, since the variables in each case, of which fear is but one, can not be predicted and are bound to influence response.

The mother of the first cat with which we experimented was brought to us in a basket from a town ten miles distant, and never left us until the following year, when she began to raid the birds on our premises and was given away; her offspring, to which I shall now refer, was born and reared on our place and, so far as we knew, it had never left it; at the time of which I speak it certainly had not shown any roaming propensities. The first six weeks of this kitten's life was spent in the barn, where it received little or no attention, and became so wild that it scarce could be handled with impunity. Shortly after this the mother began to bring it into the house; she always entered by a glass-door, which opens to a piazza at the rear, and soon formed the habit of scratching at the glass whenever she wished to be let in or out. The kitten soon acquired the same habit and lost its wild ways completely; in time it became a handsome home-loving house-cat, and we were sorry to part with it, but at the age of fifteen months, when we had to choose between its companionship and that of any nesting birds upon our grounds, its banishment became inevitable.

The first experiment casually made with this cat led me to suspect that it was impossible to turn some Thomases around, and I determined to investigate this point further at the first good opportunity. This cat was taken in a gunny-sack over an irregular course, mainly by electric car, down a series of hills to a point on the University Campus in the city of Cleveland, 4.6 measured miles from its home in Cleveland Heights; there it was given a dish of milk and the liberty of two rooms, in one of which a window had been slightly lowered at the top. This was on the morning of a Monday, and at five o'clock in the afternoon it seemed to be quite at home in its new quarters; on Wednesday morning, about forty hours later, it suddenly appeared on the back porch of our house and gave its usual signal to be admitted. In order to reach its home this cat had traversed an unknown country, consisting of city or suburban streets and allotments, had crossed the gulley of the Belt Line railroad, probably by one of its bridges, and ascended in the path of greatest resistance a series of terraces to a height of four hundred feet. That its home neighborhood could have been reached by exploratory movements, on the trial and error order, or by chance alone seemed highly improbable; the only known facts were that it made a homing attempt and succeeded.

When we tried to have this cat repeat its performance in the daytime it would not voluntarily leave the building, and even when set on the ledge of an open window it would quickly drop back to the floor; it was finally left in some shrubbery outside, and when I was called away for a brief time it disappeared and was not seen again. Regretting the loss of this cat through our failure to keep it under continuous observation, we decided to test the homing power, at the next opportunity, in the following way: (1) to take the cat, as before, under such conditions that the possibility of orientation through the receptors of sight, hearing and smell would, in all probability, be completely eliminated; (2) to convey it successively in different directions, and gradually increase the distance at each test, and (3) to release it at a uniform time at dusk, in unknown territory, and under conditions of as free behavior as it was possible to obtain.

The experiments to follow were made with another individual, a female with kittens which were about ready to be weaned; she had been adopted by a neighbor, and her previous history was not known; she was a large and powerful animal (See Fig, 1) and had

FIG. 1

This cat returned to its home seven times in succession when taken out blindfolded, by automobile, over distances of one to three miles; in the first four tests in the direction of the cardinal points, and in one instance after being put under complete anesthesia.

become such an inveterate hunter of birds and young chickens that her life had been declared forfeit. This cat could not be trusted for a moment when the chicks were about, as my neighbor observed when one evening he tried to entice her from the barn with a dish of fresh milk; thinking, however, that they would be safe as long as we stood by, a brood was released; the cat came to call, but was no longer interested in milk; like a flash she snapped up a chick from under our noses and made off with it to the barn; and this was the third victim of that day. I mention the incident to show how well this animal was able to take care of itself; whatever its history might have been, an experiment to follow proves conclusively, I think, that it had never been a vagrant over those parts of the country to which it was soon to be introduced.

Seven successive returns were made by this cat from points varying from one to three miles from its home, on June 4-23 (See table); she was secured in a sack, carried to the release station by motorcar, and placed under a wooden box which was weighted with

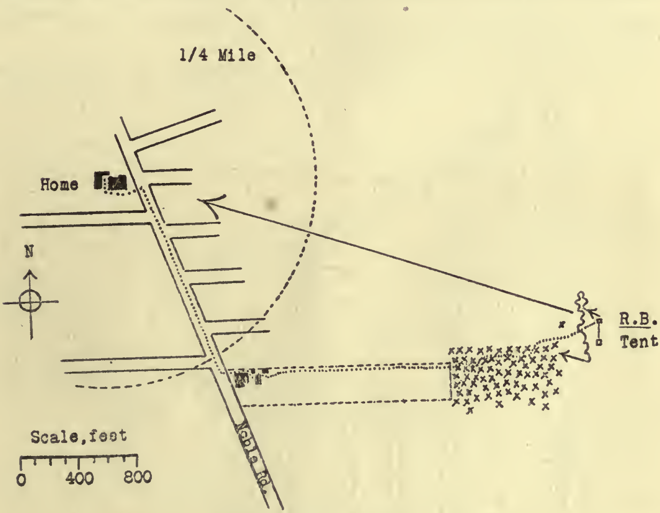

FIG. 2. HOMING OF CAT: EXPERIMENT NO. 2

Home-territory conventionally indicated by circle of one-fourth mile radius. Cat taken blindfolded one mile on course, marked by dotted line, to release-box, R. B. Long arrow marks direct course from release station to center of home-territory; path of cat after release indicated by arrows and irregular line; cat oriented correctly and started in the home-direction, but later reversed her course and made for the cover of woods (crosses) when disturbed by dogs; animal under observation 35 minutes after release. Cleveland Heights, Ohio: June 4, 1920.

stones; the box was raised at the moment of release by a cord operated from a green observation-tent 75-100 feet away; (See Figs. 2 and 3) the cat was given its freedom at about the same time in the evening, and the box was opened towards the north in every experiment except number 4, in which the opening was to the east; we wished to ascertain (1) whether the cat would continue to return to home and kittens when taken at varying distances beyond its known or probable range; (2) whether under such conditions it would orient immediately and correctly; (3) whether after making a correct orientation it would strike off in a *direct line* for its home and pursue that course, or whether it would be mainly concerned with cover and safety first. In tabulating these tests the homing time in all but one instance was less than the estimate given; it could not usually be exactly ascertained; thus if the cat was set free at eight o'clock of an evening, and was found with her kittens again at six on the following morning, the time is given as "10 hours (minus)"; she might have stolen in at any time during the night, and on one occasion was detected at two o'clock in the morning, the probable time of her arrival.

In the first four tests (Nos. 2-5 of the table) the cat was taken

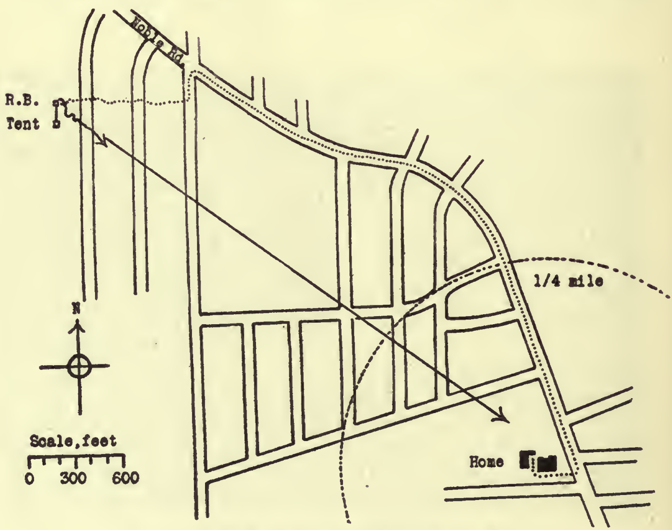

FIG. 3. HOMING OF CAT: EXPERIMENT NO. 5

The cat oriented correctly upon release, and moved undisturbed in a direct line for its home until lost to view; animal under observation six minutes after release. See table for further details; designations as in Fig. 2. Cleveland Heights, Ohio; June 18, 1920.

HOMING POWERS OF THE CAT: RECORD OF EXPERIMENTS

No.	Date	Distance in miles	Station of release	Time of release	Time of return	Homing time in hours
1		4.6 (west)	Campus W. R. Univ. Cleveland	Monday in evening	Wednesday following, 10 A. M.	38 (about)
2	June 4	1 (east)	Open field, 400 ft. from woods	7:25 P. M.	Between 11:30 P. M. Jn. 4 and 7:30 A. M. Jn. 5	8 (minus)
3	June 9	2 (west)	Open field, 150 ft. from highway	8:05 P. M.	Before 6:30 A. M. Jn. 10	10 (minus)
4	June 10	3 (south)	Open field, 900 ft. from highway	7:45 P. M.	2 A. M. Jn. 14	78
5	June 18	1 (north	Unoccupied allotment	7:55 P. M.	Before 6 A. M. Jn. 19	10 (minus)
6	June 21	1 (east)	Same as in No. 2	7:30 P. M.	Before 6 A. M. Jn. 22	10 (minus)
7	June 22	1 (east)	Same as in Nos. 2 and 6	7:55 P. M.	Before 7:30 A. M . Jn. 23	11 (minus)
8	June 23	1½ (east)	Ploughed field, 200 feet from highway	7:30 P. M.	Before 7:30 A. M. Jn. 26	60 (minus)
9	June 30	16½ (east)	Willoughby, Ohio	6:35 P. M.	No return	

Experiments Nos. 2-9 were made with the same cat; in Nos. 6 and 7 place of release the same as in No. 2; in No. 8 the animal was anesthetized before being taken out; in all cases the cats were blindfolded and taken a measured distance by electric car or automobile.

in the direction of the cardinal points, to distances of 1, 2, 3, and 1 miles respectively, not because we supposed the cat to have any interest in the compass, but simply for convenience in dividing up the available area; we had in mind also the obvious fact that an animal like the cat is liable to establish habits of roaming farther from its home in certain directions than in others, so that any area familiar to it might be described by a very irregular curve, the radii extending half a mile or possibly more in certain directions, or but a few rods in others. In each of these experiments the cat jumped from under the box, as if in response to an electric shock; in every case she oriented correctly to her home region, and started to move in its direction; in one instance (See Fig. 3 and No. 5 of table) she not only started but continued at a rather rapid pace toward home until lost to view, and in this case the right course took her past the tent. It was thus positively shown that there was no necessary backtracking over the course that was followed by the automobile in bringing her out. In the other three cases when the cat had moved but a few yards in the home direction, and then suddenly veered and sought cover in fence-rows or woods, we found that one or more persons had seen our tent and were moving towards it. The homing time, as pointed out above, could not be accurately determined in the first, second and fourth of these tests, but was probably from four to ten hours; over the course of three miles (No. 4 of table) 78 hours were required.

In the first test (See Fig. 2) the cat sprang from under the box, came to attention, as it were, for a moment, facing in the direction of her home region, which lay a few points north of east; she moved slowly for a short distance on this course, mewing almost continuously, then turned more to the north, and after going a few rods suddenly veered and made for cover in a piece of woods, four hundred feet to the south, passing within a few yards of our tent. At this juncture a farmer's boy appeared on the scene with two dogs, which were soon on the trail, but she out-distanced them and in a moment was safe in a tree; here we left her to her own devices, and all that we knew of her subsequent movements was that by six o'clock on the following morning she was again at home with her kittens. That she returned the same night, and with little delay, is most probable. The grass in the field where this test was made was not at that time very tall, and the cat could be readily seen by one standing erect; whether the bend in the curve marks the point at which the cat first sensed the approach of the boy and the dogs may be doubtful, but there is no doubt that this change in her course was due to a sudden impulse to find cover.

In the second experiment of the series the animal was taken on June 9 over a distance of two miles to a point due west, and 1 2/5 miles in air-line from its home; the tent was placed in a cornfield, one hundred and fifty feet from the highway, along which automobiles and pedestrians were liable to pass, though rather infrequently: the box was opened towards the north, as before, and the cat, when free, could move in any direction but south without passing the tent, her home-course being a point or so north of east; at the moment of release she oriented perfectly and began moving in the right direction, but as in the previous test she soon swerved to the north; at that moment also two men, who were coming down the street, stopped and made a movement as if to approach the tent; after traveling northward for about a rod, in consequence, as I believe, of this disturbance, the cat stopped, cocked her ears, glanced back at the tent, struck the home-course again and began moving rapidly up the steep hillside; she continued in the direct line for home until lost to view at 8:25 P. M., when it was quite dark; the cat had been under observation twenty minutes, and I believe made her home rather promptly, but she was not seen again until the morning following.

On the very next day this cat was subjected to a more difficult test; she was taken in the usual way over a course three miles to the south, and the tent was pitched nine hundred feet from the road in the hope of avoiding all interference; the release-box was set ninety feet away at the bottom of a run, on ploughed land, and opened eastward, north being the true course home; on this side, seventy-five feet away was a fence, with woods stretching beyond, and at about the same distance south was an unfenced stand of thick grass, while some three hundred feet to the east lay a stone wall bordered with small trees; as before the cat came out with a bound, oriented aright, and moved a few yards on the homeward line; then, as in the two previous tests she wheeled about and travelled in an opposite direction, this time entering the tall grass; in this instance the disturber of the peace was the owner of the land, who had doubtless seen us placing the tent; his approach coincided with the cat's move for cover, and as we stood watching her she gradually worked over to the easterly fence-row. This was at 8 p. m., June 10; at two o'clock in the morning of June 14, or 78 hours later, the mewing of this cat was heard under a window which opened on the lawn of its owner; this, as we had reason to believe, actually marked the hour of the cat's return.

In the fourth and in some respects the most interesting test (See Fig. 3 and No. 5 of table) we carried the cat by motor-car one mile north by east, turned into another road, and placed the tent on newly allotted land two hundred and fifty paces from the highway, and for once succeeded in avoiding all interruptions. The box was opened to the north at exactly 7:55 p. m., the home direction being a few points east of south. As in former tests the cat came out with a spring; she oriented correctly without the slightest hesitation, and at once began moving in a direct line for home; she advanced slowly, paused a number of times, and stood with ears cocked, as shown in the photograph, but never once turned from the chosen course during the six minutes that we were able to keep her under observation; she finally disappeared in a dry water-course which came from the hillside above; there can be little doubt that she made home in good time although she was not detected until early the next day.

The two experiments which followed (Nos. 6 and 7 of table) were merely repetitions of the first, and were undertaken as a check upon this test—to ascertain whether the behavior would be similar in each case, and if the homing time would be improved. In the first of these the cat got free prematurely, took the wrong initial direction, and was soon lost to view in the grass, which by that time had grown quite tall. In the next trial (No. 7), at the moment of release, she started on the wrong course, but in a moment oriented correctly, and was on the homeward path when she disappeared from sight. In neither case could we determine the time of the cat's arrival, but in all probability she made home the same night.

We have already referred to the fact that many cats revert to the wild or semi-feral state, vagabondage being sometimes adopted by choice, or more commonly it is forced upon them by the neglect of their owners. Had the second cat been a nomad of this character, and in the region about its present home, the experiments just described would have no value as tests of its homing abilities; the whole region for miles around might have been familiar ground. That the territory embraced in these tests was actually new to this animal is, I believe, clearly indicated by the next experiment; the cat was now put under complete anesthesia by chloroform, and conveyed by motor-car, as before, 1½ miles east by north of its home-site; somewhere towards the end of the journey she recovered from the anesthetic so as to appear quite able to take care of herself when let out of the bag; the animal was accordingly set free, without using the blind, in a field fifty feet from the highway; she made at once for this road, in a direction opposite that of her home, and would have gone beyond it but for a gorge which blocked her path; then she moved beside the road, very nearly back-tracking for several rods over the course which the automobile had taken, and disappeared in the cover of bushes. She returned home, as in all the previous experiments, but only after an interval of 60-70 hours; that is, to home under these conditions from a distance of 1½ miles, which ordinarily was accomplished the same night, or at most in from eight to ten hours, now required eight times as long. This could hardly have been the case if the cat had awakened to find itself in familiar territory. To hazard a conjecture I am inclined to believe that in this case the cat, finding itself on strange ground, with all relations with its home-region broken, wandered about until its lost orientation was by chance restored through the discovery of familiar objects.

At this stage in our experiments the cat had accounted for so many chickens that its owner was anxious to be finally rid of it; but it had proved so good a "homer" I felt that it had fairly earned its freedom; accordingly it was decided to take a long chance, and it was liberated in Willoughby, Ohio, 16½ miles from its home, at a point three miles north of the second bridge which crosses the Chagrin River in that section; we hope that it found a good home, where its bird-killing propensities could be more effectively checked; it never returned. It does not necessarily follow that the distance and other obstacles in this test were too great for this cat's remarkable homing ability, for the longer the course the greater the number of diversions or accidents liable to be encountered; moreover this cat's kittens had now been weaned, and the longer the attempt to home is protracted or delayed the weaker becomes the impulse to return, and the greater the chance afforded for new habits to develop and replace the old.

Possibly most of the stories of cats and other animals returning to their homes from long distances, when not composed in newspaper offices, are exaggerated, or based on inexact identification. As an instance of the latter sort, Claparède[3] mentions the story of a cat taken from Montilier on the shore of the lake of Morat to Lausanne, a distance of 50 kilometers (about 31 miles), and said to have returned the following day to its old home, a statement ample in itself to refute the account; an investigation, moreover, by Emile Yung, Professor of Zoology at the University of Geneva, proved that the cat had never left Lausanne, the one seen at Montilier being another individual of the same size and color. Claparède, however, records on reliable testimony the case of a cat carried in a basket 18 kilometers (11 1/5 miles) by rail to Geneva, and afterwards returning to its former home at Céligny. In a characteristic "Souvenir" Fabre[4] has told the story of the cats, which accompanied him and his family whenever he was obliged to change his domicile; in going by carriage from Orange to Sérignan, a distance in straight line of 4⅜ miles, the oldest cat was confined in a basket, and upon arrival it was made a prisoner for a week in the hope that it would become habituated to its new abode; but all to no purpose, for upon regaining its freedom it returned at once to Orange. When found at its former home the animal was wet to the skin, and its body was smeared with red earth, an evidence, as Fabre thought, that it had crossed the Aygues, a tributary of the Rhone, and afterwards gathered up the dust of the fields; it was May, he said, and there was no mud; two bridges cross this stream one at a point above, and the other below, the course the cat must have followed; but, said Fabre, it took neither, its instinct directing it home by the shortest course, and it even overcame its repugnance to water in order to reach its beloved abode. Upon similar evidence Fabre concluded that another of his cats had returned by crossing the river Sorgue, at Avignon, where it avoided the bridges in order to follow the more direct route.

[3] Claparède, Ed.: "La Faculté d'Orientation Lointaine," *Archives de Psychologie,* ii: pp. 133-180, Geneva, 1903.

[4] Fabre, J.-H.: *Souvenirs Entomologiques,* ii, pp. 124-133, Paris.

Hodge[5] records an interesting experiment with a large tomcat, which he and his friends took with them in a boat one dark summer's night, on a lake at Madison, Wisconsin; after a time, says Hodge, the cat became very restless and anxious to go home; he would climb out to one end of the boat, and stretching his head towards home, mew almost continuously. Hodge and his friends then amused themselves by turning the boat slowly round and round, first one way and then another, to see if they could throw Tom off his bearings; but all to no purpose for, says Hodge, "whether right side, left side, bow or stern, Tom was always on the part of the boat nearest home, and straining as far as he could in that direction. Fully a mile from any shore, how could he tell which shore was which?" But few lights were visible on the shore, and none of the party was able to distinguish their own cottages. They then wrapped Tom in a heavy blanket-shawl, and held him first on the lap and then flat on the bottom of the boat, while it was turned round as before; but whenever released, the cat started "with never a mistake and without the slightest hesitation towards the end of the boat nearest home. Whether the boat was turned by a single stroke, as on a pivot, or rowed slowly around in a circle, the result was always the same. Members of the party were blindfolded and required to guess whether the boat was turned or allowed to stand still, or was rowed in a straight line or in a circle; and it was an even chance whether they guessed right or wrong." The tomcat kept his bearings better than any of them. Hodge was inclined to believe that the cat's direction-constant was its sense of hearing and its ability to detect sounds on shore which were too faint for the human ear.

From the experiments recorded above, though few in number, I think that we are justified in drawing the following conclusions: (1) That the returns in experiments 1-5 and 8 were made from unfamiliar territory; (2) That in the tests 1-5 success did not depend upon chance; (3) That the cat did not return over the course taken by the motor-car on the journey out, or according to a so-called "law of reversal" (*loi du contrepied*), as suggested by Darwin, and revived by Bonnier and Regnaud; (4) That the homing power in a more or less direct line is independent of the sense-receptors of vision, hearing and smell; (5) That under the conditions described the cat is able to home at night, and probably does so by preference; (6) That its power of return is not affected by rotation or any ordinary treatment, barring possibly anesthetization, which the animal may receive, prior to or during the journey to the point of liberation.

[5] Hodge, C. F.: "The Method of Homing Pigeons," *Pop. Science Monthly*, Vol. 44, New York, 1893-94.

The problem of homing or of "distant orientation" in the higher animals is very ancient, and the literature of the subject, particularly as concerns the carrier pigeon, is voluminous and vexed to the last degree. Claparède in 1906 reviewed the whole field, and discussed the various theories to which the question of homing has given rise; again in 1915 Watson and Lashley[6] gave a résumé of the whole question in vertebrates, and a concluding account of their remarkable experiments on the homing powers of the Noddy and Sooty Terns; they showed that many of these birds when taken from their nests on Bird Key, Tortugas, Florida, and carried upwards of 800 miles in various directions at sea, made successful homing flights; their birds were untrained; they returned from territory through which they had apparently never passed, and over the open ocean, which could afford no landmarks, visible at least to the human eye. Their results, though admittedly negative, disproved certain theories of homing; they found no "special tactual or olfactory mechanism situated in the nasal cavity," which might function for distant orientation, but thought it "just possible" that the terns might "possess on certain parts of the body (eye-lids, ear covering or oral cavity) sensitive tactual and thermal mechanisms which might assist them in reacting to slight differences in pressure, temperature and humidity of air-columns."

We are now concerned only with the powers of an animal standing low on the ground, and moving rather slowly, in orienting to a known goal—its home, and in homing successfully and repeatedly by passing through territory unknown to it. The cat's known goal, it should be remembered, is not a point but a region, which if irregular, may be quite extensive; whatever the form of this familiar area might be, a cat would be as much at home upon any part of it as when on the hearth of its master's house. The bird, which orients to a region of far greater size, could be expected to have the power of returning to it from a correspondingly greater distance; and if there is a distinction between proximate and distant orientation there must be a division of territory surrounding the goal or its center based upon the presence or absence of familiar landmarks of some sort.

Wallace[7] maintained that the cat was able to return to its home by the aid of its olfactory sense, that is by picking up in reverse order, link by link, a chain of different odors, which it had expe-

[6] Watson, J. B., and Lashley, K. S.: "Homing and Related Activities of Birds," Carnegie Institution of Washington, Publication No. 211, Washington, 1915.

[7] Wallace, Alfred Russel: "Inherited Feeling," *Nature*, vii, p. 303, London, 1873; also "Perception and Instinct in the Lower Animals," *ibid.*, p. 65.

rienced in its going out; in other words the cat smelled its way out and back, though leaving no tracks of its own. Aside from the assumption that the cat possesses an acute sense of smell, which is probably erroneous, not to speak of the necessarily mixed and transitory character of all odors in the air, we have seen that as a matter of fact the cat does not always return over the course by which it was taken out; on the contrary it often follows the shortest and most direct route. Darwin[8] thought that the power of returning to a region from which an animal had been deported, when indications were lacking, might imply the faculty of keeping a dead reckoning or of registering the various deviations or turns made in course of the journey; he declined, however, to discuss the question as his data were insufficient.

Since the animal does not always or usually return, as we have seen, over the original course, it is evident that it is not called upon either to exercise a prodigious memory or to repeat reflexly or otherwise the movements which such a supposed "backtracking" would imply.

We have shown that the cat can return at night, and think it probable that it homes mainly during the hours of darkness. In the greatest distances covered in these experiments (Nos. 4 and 1) or 3 and 4.6 miles, respectively, the animals had in one case 28½ hours and in the other 17 hours of night-time available; if they moved forward only or mainly after dark the first would have taken an average of nine hours to the mile, while the last would have cut this to four hours, which is rather good time for an animal which travels as slowly and cautiously as the cat.

When we are thus brought squarely before the problem of accounting for the return of this animal to its home region under the conditions described, we find no solid ground on which to tread; what follows must be regarded as mainly conjecture: (1) The animal seems to have a direction-constant with reference to its home-region, which it retains through the journey out, in spite of all the manifold turnings and twistings to which its body may be subjected; the animal will not have to recover what it does not lose; if this direction-constant is lost the animal will be lost; (2) This power of maintaining orientation does not depend upon memory nor, as already indicated, upon the receptors which mediate vision, hearing or smell; (3) We get over no difficulties by assuming, as has been often done, a "sense of direction," for direction to such an animal, it would seem, can mean only the spatial relation between its body and such objects as appeal to it; and out

[8] Darwin, Charles: "Origin of Certain Instincts," *ibid.*, p. 417.

of the total effective environment of the cat no objects probably make a stronger appeal than its home or the young which it may shelter; (4) Though of course possible, it is rather improbable that an animal like the cat possesses important unknown sense-organs which come to its aid in orientation; (5) By the process of exclusion we seem to be thrown back upon (a) mental imagery, or a relation established between the visual and the visualized fields, and (b) the kinesthetic sense, the sense of movement, or as it is sometimes called the "muscle sense," which is of sufficient delicacy to yield an impulse to action whenever the body is moved.

It may be too great a tax upon our credulity to believe that the cat can form and utilize mental images in such an effective way as do human beings, and especially since blindfolding does not appreciably affect the homing power. Accordingly I am inclined at present to believe, though unable to prove, that the secret of this power lies in the kinesthetic sense, which is older by far than either seeing, smelling or hearing, and by which compensatory movements of the body can be made and maintained; in other words that the constant sought lies back of the ordinary sense-organs, and that this is in some way bound up with this primitive muscle sense, which experiment has already shown to be of far greater delicacy in many animals than in man. It would seem that Hodge's cat, to which we referred, perceived every movement of the boat, and compensated for the movement when given its freedom; if the water in that lake had suddenly become dry land, is there any doubt that the animal would have made its home in short order, as our cats have repeatedly done, when removed a much greater distance from hearth and young, and when blindfolded at that?

Whether deviations in the position of the body are constantly adjusted by compensatory movements of some sort is a matter which future experiment must decide; it did not occur to me to keep the cats under close observation during their journeys out. It does not seem probable that such an animal is able to keep a register of its movements, if it were called upon to do so, in the way Darwin suggested; were this the case it would be a perfect homing machine.

FISHES: WHY STUDY THEM?

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WHY should any one study or want to study fish? Perhaps every man who is not a lounge lizard or a confirmed valetudinarian, certainly every boy, to say nothing of many girls and women, likes to escape from the trammels of every-day life and the suffocating indoor artificialities of cities and go a-fishing. Whether it is the outdoor freedom, the lure of stream or forest, mountains or the sea, or the joy of hauling in the big fellows, the fish or the fun of fishing, we must leave to each individual to determine. At any rate few despise the after period of rest and reminiscence, when crisp trout or flaky black bass, salmon bake or Spanish mackerel *aux fines herbes,* refresh and fortify against the next day's adventures.

But to spend most of the year swapping fish yarns and overhauling tackle and the rest of the time trying to catch fish is not studying fish, although the true "compleat Angler" does really and truly study fish.

The number of people who are interested in fish in one way or another is very great, in some countries including the total population, while in countries like the United States it is far greater than one realizes. Yet, like some other things of primary economic importance very few people really know anything about fish, and still fewer make a thorough study of them, though many people are vitally interested in some economic aspect of fishes.

From the earliest times man has undoubtedly eaten fish whenever he could get any, and with the spread of mankind many ingenious devices were invented for their capture, long before the dawn of any existing historical records. Since fish cost nothing to breed or maintain, and since in many regions they came periodically in uncountable numbers, many groups of people, especially in cold climates, came to depend upon them as their most important food. In other regions, such as the low coastal plains of Asia and the islands adjacent, fish became the most important source of protein food.

Although at first a purely utilitarian proposition, fishing, like hunting, with the advent of organized society came to be a recognized sport many thousands of years ago.

Very early in the historical period far-seeing men in regions like Egypt or China began to develop the artificial culture of fresh-water fish to supplement the food supply of a rapidly increasing population. In like manner the people of Java, the Philippines, Formosa and Hawaii developed systems of pond culture for certain marine fishes. Their methods are still in use and consist in catching the newly hatched fry in the rivers or sea and transferring them to ponds where they are kept till large enough for market, herbivorous fishes only being reared.

Before the dawn of history people had also learned to dry fish both with and without the use of salt, and to cure them by smoke. Later came such processes as pickling in brine, or with the use of vinegar or spices.

With the advent of Christianity into northern Europe and the subsequent change from savagery to civilization, fish and fisheries became increasingly important and many regions arose from nothing because of their control of the production or distribution of fish. We may trace the rise of modern Holland to her development of a special method of preparing herring.

As population increased and certain countries turned their attention more and more to foreign trade, valuable fishing grounds came to be in great demand, and regions like the Grand Banks were a matter for statesmen and diplomats and fleets to struggle over.

In primitive society only a small proportion of the total quantity of fish was taken and the balance of nature was never destroyed. As population increased the additional number of fish required was obtained by improvements in capturing and preserving, while the better organization of society ensured their distribution more evenly and to more remote regions. This greater and slowly increasing call for food continued for centuries without seriously impairing anywhere the sources of supply. It was not until the advent of the modern industrial period and its rapid development that the rivers of regions like England and the North Atlantic coast of our own country began to lose their importance as sources of food supply, and later still when the tremendous increase of factory industries destroyed the swarms of luscious fish which annually visited them.

But it remained for the enormous development of fish canning to practically destroy the annual run of Pacific coast salmon, an industry which rightly handled should have been as permanent as the production of wool or beef.

It is a bitter commentary upon the organization of modern industrialism that, as a rule, the men who are in business know little or nothing about the thing which they are exploiting. The fish canner was compelled to know something about the processes of canning, often paying very dearly for his knowledge, and he knew more or less about how to sell the finished product, but as for knowing anything about fish—salmon, for instance—his ignorance was incredibly profound. As a result the salmon is, in some of the regions where it was almost unbelievably numerous, practically extinct because the packers not only were entirely ignorant but would not pay any attention to those who did know, and used their political influence to destroy the labor of those who would have made their industry a permanent one.

Another modern method of totally destroying the food supply upon which millions of people depended was exemplified in India, where the construction of dams for irrigation by well-meaning but ignorant politicians and engineers separated fish from their spawning grounds with fatal results. In other regions the taking of water for irrigation at a time when tiny young fishes swarm in the water, without providing in any way for their protection, has destroyed a primary source of food for the common people.

A little fundamental knowledge concerning fish and their life histories and habits would therefore certainly not come amiss to the business man, and would be of great utility to the far-seeing statesman or state executive, whether concerned with problems of food production and conservation, or taxation. Particularly should the latter have some slight modicum of knowledge in order to be able to appreciate the importance of fostering, to say nothing of improving, modern methods of fish culture which have revolutionized the fisheries of both fresh and salt water in many regions.

For a very long time there have been men who studied as best they could the fish life of their region, and since the time of Aristotle we have had more or less trustworthy written accounts of fishes. But the modern study of fishes dates from Artedi, a friend of Linnæus, and since that time a vast literature has arisen, treating of every conceivable topic which is in any possible way related to fishes, their lives, or any relation man sustains to them.

And yet with all this activity the actual number of people who are really engaged in studying fish is very small, and but few schools in the United States offer courses making fish the central or only subject of study. In spite of all that has been done and published, our ignorance of many problems of primary importance, zoologically and economically, is abyssal. For example, in the region in which I am now working, where fish form the principal animal diet of ten million people, we do not know the most elementary facts concerning a single fish in the Archipelago, in spite of the fact that money spent in obtaining adequate knowledge of say the herring family would be repaid incredibly in advancing the economic and dietetic welfare of the people.

The surface of the world is by now pretty well explored, and there are no new continents or even very large areas of land or water to explore, outside of the polar regions. But enormous areas on a different plane remain to be explored and there is no question but what in time very considerable portions of the oceanic depths and bottom will be studied and the kind and relative abundance of their fishes well known. At the present time our knowledge of many regions is equivalent to that which would be gained by studying the fauna of a continent from samples gained by dragging a basket on a rope hanging from a balloon several miles up in the air. Large active fishes are not likely to be caught in a dredge and there may exist, in regions not too deep, vast numbers of fishes which some day will be known and utilized. Some of them may be known to-day from a few rare, strange examples, others are undoubtedly totally unknown as yet, but with improved methods of deep sea exploration and study man will learn their haunts and habits and be able to capture them in quantity.

Probably more young people become interested in zoology through their observations of birds or butterflies than in any other way, and it is not likely that anything will ever supersede them in beauty or attractiveness.

But a good exhibit of living fish attracts as many people as perhaps any other forms of life and in the tropics at any rate the coral reef fishes are only equalled in beauty and grace of form and color by the humming birds and butterflies. Fish are certainly attractive when living, and their study, whether of living or preserved specimens, can be made equally so if properly presented. It would seem, therefore, that more schools should offer courses where fish are the chief subject rather than merely dismissing them after the study of one or two types.

The zoologist and student of evolution should realize that no other group of vertebrates offers such enormous diversity of structure, form, habitat, habits and development as does that of the fishes, and then they should act on their knowledge.

The ignorance of even comparatively well-informed people about fish is stupendous. This is well illustrated when one tells a fish story. If he tells the plain unvarnished truth about climbing perch, the gobies or blennies that chase insects over the land and which leave the water for safety when you try to catch them, or even about plain ordinary Sangamon river catfish or Cumberland river eels, they put him down as a liar. But if by way of experiment he really tells them something wholly imaginary they promptly accept it as fact and perfectly all right. Only the other day a party of tourists violently disputed what I was telling them about a fish in the Aquarium, although they had to admit they did not know anything about it. The trouble is that people have a preconceived idea of "fish," and of its limitations, and do not realize the enormous plasticity of the class of fishes. In the matter of fish shapes alone, no human being, even if gifted with the imagination of an insane Doré, could conceive the vast number of weird, grotesque, or "impossible" shapes which are actually found among living fishes. If we merely named examples, whether of unusual shape, strange physiological powers as that of electricity, almost unbelievable migrations as that of the common eel, startling metamorphoses, or astonishing habits, it would require a volume.

It is true that the study of systematic ichthyology requires the use of a large, expensive and bulky collection of alcoholic specimens, and access to an exceedingly diverse and often very expensive literature, but this last item is true of all systematic work, whether botanical or zoological. But the extended study of systematic ichthyology is only one phase, and by no means always the most important one at that, of the study of fishes. The collecting of fishes in a neighborhood or limited region is not difficult or expensive and their determination is a simple matter in Europe, North America, and many other regions. But there is a vast deal to study and to learn concerning the fishes of almost every region. Not only do many fishes undergo startling transformations, but the embryology and metamorphosis of many common fishes are totally unknown. In other cases "we only know a little and that is all wrong," as has been said about another matter. The breeding habits of many fishes, both salt and fresh water, are not at all known while their study could be carried on by any one willing to devote some time to it over a series of years.

The rate of growth, the time required to reach the reproductive period, the size reached and the duration of life after sexual maturity, are all problems concerning which we are ignorant even about many very common fishes, while their solution demands only careful observation over a term of years until sufficient data are accumulated to deduce the general principles underlying them. The migrations and seasonal movements of fishes, whether due to variations in the food supply, to sexual impulses, or to climatic causes, whether latitudinal or vertical in their range, are also matters of vital importance concerning which we have yet very much to learn.

Like all other organisms, fishes are the victims of disease, "plague, pestilence and famine," while "battle, murder and sudden death" are of course their daily lot. Parasitic fungi, protozoa, crustacea and worms make life a burden to great numbers, and some of these, as certain tapeworms, may be readily transmitted to man. Yet very little is known of fish diseases and a vast amount of valuable work may be done without any necessity for a great collection of fishes. Many fish, often in uncountable numbers, are killed by some physiological disturbance which may be due to an incalculable increase in diatoms or flagellate protozoa, or to obscure causes which as yet we can not fathom. Proper conservation of the world's natural resources, therefore, asks that work be done along these lines, and in almost any college such research could be carried on while the results would benefit the whole nation.

Biology, any science, must find its excuse for existence in the extent to which it is capable of being interpreted or translated into terms of human welfare. Judged by this standard, the study of fishes, ichthyology, pisciculture, any of its departments, is eminently worth while. The study of fishes, rightly considered and pursued, will in some one or more of its multifarious phases touch the life and affect the welfare of almost every one.

Whether it is the statesmen and scientists of Japan, nearly one third of whose redundant population derives its living from the fisheries, or Norway, striving to so husband and develop the fisheries as to permanently ensure food and a surplus for export, the professor studying the evolutionary aspects of degeneration or luminosity in fishes, or the business man who seeks the aid of ichthyologists in making his business of canning permanent by having it accord with the biological principles controlling the life history of the fishes he handles, all are alike profoundly interested in extending and perfecting our knowledge of fishes.

And is not the mountaineer with home-made tackle, or the city sportsman, or the Banks fisherman equally interested in the same thing? Yes, even though he does not always recognize or admit it. And it is the duty of the leaders of scientific education and thought to help to make him realize it.

And he, too, who gazes at fish with the eyes of artist or lover, enchanted by their marvelous variation of color and shape, and the grace and incredible speed of their movement, or it must be confessed sometimes amused by their grotesque or bizarre shapes or movements, is repaid in terms of human welfare.

Whether a human being be inspired by a poem, his emotions be transformed by the work of master musicians, or he is enraptured before a noble painting, he is certainly in contact with something which may profoundly affect human welfare, no matter how intangible or superfluous it may seem to some.

And so when one watches the incomparable beauty and grace of the living meteors that swarm about the coral reefs of the tropic seas and studies them in their environment, while the world of every-day affairs drops away from him, he is benefitted in the same way that a wonderful landscape, a perfect sunset or any work of art benefits the beholder.

We might add, too, that anything which helps to satisfy the thirst for knowledge concerning our world and all it contains is worth while, even if it served no other function.

By studying fish, we may be enabled to sustain or transform existing industries or develop new ones, thus adding enormously to the resources of society, we may throw additonal or even new light upon problems of development, animal distribution and evolution, and we may help to diffuse more generally interest in and knowledge of a group of animals second only to the domestic animals in importance and, taken in connection with their setting, unsurpassed in beauty and esthetic interest.

THE ETHER THEORIES OF ELECTRIFICATION

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IN a previous paper on "The Electric Fluid Theories" it was shown that neither the one fluid nor the two fluid theory gave any physical explanation of the cause of electric attraction or repulsion, though it was this explanation which was the principal purpose of the earlier emanation theory. It was also shown that a fundamental question which was left unsettled was how the electric fluid is held to a conductor while there is no attraction between it and the particles of matter.

The only theory proposed during this time which seems to suggest any explanation of this phenomenon was one proposed by Cavendish, who regarded the electric fluid in conductors as under an external pressure and as always flowing in the direction of least pressure. Cavendish did not discuss the question of the retention of a charge upon a conductor, for he regarded the electric fluid as being attracted by the particles of material bodies; but he seems to have had a very definite notion of an external pressure exerted upon the electric fluid in a charged body and of the reaction of the electric fluid to this pressure. Thus he says:

> When the electric fluid within any body is more compressed than in its natural state, I call that body positively electrified. When it is less compressed, I call the body negatively electrified.
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> It is plain from what has been here said that if any number of conducting bodies be joined by conductors and one of these bodies be positively electrified, that all the others must be so too.
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> If two bodies, both perfectly insulated, so that no electricity can escape from them, be positively electrified and then brought near each other, as they are both overcharged they will each, by the action of the other upon it, be rendered less capable of containing electricity; therefore, as no electricity can escape from them, the fluid in them will be more compressed, just as air included within a bottle will become more compressed either by heating the air or by squeezing the bottle into less compass: but it is evident that the bodies will remain just as much overcharged as before.

It will be seen from the above quotations that Cavendish regarded the compressed electric fluid in one charged body as capable of transmitting in some way a pressure to the fluid in another body brought near it. This would seem to indicate that he supposed this pressure to be exerted by some external elastic medium which was itself thrown into a state of stress by the reaction of the compressed electric fluid.

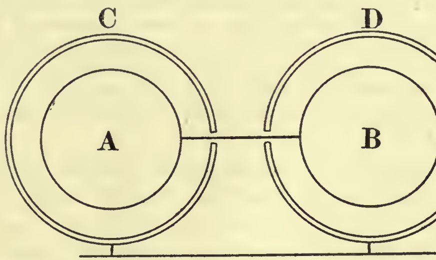
Apparently the first physicist to definitely suggest the pressure of an elastic medium as the cause of electric attractions and repulsions was Dr. Thomas Young. In his lectures which were given before the Royal Institution and published in 1807 he says:

> It must be confessed that the whole science of electricity is yet in a very imperfect state. We know little or nothing of the intimate nature of the substances and actions concerned in it: and we can never foresee, without previous experiment, where or how it will be excited. We are wholly ignorant of the constitution of bodies, by which they become possessed of different conducting powers; and we have only been able to draw some general conclusions respecting the disposition and equilibrium of the supposed electric fluid from the laws of the attractions and repulsions that it appears to exert. There seems to be some reason to suspect from the phenomena of cohesion and repulsion that the pressure of an elastic medium is concerned in the origin of these forces; and if such a medium really exists, it is perhaps nearly related to the electric fluid.

Between the time of Cavendish's writing and the publication of Young's lectures there had been great advancement in electrical knowledge and very important improvement in facilities for electrical measurement. The most important discovery in electrostatics was Bennett's discovery of contact electrical charges. Galvani's discovery of muscular contractions due to electrical stimulation of the nerves had attracted a great deal of attention, and there was much controversy over the question whether the force with which Galvani was experimenting was really electrical, or whether it was some force before unknown and which was called Galvanism. This question was finally settled by Volta, who in 1796 discovered the electrical current set up in a circuit containing two metals and an electrolytic conductor. Then in 1800 Volta announced the discovery of the voltaic pile, by means of which the electromotive force of a single metallic pair could be increased to any desired degree. This was followed the same year by the discovery by Carlisle and Nicholson of the separation of water by electrolysis and very rapidly thereafter by the experiments of Davy and others on electrolytic dissociation. As a result of these investigations, the study of electrostatic phenomena was neglected, and aside from the work of Faraday but little of consequence has since been done in this field.

Faraday's most important contributions to electrostatics were his proofs of the perfect equality of the inducing and induced charges in all cases; his proof that electric induction might sometimes act in curved lines (as he stated it) and hence could not be due to the action of forces at a distance, as such action would necessarily be rectilinear; and finally, in 1837, the discovery of specific inductive capacity.

This discovery as made by Faraday consisted in determining the division of an electric charge between two equal conductors when one was surrounded by air and the other by some other insulating medium. The apparatus used consisted of two brass balls 2.33 inches in diameter and exactly alike mounted upon insulating supports concentrically inside of two similar hollow brass spheres 3.57 inches internal diameter. The inner balls were carefully insulated from the outer hollow conductors, and the space between could be left filled with air or could be filled with some insulating solid or liquid. The outer hollow spheres were joined to earth.



Thus in the diagram in Figure 1 the inner spheres are indicated by A and B, the outer hollow spheres by C and D. C and D are joined to earth. If, now, A and B are connected and charged, then separated and the hollow spheres removed from around them, they are found to have equal charges.

Faraday found that when the space between A and C was half filled with sulphur and A and B were connected and charged as before and the outer spheres and the sulphur were removed A was found to have 2.24 times as great a charge as B. The experiment was repeated with glass, shellac and other substances instead of sulphur, and it was found that in every case A took a greater charge than B, but that the magnitude of the charge depended upon the insulating material between A and C.

Faraday believed that the so-called charges upon A and B were merely manifestations of some condition known as induction which had been produced in the medium between the inner and outer spheres, though why this condition should persist after the medium was removed he does not say. In Article 1174 of *Experimental Researches* he says:

The conclusion I have come to is that non-conductors, as well as conductors, have never yet had an absolute and independent charge of one electricity communicated to them, and that to all appearance such state of matter is impossible.

Again (Arts. 1177 and 1178), as far as experiment has proceeded, it appears, therefore, impossible either to evolve or make disappear one electric force without equal and corresponding change in the other. It is also equally impossible experimentally to charge a portion of matter with one electric force independently of the other. Charge always implies *induction,* for it can in no instance be effected without; and also the presence of the *two* forms of power, equally at the moment of development and afterwards. There is no *absolute* charge of matter with one fluid; no latency of a single electricity. This, though a negative result, is an exceedingly important one, being probably the consequence of a natural impossibility, which will become clear to us when we understand the true condition and theory of the electric power.

The preceding considerations already point to the following conclusions: bodies cannot be charged absolutely, but only relatively, and by a principle which is the same with that of *induction.* All *charge* is sustained by induction. All phenomena of *intensity* include the principle of induction. All *excitation* is dependent on or directly related to induction. All *currents* involve previous intensity and therefore previous induction. INDUCTION appears to be the essential function both in the first development and the consequent phenomena of electricity.

From this point of view, the charges of A and B in the above experiment were merely manifestations of some condition in the medium between A and C and between B and D. If A assumed a larger proportion of the total electrification than B, it was because induction took place more freely between A and C than between B and D. Faraday accordingly said that sulphur had a greater capacity for electrical induction than air, and that if the inductive capacity of air were taken as 1, the inductive capacity of sulphur would be greater than 2.24.

It may be interesting at this point to consider briefly the difference between the views of Cavendish and Faraday. Cavendish believed all bodies to contain an unknown quantity of a single electric fluid, and that this fluid was always under some kind of external pressure and that in conductors it always flowed toward the region of least external pressure and could be in equilibrium only when the external pressure was everywhere the same over the surface of the conductor or system of conductors in which the fluid was confined. From his point of view, the reason that A took a greater charge than B in the Faraday experiment was that the external pressure on a given charge was less around A than around B, and hence that an excess of fluid would flow into A until this external pressure was equalized upon the fluid in the two spheres.

Faraday attributed the state known as electrification not to any changed condition inside the charged conductor, but wholly to conditions in the insulating medium surrounding the conductors concerned. A charged conductor was only one limiting boundary of an electrical field. A charge could not penetrate into a conductor, because the state of strain which was the essential condition of induction could not exist in conductors. In order for this state of strain to exist the bounding surfaces of the strained medium must be on different conductors insulated from each other, because from this theory the different surfaces must support equal and opposite stresses, and this is impossible over a conducting surface, which from its nature cannot support an electric stress at all. If the two surfaces of the region of strain, which Faraday called the dielectric, are joined by a conductor, the strain is relieved and the electrification disappears. Hence there can be no electrification upon the inner walls of a closed hollow conductor, since this would involve a condition of equal and opposite strains resting upon the same conducting surface.

It will be seen from the above that Faraday's theory does not involve the existence of any electric fluid whatever. Faraday calls attention to this in a foot-note to his Article 1298. He says:

> The theory of induction which I am stating does not pretend to decide whether electricity is a fluid or fluids, or a mere power or condition of recognized matter.

Even in the production of a current Faraday does not admit the necessity for the passage of any electric fluid through the conductor. From his point of view, since charging a body consists in setting up a certain condition of strain in the dielectric between it and another body, or other bodies, so discharging an electrified body consists merely in removing this state of strain in the dielectric around it. This strain can exist permanently in an insulator; it breaks down rapidly in a conductor. While it is breaking down the current is said to be passing through the conductor.

Faraday's notion as to the nature of the condition which he called induction was not clear, as may be shown by the following quotation from Article 1298:

> Induction seems to consist in a certain polarized state of the particles, into which they are thrown by the electrified body sustaining the action, the particles assuming positive or negative points or parts, which are symmetrically arranged with reference to each other and the inducting surfaces or particles. The state must be a forced one, for it is originated and sustained only by force, and sinks to the normal or quiescent state when the force is removed. It can be *continued* only in insulators by the same portion of electricity, because they only can retain this state of the particles.
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> When a Leyden jar is *charged*, the particles of the glass are forced into this polarized and constrained condition by the electricity of the charging

apparatus. *Discharge* is the return of these particles to their natural state of tension, whenever the two electric forces are allowed to be disposed of in some other direction.

The question as to the cause of this state of polarization is left entirely unanswered by Faraday, and this question is fundamental. The fact that electrical induction could take place in the best air pump vacuum seemed to require that all space must be filled with a medium made of polarizable particles, and this assumption was not readily accepted, especially at a time when the notion of force acting at a distance had become the common heritage of physicists. For this and other reasons Faraday's electrical theory did not meet with general acceptance at the time when it was proposed.

In 1873 Maxwell published the first edition of his *Electricity and Magnetism* which brought the fundamental ideas of Faraday into a position of prominence in English speaking countries which they have largely maintained up to very recent times.

Maxwell undertook to show in his treatise that the quantitative laws of electricity and magnetism which had been put into mathematical form on the assumption of forces acting at a distance could also be put into mathematical form on the basis of Faraday's notion of induction.

Thus Maxwell says:

I was aware that there was supposed to be a difference between Faraday's way of conceiving phenomena and that of the mathematicians, so that neither he nor they were satisfied with each other's language. I had also the conviction that this discrepancy did not arise from either party being wrong.

I was first convinced of this by Sir William Thomson, to whose advice and assistance, as well as to his published papers, I owe most of what I have learned on the subject.

As I proceeded with the study of Faraday, I perceived that his method of conceiving the phenomena was also a mathematical one, though not exhibited in the form of mathematical symbols. I also found that these methods were capable of being expressed in the ordinary mathematical forms, and thus compared with those of the professed mathematicians.

For instance, Faraday, in his mind's eye, saw lines of force traversing all space where the mathematicians saw centers of force attracting at a distance: Faraday sought the seat of the phenomena in real actions going on in the medium; they were satisfied that they had found it in a power of action at a distance impressed on the electrical fluids.

When I had translated what I conceived to be Faraday's ideas into a mathematical form, I found that in general the two methods coincided, so that the same phenomena were accounted for, and the same laws of action deduced by both methods, but that Faraday's methods resembled those in which we begin with the whole and arrive at the parts by analysis, while the ordinary mathematical methods were founded on the principle of beginning with the parts and building up the whole by synthesis.

I also found that several of the most fertile methods of research discovered by the mathematicians could be expressed much better in terms of ideas derived from Faraday than in their original form.

Maxwell takes pains to emphasize this statement of the purpose of his treatise. Thus in Vol. II, p. 176, 3d Ed., he says:

> It was perhaps for the advantage of science that Faraday, though thoroughly conscious of the fundamental forms of space, time and force, was not a professed mathematician. He was not tempted to enter into the many interesting researches in pure mathematics which his discoveries would have suggested if they had been exhibited in a mathematical form, and he did not feel called upon either to force his results into a shape acceptable to the mathematical taste of the time, or to express them in a form which mathematicians might attack. He was thus left at leisure to do his proper work, to coordinate his ideas with his facts, and to express them in natural, untechnical language.
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> It is mainly with the hope of making these ideas the basis of a mathematical method that I have undertaken this treatise.

Maxwell accordingly undertook to specify the conditions in a dielectric medium by means of which the induction effects discussed by Faraday could be explained from the known laws of mechanics. In doing this he used as much as possible the fundamental concepts of Faraday in so far as these could be determined.

Faraday's researches were carried on through a term of years and were presented as they were finished. Naturally, one who departed so fundamentally in his electrical concepts from all who had preceded him, and who discovered so many new phenomena in electricity and magnetism, was obliged to modify his views as he proceeded. In his *Experimental Researches* Faraday gives us, not his mature opinion at the conclusion of his work, but the evolution of his theory as it took shape in his mind. It is accordingly possible to get different notions of Faraday's theory from different parts of his Researches.

Thus, in the discussion of induction which has been in part quoted Faraday speaks of the phenomena as being entirely due to a condition in the dielectric medium, and he discusses the direction of the lines of force of the inductive stress in this medium. In the early stages of his work he uses the term "lines of force" in a purely mathematical sense, that is, as giving throughout their length the *direction* of the inductive force. Later he came to think of the dielectric medium as consisting wholly of *physical* lines of force. In one of his latest papers (Proc. Roy. Inst., June 11, 1852) he discusses the characteristics which must distinguish physical lines of force from abstract, or mathematical, lines of force, and decides that both electrical and magnetic phenomena are dependent upon physical lines of force; that is, the lines of force are no longer used to *describe* phenomena, but to *explain* them.

His later ideas as to the nature of these physical lines of force are perhaps most fully explained in a letter to Richard Phillips, Esq., written in May, 1846, and published in *Experimental Researches,* III., p. 447. Some extracts from this letter are given below.

> You are aware of the speculation which I sometime since uttered respecting that view of the nature of matter which considers its ultimate atoms as centers of force, and not as so many little bodies surrounded by forces, the bodies being considered in the abstract as independent of the forces and capable of existing without them. In the latter view, these little particles have a definite form and a certain limited size; in the former view such is not the case, for that which represents size may be considered as extending to any distance to which the lines of force of the particles extend: the particle indeed is supposed to exist only by these forces, and where they are it is. The consideration of matter under this view gradually led me to look at the lines of force as being perhaps the seat of the vibrations of radiant phenomena.
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> The ether is assumed as pervading all bodies as well as space: In the view now set forth, it is the forces of the atomic centres which pervade (and make) all bodies, and also penetrate all space. As regards space, the difference is, that the ether presents successive parts or centres of action, and the present supposition only lines of action; as regards matter, the difference is, that the ether lies between the particles and so carries on the vibrations, whilst as respects the supposition, it is by the lines of force between the centres of the particles that the vibration is continued.

Again, in *Experimental Researches* II, p. 291, Faraday presents his theory of the nature of matter in much the same manner as above. At the conclusion of this discussion, he says:

> The view now stated of the constitution of matter would seem to involve necessarily the conclusion that matter fills all space, or, at least, all space to which gravitation extends (including the sun and its system); for gravitation is a property of matter dependent on a certain force, and it is this force which constitutes the matter. In that view, matter is not merely mutually penetrable, but each atom extends, so to say, throughout the whole of the solar system, yet always retaining its own centre of force.

We see from the above that Faraday's later electrical theory was based upon a concept of the nature of matter which is no longer regarded as tenable, but which necessarily profoundly modified his views on electrical phenomena. It did away at once with all distinction between matter and the ether, unless those parts of space in which the centers of force were less numerous than in other parts could be regarded as a separate medium. Any question as to the number of electrical fluids, or whether there was any electrical fluid at all, could have little significance. The atoms of bodies were merely centers from which innumerable contractile filaments which he called lines of force radiated in all directions and throughout all space. From his reasoning, these filaments must extend to the limits of the physical universe, and every point in space must be traversed by lines from all the centers in the universe, as otherwise there would be points in which the law of gravitation would not apply. Whether these lines of force are of different kinds, so that gravitation depends upon one kind, electric phenomena upon another kind and magnetic phenomena upon a third kind, Faraday does not state, but this condition would seem to follow from the rest of his theory.

When Maxwell undertook to interpret Faraday to the mathematicians he was compelled to choose between the more or less contradictory views which Faraday had expressed at different times, and he naturally undertook to select the views which could be used as the most satisfactory basis for a mathematical theory of electricity and magnetism. In doing this, he does not adopt Faraday's extreme views of the identity of matter and force. The distinction between force and energy was much more clearly understood at the time of Maxwell's writing than it was when Faraday was carrying on his investigations. In fact, energy, as a concept distinct from force, was not known to Faraday, and Maxwell shows early in his treatise that what had been defined as electricity or electrical quantity could not be measured as energy. He does, however, adopt Faraday's concept of physical lines of force, but somewhat in the manner of Faraday's earlier views, in which the lines of force were regarded as chains of polarized material particles.

Maxwell first defines his lines of force in a purely mathematical sense. Thus he says (*Elec. and Mag.* I, 97):

> If a line be drawn whose direction at every point of its course coincides with that of the resultant intensity at that point, the line is called a Line of Force.
>
> In every part of the course of a line of force, it is proceeding from a place of higher potential to a place of lower potential.
>
> Hence a line of force cannot return into itself, but must have a beginning and an end. The beginning of a line of force must, by Number 80, be in a positively charged surface, and the end of a line of force must be in a negatively charged surface.

It is easily seen that such a line of force does not pull the positively and negatively charged surfaces together. It is merely the path along which a positively or negatively electrified particle would move if set free on the line of force. It does not explain the motion of the particle, it merely describes it. When he undertakes to explain *why* an electrified particle would travel along a line of force, Maxwell says:

> At every point of the medium there is a state of stress such that there is a tension along the lines of force and pressure in all directions at right

angles to these lines, the numerical magnitude of the pressure being equal to that of the tension, and both varying as the square of the resultant force at the point.

In another place Maxwell argues that the state of stress described above is the only one consistent with the observed mechanical action of the electrified bodies and also with the observed equilibrium of the fluid dielectric which surrounds them.

Sir J. J. Thomson, who edited the third edition of Maxwell's treatise, takes exception to this claim. He says in a foot-note on page 165:

> The subject of the stress in the medium will be further considered in the supplementary volume; it may however be noticed here that the problem of finding a system of stresses which will produce the same forces as those existing in the electric field is one which has an infinite number of solutions. That adopted by Maxwell is one which could not in general be produced by strains in an elastic solid.

This, in connection with the preceding quotation from Maxwell, indicates that Maxwell regarded his dielectric medium as necessarily a fluid; hence when the only dielectric between the positive and negative electrical condition is the ether of space, this medium must be a fluid. This seems to contradict the well-known fact that the only known forms of ether radiation are of the nature of transverse waves.

Maxwell goes no further than Faraday in explaining the condition of stress which is supposed to constitute induction. He merely attempts to describe it. He says:

> It must be carefully borne in mind that we have made only one step in the theory of the action of the medium. We have supposed it to be in a state of stress, but we have not in any way accounted for this stress, or explained how it is maintained.
>
> . . . .
>
> I have not been able to make the next step, namely, to account by mechanical considerations for these stresses in the dielectric. I therefore leave the theory at this point, merely stating what are the other parts of the phenomenon of induction in dielectrics.

Maxwell's claim is, accordingly, that if the dielectric medium between two charges, said charges being always necessarily upon the opposite surfaces of the dielectric, should contract in the direction of the lines of force normal to its charged boundaries and should expand in all directions at right angles to these lines of force, this contraction and expansion would enable him to account for the other phenomena of electrostatic induction.

Maxwell does make the further assumption that this stress in the dielectric is analogous to an elastic stress in material bodies. Thus he says:

The analogy between the action of electromotive intensity in producing electric displacement and of ordinary mechanical force in producing the displacement of an elastic body is so obvious that I have ventured to call the ratio of the electromotive intensity to the corresponding electric displacement the *coefficient of electric elasticity* of the medium. The coefficient is different in different media, and varies inversely as the specific inductive capacity of each medium.

Farther along in his treatise Maxwell argues that this "Electric Elasticity" is the elasticity by means of which light waves are propagated through the ether. Thus he says (Vol. II, p 431):

According to the theory of emission, the transmission of energy is effected by the actual transference of light corpuscles from the luminous to the illuminated body, carrying with them their kinetic energy, together with any other kind of energy of which they may be the receptacles.

According to the theory of undulation, there is a material medium which fills the space between the bodies, and it is by the action of contiguous parts of this medium that the energy is passed on from one portion to the next, till it reaches the illuminated body.

The luminiferous medium is therefore, during the passage of light through it, a receptacle of energy.

In the undulatory theory as developed by Huyghens, Fresnel, Young, Green, etc., this energy is supposed to be partly potential and partly kinetic. The potential energy is supposed to be due to the distortion of the elementary portions of the medium. We must therefore regard the medium as elastic. The kinetic energy is supposed to be due to the vibratory motion of the medium. We must therefore regard the medium as having a finite density.

In the theory of electricity and magnetism adopted in this treatise, two forms of energy are recognized, the electrostatic and the electrokinetic (see Arts. 630 and 636), and these are supposed to have their seat, not merely in the electrified or magnetized bodies, but in every part of the surrounding space, where electric or magnetic force is observed to act. Hence our theory agrees with the undulatory theory in assuming the existence of a medium which is capable of becoming the receptacle of two forms of energy.

Let us next determine the conditions of the propagation of an electromagnetic disturbance through a uniform medium, which we shall suppose to be at rest, that is, to have no motion except that which may be involved in electromagnetic disturbances.

Maxwell then proceeds to develop an equation for the velocity of an electromagnetic disturbance in terms of the specific inductive capacity and the magnetic permeability of the medium and which, if the specific inductive capacity be taken as the reciprocal of the elasticity and the magnetic permeability be taken as the density of the medium gives an expression for the velocity of a wave motion in an elastic medium. It also gives an expression for the ratio of the electromagnetic to the electrostatic unit of electricity, or the velocity with which a unit electrostatic charge must move in order to become electromagnetically a unit current. This ratio can be determined experimentally, and gives a quantity numerically equal to the velocity of light.

He then says:

> In other media than air the velocity V is inversely proportional to the product of the dielectric and the magnetic inductive capacities. According to the undulatory theory, the velocity of light in different media is inversely proportional to their indices of refraction.
>
> There are no transparent media for which the magnetic capacity differs from that of air more than by a very small fraction. Hence the principal part of the difference between these media must depend upon their dielectric capacity. According to our theory, therefore, the dielectric capacity of a transparent medium should be equal to the square of its index of refraction.

In Maxwell's theory we accordingly find the dielectric medium of Faraday identified with the luminiferous ether. But the elasticity of the luminiferous ether which is involved in the transmission of all known forms of radiation must be of the nature of rigidity, and a fluid dielectric such as Maxwell's assumption of contracting lines of force seems to require does not possess rigidity.

It would accordingly seem that while Maxwell's method of calculating the velocity of light from purely electrical experiments *seems to prove beyond question that the luminiferous ether is the medium of electric and magnetic induction,* the assumption as to the contraction of this medium in the direction of the electrical lines of force and its expansion in all directions at right angles to these lines may require modification.

It is plain that this assumption that an electrical charge is merely one aspect of a stress in the ether is equivalent to a denial of an electrical substance *per se*. It is difficult to see, however, how from the assumption of a mere contraction of the dielectric between two conductors the surfaces of the conductors could be put in qualitatively different electrical conditions such as are known to distinguish positively and negatively electrified bodies. Both aspects of such a stress would appear to be exactly alike, just as the stresses at the opposite ends of a stretched elastic cord.

It accordingly became necessary to make some further assumptions to account for the difference in the positive and negative electrical surfaces. Here recourse was again had to Faraday's notion of a polarizable medium; that is, a medium made up of particles having opposite electrical properties at two opposite extremities. The ether accordingly came to be regarded by many of Maxwell's successors as made up of particles or "cells" holding positive charges on one side and negative charges on the opposite side, very much as the current magnetic theory regards a magnet as made up of molecules having a north magnetic pole on one face and a south magnetic pole on the opposite face. The polarization of the medium in electrical induction was supposed to consist in the orientation of these hypothetical particles so that their charges of the same kind were turned in the same direction.

Thus Lodge (*Modern Views of Electricity,* p. 349) says:

Is the ether electricity then? I do not say so, neither do I think that in that coarse statement lies the truth; but that they are connected there can be no doubt.

What I have to suggest is that positive and negative electricity together may make up the ether, or that the ether may be sheared by electromotive forces into positive and negative electricity. Transverse vibrations are carried on by shearing forces acting in matter which resists them, or which possesses rigidity. The bound ether inside a conductor has no rigidity; it cannot resist shear; such a body is opaque. Transparent bodies are those whose bound ether, when sheared, resists and springs back again; such bodies are dielectric.

A similar view to this was expressed in most text books on Electricity written in the English language between 1890 and 1900. Thus in his well-known text book on Electricity and Magnetism (Edition of 1895) S. P. Thompson attempts to define electricity as follows:

Electricity is the name given to an invisible agent known to us only by the effects which it produces and by various manifestations called electrical. These manifestations, at first obscure and even mysterious, are now well understood; though little is yet known of the precise nature of electricity itself. It is neither matter nor energy; yet it apparently can be associated or combined with matter; and energy can be spent in moving it. Indeed its great importance to mankind arises from the circumstance that by its means energy spent in generating electric forces in one part of a system can be made to appear as electric heat or light or work at some other part of the system; such transfer of energy taking place even to very great distances at an enormous speed. Electricity is apparently as indestructible as matter or energy. It can neither be created nor destroyed, but it can be transformed in its relations to matter and to energy, and it can be moved from one place to another. In many ways its behaviour resembles that of an incompressible liquid; in other ways that of a highly attenuated and weightless gas. It appears to exist distributed nearly uniformly throughout all space. Many persons (including the author) are disposed to consider it as identical with the luminiferous ether. If it be not the same thing, there is an intimate relation between the two. That this must be so is a necessary result of the great discovery of Maxwell—the greatest scientific discovery of the nineteenth century—that light itself is an electric phenomenon, and that the light waves are merely electric, or, as he puts it, electromagnetic waves.

In 1893 J. J. Thomson published his *Recent Researches in Electricity and Magnetism,* in which he carried the Faraday-Maxwell theory to a development almost as extreme as the later views of Faraday, to which reference has already been made. Only a short time later, he and his fellow workers succeeded in identifying the electrical fluid concerning whose existence there had been so much argument for 150 years. The development of the ether theory by Thomson should form the subject of another paper.

FALSIFICATIONS IN THE HISTORY OF EARLY CHEMISTRY

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THE earliest developments of any science present difficulty to historians by reason of the fragmentary character of surviving records, but with the progress of time and the advance of research the story becomes gradually clearer and more coherent. In the case of the history of the science of chemistry, however, more perhaps than in any other, factors have been operative that have made peculiarly difficult the solution of the problems of its early history.

The beginnings of the history of chemical theory, the notions of the nature of matter and its changes are found in the Greek philosophers from Thales to Aristotle, and for our knowledge of these we are mainly dependent on the records of Plato and Aristotle.

For our knowledge of the earliest data on the practical arts of chemistry we are in the first instance dependent upon evidence accumulated by archeological research with respect to remains of works of art or manufactures involving chemical knowledge or skill; in the second instance, to surviving documentary records of ancient times of established authenticity.

Such in the domain of chemistry are, particularly, Theophrastos of Eresus (born 371 B. C.), Pollio Vitruvius (1st century B. C.), Dioscrides and Pliny the Elder (first century A. D). These writers were, however, not chemists by occupation or by experience.

The earliest practitioners of the chemical arts of whom we have some definite knowledge appear to have been Egyptian or Greek-Egyptian practitioners of the arts of metal working, goldsmiths and dyers. These arts seem to have been long held as a monopoly by a certain cult of the Egyptian priesthood, and these arts had been guarded and kept secret, only imparted to initiates bound by solemn oaths not to reveal them to the uninitiated.

The first recognition of this chemical cult and the philosophy developed by it connects with the Greek-Egyptian schools at Alexandria early in the Christian Era. The art called by the early Alexandrian writers the sacred or the divine art became only gradually more widely known through the destruction of the pagan temples and schools, and the scattering of their scholars, by the early Christians.

The earliest known designation of this Greek-Egyptian art which gave rise to our word chemistry is the Greek word chemeia and is first met with in the third century of our era in writings of a Christianized Alexandrian, Zosimus, who endeavors to explain the origin of the term by a fabulous myth. The term is also met with in the same century in the decree of the Emperor Diocletian against the practice of this art of chemeia and ordering the destruction of all works relating thereto. This decree was issued, it appears, on account of the belief that these chemists were able to make artificial gold and silver and that thereby the finances of the empire might be seriously disturbed.

With the abolition of the Alexandrian and other pagan schools and the downfall of the Egyptian priesthood, their chemical arts as practiced were indeed not lost, though their practitioners were scattered. The early scholars of this chemical cult did not write for the public. Those who in time ventured to write about the sacred art, either by reason of their desire not to be considered as violating their oaths of secrecy, or for fear of not being thought good Christians, wrote in obscure and mystical allegories or in vague descriptions of, or allusions to, processes which generally centered about the transmutations of base metals to precious metals, or the preparation of elixirs and the philosopher's stone. With the increase of power of the Christian Church there seems to have been a decline of interest in Western Europe in this phase of Alexandrian chemical philosophy, though in Byzantium there seems to have been a cult which kept alive to some extent those traditions and ideas and preserved such writings as then existed.

With the rise of the Moslem power and their conquests of Persia, Asia Minor, Egypt, Morocco and Spain in the sixth to the eighth centuries, the Arabs absorbed and assimilated the Greek Alexandrian science, which had been preserved and cultivated notably by Syrian schools founded by fugitive scholars from Alexandria and other suppressed pagan schools. This Greek science of chemeia thus became known as al-chemia, under which name it was in the eleventh to the thirteenth centuries again introduced to western Europe, largely through the medium of Christian scholars from Spain, Italy and other nations who studied at the Spanish Mohammedan schools.

This re-introduction into Europe of Arabian elaborations of Greek-Egyptian alchemy was not without serious opposition. It was very generally believed that the alchemists possessed the power to make gold and silver from base metals, and hence their activities were viewed with suspicion by civil and ecclesiastical authorities who feared that state or national finances might be disturbed. Monarchs of France and of England and other lesser rulers, and in the fourteenth century Pope John XXII forbade under penalties the practice of alchemy and the possession of alchemical literature. As the practice of alchemy was often associated with supposed magical powers and the cooperation of evil spirits, church authorities, both Christian and Mohammedan, endeavored to suppress alchemists and their writings.

One natural result of this situation was to discourage conservative and law-abiding persons of scholarly taste from entering this field of science. Another result was to cause those who nevertheless refused to heed the prohibition decrees either to exercise great caution in their expressions or to conceal their identity as authors.

There were numerous such alchemical writers, for the administrative machinery was notoriously defective in those times and the hope of gain in wealth or long life of many influential and powerful persons—even princes—often operated to protect many who pretended to possess the great art.

Thus in the middle ages, while there were written a very large number of treatises on alchemical philosophy or pretending to the knowledge of transmutation or to give instruction in the art, such writings were nearly always anonymous or pseudonymous. The authors concealed their personal identity by issuing their manuscripts without name, place or date, by giving false dates and places, or to give their writing greater importance by ascribing them to some author of established authority in some natural science, safely dead.

During this period also the literature of technical chemistry outside of the domain of alchemy proper was very meager. The artisans and manufacturers were not generally scholars. They had also little object in informing the public generally as to the details of their business. So far as writings of that character were issued, they were for the use of a limited constituency and attracted little notice outside of the particular trade for which they had practical value. Such manuscripts were rarely preserved in permanent collections or libraries.

From these causes it can be understood that the history of chemistry in the middle ages presents peculiar difficulties, and that surviving records give occasion for many perversions of history. An early instance of such perversion is found in early writings issued under the name of Democritus and generally attributed to the Greek philosopher Democritus of Abdera (5th Century B. C.). The writings in question, however, are typical alchemical of the Alexandrian school. While they contain recipes for making imitations of gold and silver, and for dyes and dyeing, etc., they contain also much mystical philosophy and obscure allegories. Even Pliny, about 75 A. D., refers to magical and superstitious writing of Democritus, and expresses the belief that they are by Democritus of Abdera, though he admits that that is disputed by others. Pliny's contemporary, Columella, however, asserts that much that is attributed to Democritus was in reality written by a certain Bolos of Mendes in Egypt. This psuedo-Democritus was held in the highest reverence by later alchemists and by them generally considered as Democritus of Abdera. Zosimus about the third century A. D. refers to him as a great master of the art. So late as the eighteenth century Lenglet du Fresnoy in his history of alchemy assumes that Democritus of Abdera is the author of this literature, though by later historians it is well recognized that the alchemist Democritus is a writer of between the first and third centuries of our era.

Even Aristotle was the victim of medieval impostors. Thus the work on minerals—*de mineralibus*—attributed to him seems to have been originally written by a Syrian-Arabian writer of about the ninth century, though rewritten and extended by later Latin editors. According to Ruska it is the earliest Arabian work on mineralogy and was a principal source of medieval mineralogy. Other works falsely attributed to Aristotle are not earlier than the 11th century and some much later.

So also the eminent Arabian physicians, Rhazes (Al Razi) of the 9th-10th centuries and Avicenna (Ibn Sina) of the 10th-11th centuries, were fraudulently credited with works of alchemical character of a century or so after their deaths, which were much quoted by Vincent of Beauvais, Albertus Magnus and Roger Bacon in the thirteenth century. These writing are now believed to have had no Arabian originals but to have been written by Latin writers in the 12th and 13th centuries.

A notable perversion of history was the appearance about 1300 A. D. of certain writings important in the history of chemistry purporting to be the work of the Arabian Geber, which was the Latinized name of Djaber. The real Djaber lived probably about the eighth century, and little is known of his personality. He is, however, considered by later Arabian alchemists as of high repute in the art. His writings seem to have been unknown to European chemists during the medieval period. Though his name appears two or three times among authorities of reputation, neither Vincent of Beauvais nor Albertus Magnus seems to have known anything definite of his works. The works appearing under the name of Geber were very notable, and made a great impression in the fourteenth century. They were manifestly the work of an experienced and capable chemist familiar with and describing well methods of distillation, sublimation, many furnace operations and the preparation and purification of many metallic salts and solutions. They contained our first definite information concerning the preparation and use of mineral acids—sharp or corrosive "waters." The credulous middle ages accepted generally without question the authenticity of these works as by the eighth century Geber, and the early historians of chemistry, Hoefer, Gmelin, Kopp, accepted this interpretation. Kopp indeed in his "Geschichte der Chemie" expressed some doubts, but did not, however, alter the traditional course of history. In his later work, however—"Beiträge zur Geschichte der Chemische"—he gives strong reasons for doubting the early date of these writings and that they were indeed translations from any Arabian originals. It remained for M. Berthelot to establish beyond doubt the pseudonymous character of these writings. In the libraries of Europe he located and had translated a number of works, manuscripts in Arabic credited to the original Djaber or Geber. None of these works bore any resemblance in style or contents to the work of the Pseudo-Geber. They are indeed much more like the writings of the early Greek alchemical writings upon which they are manifestly based.

The acceptance of these thirteenth or fourteenth century writings as of Arabian origin in the eighth century up to very recent times has had the result of early Arabian chemists receiving credit for an advanced knowledge of chemistry which has not been evidenced by any Arabian literature known at the present time. This advanced knowledge is rather to be credited to some European chemists, probably both Mohammedans and Christians, of the latter part of the thirteenth century, and the Pseudo-Geber was probably not himself Arabian but a Latin-writing Spaniard or at any rate from some other country of southern Europe conversant with the development of Spanish-Arabian chemistry of that period.

The chemical literature of the fourteenth and fifteenth century contains almost nothing that evidences any material advance upon the Pseudo-Geber and his predecessors. Alchemical treatises of that period are indeed numerous. They are, however, nearly all anonymous, or pseudonymous. Many were ascribed to the authorship of prominent writers deceased. Many were ascribed to eminent churchmen—Albertus Magnus, St. Thomas Aquinas, Raimundus Lullus (Lully) and Roger Bacon. In the case of Albertus

Magnus, two alchemical papers attributed to him are included in the collection of his works published by the French government, though the principal one of these contains references to authorities long subsequent to his death. The judgment of recent students of chemical literature, on the basis both of internal and external evidence is that all alchemical literature attributed to Albertus, St. Thomas Aquinas and Lullus are the work of impostors of from a half-century to perhaps two centuries later. In the case of Roger Bacon, while there are genuine writings in which he talks about alchemy and expresses his faith in some of its claims, it appears quite certain that those writings which pretend to a personal experience in the alchemist's arts are all falsely attributed to him.

Raimundus Lullus was a prominent churchman and writer on theology and philosophy at the close of the thirteenth century who was killed at Tunis in 1315 while carrying on missionary work among the Moors. He was reputed as a great master of alchemy in the later middle ages, and a considerable alchemical literature exists under his name. His scholarly biographer, B. Haureau, cites the titles of some eighty alchemical treatises—printed or not—which are attributed to him, yet it seems well established that he wrote nothing of that kind. Several of the most popular and apparently earlier works are circumstantially dated between 1330 and 1333, and even these there are reasons to believe are antedated. The alchemical literature attributed to Lullus is probably not earlier than the middle of the fourteenth century and much of it later. It is also very probable that most if not all the alchemical treatises ascribed to the Spanish physician, Arnald of Villanova, another eminent authority with medieval alchemists, is apocryphal.

The early part of the sixteenth century is marked by three writers of note in the history of chemistry, Theophrastus von Hohenheim, called Paracelsus (1493-1541), Vannuccio Biringuccio (his single book on mining and metallurgy was published 1540) and George Bauer or Agricola (1494-1555). The well-known works of these authors were widely appreciated by their century, were printed and passed through many editions and translations. The works of Biringuccio and Agricola were both important technical treatises appealing mainly to mining and metallurgical coworkers. The works of Paracelsus were medical and chemical and dealt in his peculiar way with natural philosophy in general and attracted great attention on account of his emphasis upon the place of chemistry in medicine.

At the close of the sixteenth century and early in the seventeenth, there appeared certain treatises, printed in German, published by Johann Thölde, said by him to be translations of ancient

Latin manuscripts, and to have been written by an alleged Bene dictine monk—Basilius Valentinus. The works attributed to Basilius attracted wide attention. They were a strange mixture of alchemical lucubration and of advanced chemical knowledge. They dealt with the importance of chemistry in medicine, and with chemical medicines. They criticized severely the medical profession. In all this they resembled the literature of Paracelsus. Moreover, the theory of the *tria prima*, of salt, sulphur and mercury as the constituent principles of all material substances, a theory which Paracelsus had formulated and much reiterated, was found just as clearly stated. Many passages were so similar in the writings of the two that students were not slow to infer that one author must have copied his ideas from the other. Much speculation and controversy was excited as to date and authorship of the Basilius literature, but eventually the seventeenth and eighteenth centuries accepted it as of the late fifteenth century and therefore pre-Paracelsan. To be sure, the archives of the Benedictine order when searched revealed the name of no such member, nor was any reference to any such author or his works known previous to 1600. Nor was any such specific chemical knowledge as was contained in some of these works contained in earlier writings than of the sixteenth century. No original manuscripts from which these books were supposed to be translated were ever in evidence.

As the bitter war in the medical profession between the opponents and partisans of Paracelsus and the chemical medicines introduced by him was then at its height, and the conservative and more scholarly university faculties and the conservative party in the medical profession were antagonistic to Paracelsus, it is not improbable that there was a willingness on their part to believe that Paracelsus had borrowed from Basilius rather than the contrary. However that may be, the result was that the Basilius literature was quite generally accepted as of the latter part of the fifteenth century, and the earlier historians, as Gmelin, Kopp and Hoefer and their successors, generally adopted this assumption. At the same time these historians were skeptical as to the existence of the alleged Dominican monk of that name.

Kopp, who in his history of chemistry (1843-7) had accepted the fifteenth century as the period of these writings, in his later "Beiträge zur Geschichte der Chemie" (1875) presented strong evidence that the Basilius literature was not previous but subsequent to Paracelsus, and in his last work "Die Alchemie" (1886) he reiterates his belief in the fraudulent character of the work and that Thölde himself was the real author, a conclusion which later researches have only confirmed. Prof. Karl Sudhoff, than whom no living scholar is more conversant with the medical literature of that period, stated in 1913 in a personal communication that after perusing thousands of manuscripts there is no possible room for doubt but that the Basilius literature as well as the Hollandus literature is all post-Paracelsan.

The works attributed to the alleged father and son Hollandus are of the same period as those of Basilius. The date of the first treatise published under the name of Johann Isaac Hollandus is 1572, at which time practically all the Paracelsus literature had been printed. The rest of the Hollandus literature was considerably later. These works also contain much that is similar to much in Paracelsus. The doctrine of the three principles was here also clearly stated. These writings also professed to be of earlier date and were accepted by the seventeenth and eighteenth centuries as also of the fifteenth century on no definite evidence. The works of the two Hollandus, whoever they were, and if there really were two, are of much less interest or value than some of the Basilius works, yet they contained also a great many chemical facts or points of view not known to the fifteenth century, and the incorporation of this literature into the fifteenth century history in the systematic histories of Gmelin, Thomson, Kopp and Hoefer caused a perversion of the story of chemistry, and gave an importance to these writers which they would not have received if they had been located in their proper chronological order. Not only did the sixteenth century chemists not depend on them, but the authors of the Basilius and Hollandus literature had or might have had the advantage of the works of Paracelsus, Biringuccio, Agricola and other less important chemists of the sixteenth century.

Works of alchemical character were also published under the name of George Agricola entirely foreign to his thought and easily recognized as spurious by the historians of chemistry. The literature of Paracelsus still presents unsolved and difficult problems as to authenticity in the great volume of works attributed to him and first published thirty to forty years after his death.

The foregoing sketch makes no pretension to a complete account of falsifications in the early history of chemistry, but comprises the most notable instances and will serve to illustrate the difficulties that have attended the story of the early development of chemical science and the misapprehensions affecting the reputations of early scholars in science.

THE ORGANIZATION OF SCIENTIFIC MEN

By J. McKEEN CATTELL

THE modern world is notable for the advance of science, of education, of democracy and of social organization. It may be assumed by a scientific man in a scientific journal that the advance of science is the most fundamental, for it has made the others possible. The entire development of our industrial civilization is due to the applications of science. Democracy has progressed because the productivity of labor has been so multiplied that one man can now do the work that once required four, because the length of life has been so increased that the years of work are doubled. Available wealth having increased four-fold, education and equality of opportunity for all have become practical ideals.

Trade guilds, of which universities were once examples, date to long passed centuries; the modern period has witnessed an elaborate organization of industrial and social groups. Legislatures are themselves such groups, representing mainly the holding classes. In order to obtain legislation for others, such as woman suffrage or the improvement of the conditions of labor, special organization is required. It is equally essential in commerce and in industry. Corporations and trade unions have largely replaced the competitive system among individuals and are integral parts of our social order. There is scarcely any group that has been so backward in democratic organization as men of science; there is no other in which the conditions make the right kind of organization more necessary.

In the slow movement toward democracy men of science have played a curious part. Their work has made democracy possible, although this is a result that as a group they have neither sought nor recognized. They have indeed often regarded it as ignoble to do useful or profitable work and have not accepted as equals those who did such work. Men of science have come from the privileged classes or have been dependent on them. They do not earn their livings by scientific research, but are usually amateurs, having either inherited wealth or doing other work for the support of their families. The most typical scientific man to-day is a university professor, meagerly supported by charity to tutor the children of the well-to-do, devoting his spare time to science from curiosity and emulation.

The satisfaction of curiosity is a fundamental instinct, the game of scientific discovery is one of the finest of sports, the appreciation or kindly envy of others is a pleasant tribute; but the rewards of science are queerly out of proportion to what science has accomplished for human welfare. Mr. Carnegie and Mr. Rockefeller may return some of the millions acquired through the applications of science; but science would be indefinitely richer if a cent were paid to it each time a match were struck or a pin used. Full payment would be three fourths of the wealth produced annually by the industrial nations. It might be admirable for scientific men to give what they can and to get only what they need, if they did so voluntarily; but they deserve about as much credit as the natives in an African protectorate. And they do not get what they need, for their fundamental want is to be in a position to advance science to the limit of their ability.

The two most important services to society are the bearing and rearing of children and scientific research. Their performance has been dependent on fundamental instincts which organized society has done more to thwart than to strengthen. It is essential for the welfare of all that these services shall be rendered. It seems unlikely that women will permanently accept the promise of bliss in heaven as a reward for pain on earth, or that scientific men will regard a title or a degree, a medal or membership in an academy, as fit payment for their work.

Competitive social organization enables a man to sell his services to those who will buy them; it makes no provision for services to society. When physicians limit the spread of disease by learning its causes they are not paid, but on the contrary lose the fees of patients. When lawyers avoid litigation, their reward is the lack of retainers. Should newspapers seek to prevent war they would limit their circulation. And so it is in all directions.

Art, like science of universal value, is in a better economic condition, for its products can be sold. Joy in work should be the right of every worker; it may be the greatest in the creative work of art and of science; but it does not give exemption from the ordinary needs of life; it can scarcely exist if the worker has not the means and the time to do his work in the best way. Printing and engraving, methods of automatically reproducing acting and music, are scientific inventions which have made art both democratic and self-supporting. It is also the case that the state pays for works of art for the use of all. The people and the state must learn to pay for the products of scientific research.

The situation for science is slowly improving, but through the working of economic forces, rather than through the efforts of scientific men. Students in medical, engineering and scientific courses must be trained by professors competent in science, and the university recognizes the advancement of science and scholarship as one of its functions. Foundations are endowed expressly for scientific research. Commercial firms need chemists, physicists and biologists in their business, and patent laws make some kinds of research profitable. The government has learned that it pays to employ scientific men for practical results, and that in some directions new investigations must be made. It is recognized that research not obviously and immediately useful is necessary, although no satisfactory method has been devised to defray its cost.

Society, controlled by privilege and precedent, has been parasitic on inborn instincts and inbred sentiments for its scientific research. The instincts and sentiments are in large measure inherited from the feudal and aristocratic period and will gradually atrophy, for the reactions only occur in answer to adequate stimuli. A complete revolution is demanded by modern democracy. The promotion of science being for the benefit of all is a function of the state and of a world organization. If a group of nations may make the maximum military establishment of a given nation a hundred thousand soldiers, it can perform a more useful function by making the minimum scientific establishment a hundred thousand men engaged in research. A decent regard for the opinions of mankind should lead each nation to support one research institution of the same cost as each of its battleships. The benefits of scientific research are greatest for the nation conducting it; but they accrue to the whole world, and each nation should contribute in proportion to its consumption.

Applied science has accomplished much by providing food, clothing and shelter for nearly all, bath-tubs, telephones and automobiles for many. But so long as

> A man's work lasts from sun to sun,
> A woman's work is never done,

so long as children work to their hurt and are denied the chance to prove what they can best do, the production of wealth must be further increased by scientific research and invention. By medicine, hygiene and better living conditions, infant mortality in some places has been reduced from one half to one tenth; cholera, smallpox, yellow fever and the plague have in large measure, tuberculosis, typhoid and other diseases have to some extent been controlled. But so long as ten million children die needlessly every year, so long as an epidemic of influenza may kill five million people, the need for research and its applications is more urgent than any other need.

Science has concerned itself mainly with the control of the physical world: the science of human conduct and of its control is only beginning. We have been more successful in the production of wealth than in its distribution and use. Our churches, schools, law courts, governments and other institutions are in large measure survivals from a pre-scientific and a pre-democratic era. But little has been done to investigate the relation of the individual to his surroundings and to make the most desirable adjustment, still less to obtain the best kind of individuals. The contribution of the psychological sciences to the production of wealth should equal that of the material sciences; their total contribution to human welfare should be greater. For science has not only supplied the economic basis for our civilization; it has not only made economic slavery wanton and intolerable; it has freed us from superstition and unreason; it is in itself the most perfect art and the best religion, the force not ourselves that makes for truth and righteousness.

"The harvest truly is plenteous, but the laborers are few." And this is in large measure because we limit ourselves to the solution of St. Matthew: "Pray ye therefore the Lord of the harvest, that he will send forth laborers into his harvest." We scientific men like "the conies are but a feeble folk"; but unlike them we do not make our "houses in the rocks"; rather as sheep we follow the shepherd to the shearing. We work for the lords of the harvest and depend on them to care for us. We have not awakened from the old dreams; we do not see the new world in which the workers of the world are learning to direct its work. What was printed many years ago is surely forgotten, so a reference[1] to the situation may be quoted as the writer saw it then, as he sees it now:

> Evolution has progressed by the survival of the strong and the cunning, of those armed with tooth and claw, of those quick to run and ready to hide. It has given us the vulture and the parasite. Human history has left us the legacy of the iron hand and the crooked back. The man engaged in scientific work has too often filled the position of an upper servant—a tutor to the sons of the rich, a priest subscribing to tenets that are outworn, an employee dependent on the favor of presidents and boards,—for whom silence is silver and flattery gold. As the downtrodden have submitted to servitude on the ground that they will have their reward in a future life, so scientific men have labored in the hope of recognition and posthumous fame. They have scrambled for degrees, titles, membership in academies and the like, trying to climb upon each others' necks. But the things that have been are not the things that shall be. The men who labor with their hands have learned to unite in trade unions; they have shown themselves ready and able to make the utmost sacrifices for their common cause. And they have won; they have used the governors of states and the president of the United States for their purposes. Their leader can speak to the president on terms of equality; the

[1] Address of the president of the American Society of Naturalists. *Science,* April 10, 1903.

members of the National Academy of Sciences waited last spring for an hour in the anteroom of the White House until he did them the honor to shake hands with them. Is there a university in the world whose faculty would resign because one member was unjustly treated, or would scientific men subscribe ten per cent. of their incomes to support a faculty that had so resigned? But the things that have been are not the things that shall always be.

Year after year has passed since this was written. The head of the American Federation of Labor still dictates to the president of the United States; scientific men still wait hat in hand on the almoners of Mr. Carnegie and Mr. Rockefeller. University professors even yet find silence to be silver, flattery to be gold. Now as then the National Academy of Sciences plays the part of an exclusive social club for those who have arrived. Royal Societies and Imperial Academies were fine embodiments of the spirit of a past period. The universities had fallen into dogmatic routine and external control; scientific men made notable progress by the organization of academies which they themselves conducted. Scientific invention was then youthful and vigorous; it was stimulating for the amateurs of a city to meet in a club to discuss their discoveries, usually trivial, but at times of fundamental importance.

But we no longer live in the seventeenth or the eighteenth century, even though their dead hands still lie heavy upon us. Science begot industrial civilization and must now dwell in the house of the giant that is its offspring. The noble and his serfs, the squire and his peasants, have been replaced by the capitalist and the proletariat. Kings yielded to parliaments, the barons to the commons. Now we have an unstable combination of indirect democracy and temporary dictators, while corporations and trade unions are becoming the real forces of government. The Bible has in large measure been supplanted by the newspapers, the church by the movies. Mr. Edison rather than Lord Rayleigh is the scientific representative of the industrial world. The park-like civilization of aristocracy with its hidden peasant hovels is being razed for the creation of cities and factories. The etiquette of the gentleman is yielding to the rough ways of democracy.

The adjustment of scientific men and their organizations to modern democracy has been slow and partial. The land that is the "mother of parliaments" was responsible for the organization of the first special scientific societies. The Linnean Society for the promotion of zoology and botany was founded in 1788; the Royal Astronomical Society in 1820; the Zoological Society in 1826; the Chemical Society in 1841. In Germany, under the leadership of Humboldt, the first national association for the advancement of science was established in 1828; the British Association followed in 1831. There are now special scientific societies for different sciences and national associations for the advancement of science in all the greater countries.

The American Association for the Advancement of Science held its first meeting in 1848, being the continuation of the Association of American Geologists and Naturalists, founded in 1840. The American Chemical Society was organized in 1876; the American Society of Naturalists in 1883; the American (then the New York) Mathematical Society and the Geological Society of America in 1888. The national associations for medicine, engineering and education were organized at a comparatively early period. There are now more than fifty national societies in the United States devoted to the different branches of science.

The principal objects of these organizations have been to hold meetings for the presentation of scientific papers and in some instances to conduct journals. But they also perform to a certain extent the functions of guilds or trade unions, and this is more especially true of the societies concerned with engineering, medicine and teaching. The American Association of University Professors, organized in 1915, had such functions primarily in view, although it has been timid about the question of salaries and privileges. A union of scientific employees of the government and unions of academic teachers, affiliated with the American Federation of Labor, have recently been formed.

The American Association for the Advancement of Science has made notable progress beyond the similar associations of other nations by the support of a weekly official journal and by affiliation with the national societies devoted to the different sciences. It may be regarded as an association of these societies; they are represented by delegates on its council and have charge of the scientific programs when they meet with it. The sixteen sections of the association cover completely the pure and applied sciences, including the psychological, humanistic and political sciences. Committees of these sections are formed of representatives of the association and of the affiliated societies. The council of the association and the sectional committees are thus organized on a democratic basis to represent through the association and through the national scientific societies the scientific men of the country.

All those professionally engaged in scientific work are eligible to fellowship in the association and all those interested in the advancement of science to membership. The members number about 12,000; there are funds for research amounting to over $100,000; the annual dues are only five dollars. In England it costs fifteen dollars to be a member of the British Association and to receive the national weekly scientific journal.

The American Association has accomplished important work through its council, through its executive committee, through its sectional committees and through numerous special committees, including the committee of one hundred on public health and the committee of one hundred on scientific research. The latter committee, organized in 1914, arranged subcommittees on research in each of the sciences, on grants for scientific research, on research in educational institutions, on research under the government, on research under states and municipalities, on research in industrial establishments and in other directions. In order, however, that the association may represent and forward the interests of science and of scientific men, a more general concern for its work is essential. Scientific men are intellectually too individualistic and socially too submissive to unite with the loyalty which characterizes the trade unions. But the future belongs to the national scientific societies and to the association of scientific workers in which they are combined.

In addition to a house of commons, we still have a house of lords. The National Academy of Sciences was chartered by the Congress in the emergency of the civil war, and was made by law the adviser of the Government on scientific questions, with the stipulation that no member should receive payment for his services. It was originally limited to 50 members elected for distinction in science; the members now number about 200. The academy administers funds for research and medals amounting to over $200,000.

For some fifty years the academy enjoyed a peaceful and pleasant existence. Membership was an honor appreciated by the elect, and the social features of the meetings were agreeable to the privileged. At that time the eighteenth amendment had not been even threatened, and certainly no one ever dreamed of the application of the nineteenth amendment to the academy. The duty of listening to papers on the scientific program was not onerous, for while they were often unintelligible they were not numerous. At one meeting Benjamin Peirce, after writing, correcting and erasing equations on a blackboard for an hour, remarked that he was sorry that the only member who could understand them was in South America. The election of new members was the great event of the meeting. No other business transacted was perhaps more significant than a resolution to endorse the metric system, which was voted in the negative.

The academy has been called on by the Government to render only a few reports. Perhaps the most typical of these was to determine whether the ink with which the Declaration of Independence was written can be prevented from fading; for it was not, of course, a question of preserving the sentiments of that document. It may also be significant that the academy holds its annual meetings in a museum and is presided over by our most eminent student of invertebrate fossils. It is said that a representative once asked in the House "What does the National Academy of Sciences do?" and the reply was: "The members write obituaries of each other when they die, and it is a pity they have so little to do."

The advice of the academy has not been sought by the government because it has developed its own departments, employing hundreds of scientific men, and the heads of the bureaus are not usually members of the academy. Advice given without responsibility and free of charge is usually worth about what it costs. When thirteen years ago the academicians made their quadrennial visit to the White House to wait upon President Taft and, following various delegations of men, women and children, passed before him, he recognized Dr. Weir Mitchell and said: "Why, Mitchell, what on earth are you doing in this crowd?" Dr. Mitchell explained with much dignity what an honorable body it was, being by law the scientific adviser of the government; but it may be doubted whether President Taft subsequently remembered the academy's existence.

President Wilson, an eighteenth century academician cast on the rough waters of the democratic politics of to-day, had appreciative sympathy for the National Academy. Shortly after his inauguration, the American Association appointed a committee to urge the selection of a scientific man for chief of the Weather Bureau, and the committee proposed to the president that he ask the advice of the academy in accordance with the provisions of the law. This he did and appointed one of the three scientific men named by the academy. He also appointed as chief of the Bureau of Fisheries the scientific man recommended by the American Society of Zoologists. Such methods are useful so long as scientific offices are in danger of being used as part of the spoils of office; but the appointment and promotion of scientific men in the government service should be through the choice of their associates, rather than on the recommendation of an outside body.

The recent revival of the National Academy has, however, not come from the modest recognition given to it by President Wilson, but is an adaptive response to modern conditions. Similar movements have occurred in the churches, in the universities and in other inherited institutions. When in the course of evolution, God let the dry land appear and saw that it was good, the creatures of the swamps suffered diverse fates. Most of them became extinct, some survived in their shells, a few developed into the higher animals of to-day. Like the churches, the universities and the rest, the National Academy of Sciences lies at present on the knees of the Gods, and only omniscience knows its fate. It may be an eddy in the stream; it may be a stepping stone.

A proximate cause of the reanimation of the academy was the enterprise of a distinguished man of science, elected to membership at a comparatively early age, as is the fortune of astronomers—for most astronomers are born to greatness through the circumstance that the superiority of their intellect is enhanced by their costly instruments and by the inaccessibility and sublimity of the starry firmament. This able and ingenious entrepreneur in science stirred several academicians by the contagion of his enthusiasm and took the academy in hand. Lectures have been endowed for the meetings; proceedings have been established where by resolution of the academy members are instructed to bury the cream of their researches; within a single year the ex-president of the nation and the ambassador of that empire on whose commerce the sun never sets made addresses at the dinners; an earl and a prince were present. The Carnegie Corporation has undertaken to erect for the academy its marble mausoleum.

A national academy, however, is wrapped in the inertia of its great traditions and bears the Atlantean load of a crystallized earth. Most ingeniously, a National Research Council has been established as a committee of the academy. This morganatic spouse can wear the royal jewels and yet associate with ordinary scientists, engineers and the like. She can be fertile without limit in committees, as their nourishment may be entrusted to charity. For this reason she can also adopt all the children on which she can lay her hands; indeed she may entice or kidnap certain gilded youths who will add to the family wealth. She has spread her net over the oceans and has set her traps for international fish, excluding those held to be unclean.

Even the humble children of the present writer have not escaped the telescope of this mother of enterprises. While his legal offspring may stay at home, some of those of which he was only one of many guardians have been abducted. Thus all the sub-committees of the committee of one hundred on scientific research of the American Association were bodily conveyed to itself by the Research Council, and the sectional committees of the association, representing the national societies, have been duplicated by the council. The committees of the council were originally nominated in equal share by the American Association, the National Academy and the Special National Societies; the writer urged that they should be equally responsible to those bodies. But cooperation prevailed, and when the lion and the lamb lay down together the lamb was inside the lion. The Research Council also proposed cooperation with the American Association as a whole. It offered to provide a permanent secretary for the association, to rent an office to the association in the attic of its building, and to let the association attend to the popularization of science while the council cared for research. Whether the Research Council belongs to the National Academy, or the National Academy belongs to the Research Council, or both are satellites of Pasadena, is a problem of three bodies that is difficult of solution. The American Association still belongs to its twelve thousand members, even though they have not learned to use their heritage.

The Carnegie Corporation, the Rockefeller Foundation and the National Research Council are another problem of three bodies. The Research Council depends on the endowed establishments for support, but the chairman of the Research Council became president of the Carnegie Corporation and its secretary has became a trustee of the Rockefeller Foundation. Scientific research certainly needs all the money it can get; it is in the interest of the nation that it get all the money that it needs. *Pecunia non olet.* A clergyman once told his congregation that it was well when the righteous gave to the Lord, but it was still more blessed when the money was obtained from the wicked, for then it was all gain. If we are taxed for the use of steel and petroleum, it is not amiss that a fraction of the proceeds should be returned to us for science and education. But after all the people can tax the preemptors of steel and petroleum, and it may in the long run be safer and even more profitable for men of science to be free from the charity and control of the classes of privilege and sell their services to the people for what they are worth.

One of those high in office in the National Research Council began an address:

> A general of the regular army listening to a description of the National Research Council remarked, "You are the General Staff of the Army of American men of science."

Mr. Elihu Root, trustee of many institutions and attorney for many corporations, says in a paper written for the council and widely distributed by it:

> The effective power of a great number of scientific men may be increased by organization, just as the effective power of a great number of laborers may be increased by military discipline.

It may be that the officers of the National Research Council are prepared to command the privates of science and that some employers would like to increase the effective power of laborers by military discipline. But what do the laborers and the scientific men think about it?

Frivolity may be unbecoming in the sanctuary of the higher organization of science; but the individual organism can exhibit only those defensive reactions which are its natural response to the situation. The Rockefeller-Carnegie Research Council (the R_2C_2) is prepared to direct scientific research and has good intentions for every day on the calendar. But there you are. Dr. John C. Branner, in his admirable book of negro stories printed just before his death, tells us that long ago he visited one of the former slaves of his father's plantation and asked her: "Don't you think you were better off as a slave?" And this is what Aunt Ellen replied:

> De Lawd bless yo' soul, chile, dat's a fac'; hit's jes lak you ben a sayin'. I knows I had mo' to eat an' mo' to wear, an' a better house to live in, an' all o' dem things, an' you all was mighty good to me; an' I didn' have none o' dese here doctah's bills to pay. But Law', honey, atter all, dah's de feelin's.

Unlike the worldly-wise steward in the parable, the scientific man can dig and to beg he is not ashamed. He digs for others and then begs for a bit of the gold that he has dug. But why should he not keep for himself and for his work part of the treasure that he discovers? The applications of electricity due to research work in the laboratory add billions of dollars a year to the wealth of the world. Why can not scientific men learn how to retain even one per cent. of such wealth, which when reinvested in research would again yield high usury to science and to society? It is a long way, but the world does rise slowly in spiral course to higher levels. The prime mover is scientific research and its applications. Without the commerce and the industry created by science, there could be only a hereditary aristocracy of privilege and wealth controlling slaves. We have now reached the stage where we can at least foresee economic freedom for all. People must be fed and sheltered before they can be happy and free; they must be happy and free before they can be good and wise. Economic liberty must precede intellectual liberty. Science and its applications should be the chief concern of a democratic nation that would preserve its democracy and advance the freedom and the welfare of its people.

MARTIAN POLAR RIFTS

By Dr. G. H. HAMILTON
LOWELL OBSERVATORY

IN 1902, Dr. Lowell published an extremely interesting article on the rifts in the north polar cap of Mars (*Popular Astronomy* for March, 1902). It is on account of this article that the present paper has its being.

Realizing that the oppositions of 1916, 1918 and 1920 had occurred at about the same Martian season as that viewed by Lowell—a study was made of drawings of the planet at these times. It is interesting to note that the observations not only confirm those of Lowell but add their weight to his conclusions.

It is purposed to chronicle the observations of the three last oppositions with deductions and show in what manner they agree with the conclusions arrived at by Dr. Lowell.

In 1916, the two drawings showing the region termed *Aeria* near the center of the disk and the north polar cap—those of March 4 and 9, in the cut—depict a rift in the cap, which seemingly the continuation of the canal *Cadmus*. That of March 9 also shows another rift to the north and west of the *Arethusa Lucus*. The season on Mars corresponded at that time to our May 24. The cap was in process of melting and the rifts were seemingly due to some underlying cause such as would hasten the melting of the polar snows at those points.

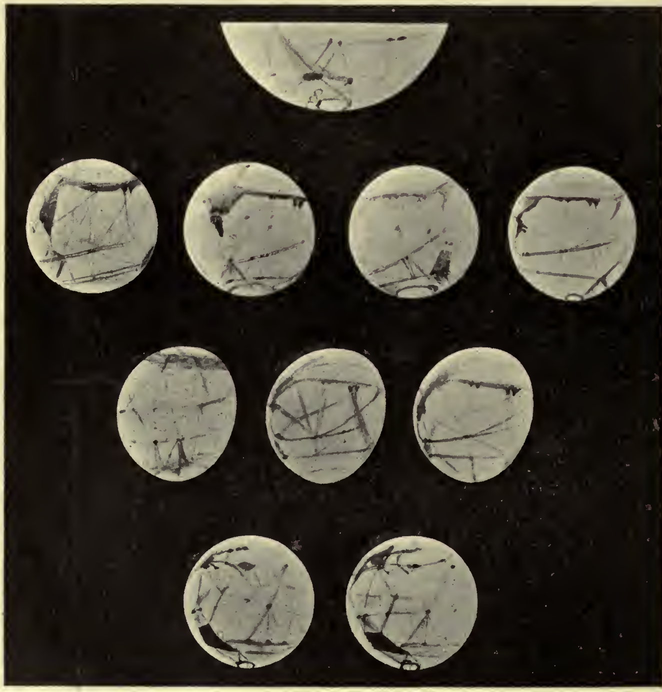
A similar rift to that in the drawing of March 9, 1916, was observed on February 15, 1918, with a period of slightly over a Martian year between the two observations. The effect of the later seasonal date can be observed in the diminished size of the polar cap. The positions of this second rift on the two dates do not correspond exactly, but this can be accounted for by the difficulty of positioning small detail or by the fact that there are many nearly parallel canals in this region, any one of which may have produced the effect observed.

In 1920, the north polar cap was at about its smallest on May 24, and the canal *Cadmus* was easily seen to extend northward to the cap along the position of the rift seen in the drawings of 1916. In the large drawing of the polar cap of May 27, 1920 (Martian date August 13) the *Cadmus* can be seen very well and there is another rift in the small remaining cap.

The action of this canal and the rift it seemingly makes in the polar cap corresponds to the observations made by Dr. Lowell and the inferences that he draws from them. He says:

> If there were strips of vegetation in the midst of the desert that underlies the polar cap, such vegetation would make its presence known by appearing as rifts in the snow-field. Such would be the case for the following reason. The life of plants has this in common with the life of animals, that their vital processes both generate heat. The fact was not recognized as true of plants until long after it was well known of animals. Indeed, the discovery that plants give out heat in growing is of comparatively recent detection.

Now the calorific action of vegetation on snow is very often observed on earth and we have seemingly had evidence of the same character upon Mars. If this be so, the two suspected materials—snow and vegetation—on the planet, vouch for each other. The



POLAR RIFTS ON MARS

May 27, 1920.
March 4, 1916. March 9, 1916. February 15, 1918. May 24, 1920.
July 8, 1920. August 2, 1920. August 3, 1920.
May 11, 1920. May 12, 1920.

snow, if it be snow, is melted as on earth by vegetation; and the vegetation, if it be vegetation, melts the snow as on earth.

Observations of this character again were made on August 2, 1920, and the following date, September 20, Martian calendar. One of the first northern snowfalls occurred near that time, and a canal was easily seen going north from the *Arethusa Lucus,* but was obliterated completely further north by the new-fallen snow. The drawing of the next day, August 3, shows that the snow has melted over the canal—as it would over vegetation—and that there is left a rift where the day before the cap showed an even contour, but on the following is made up of two lobes, one on each side of the now triumphant and still flourishing canal.

Before this date, a snowfall occurred north of the *Proponti,* and from the rift seen in the drawing of July 8, this snow must have fallen earlier even than this and melted over the canal that leaves the *Propontis* in a northerly direction towards the cap. This is an identical example of the phenomenon seen on August 3. It is also interesting in that it shows the depth of the new-fallen snow to be much thinner, as Dr. Lowell suggests, than the old winter cap itself; which can be seen dimly, together with its dark surrounding band, through the new covering of snow.

That the tiny northern cap itself was thin is evidenced in the drawings of May 11 and 12, 1920, where a slight rift is visible cutting the cap nearly in two. This is no doubt similar to the "Open Polar Sea" that Dr. Lowell talks of in referring to the small southern cap.

Detail on Mars is so complex, and the conclusions one can draw from the secular and seasonal changes so interesting, that when by careful scrutiny of the disk a marking of great interest is observed—it would be really better to devote one's attention to that area alone and draw it—rather than attempt a drawing of the whole disk. The marking itself would be swamped in a complete drawing, without regard to the attention taken from it by an endeavor to portray the rest of the surface features of the planet.

Mars has given to this world a most interesting and instructive line of research—I might almost say vital to the future welfare of the race on Earth.

ARCHITECT'S DRAWING OF THE BUILDING TO BE ERECTED BY THE CARNEGIE CORPORATION FOR THE NATIONAL ACADEMY OF SCIENCES

THE PROGRESS OF SCIENCE[1]

BUILDING OF THE NATIONAL ACADEMY OF SCIENCES

A HOME for the National Academy in the national capital will be provided through the erection of a magnificent building costing $1,300,000 that will house the activities of the academy and the National Research Council. A description of the new building was given by Dr. C. D. Walcott, president of the academy, at the recent meeting in Washington.

Facing the Lincoln Memorial, the marble building in simple classical style will rise three stories from a broad terrace. It has a frontage of 260 feet. On the first floor there will be an auditorium seating some 600 people, a lecture hall holding 250, a reading room, library, conference rooms and exhibition halls. The basement contains a cafeteria and kitchen. The two upper floors will be devoted to offices.

The building is the gift of the Carnegie Corporation of New York, while the ground was bought at a cost of about $200,000 through the donations of about a score of benefactors. Bertram Grosvenor Goodhue of New York is the architect. He is one of the best known architects in the country and designed the St. Thomas Church, the West Point buildings, the Nebraska State Capitol and many other buildings. The contract for the construction of the building has been let to Charles T. Wills, Inc., of New York, and it is expected that the building will be ready for occupancy in the autumn of 1923. Lee Laurie, the sculptor, has been selected to do the decorations, which will symbolize and depict the progress of science and its benefits to humanity. A series of bronze bas-reliefs will show a procession of the leaders of scientific thought from the earliest Greek philosophers to modern Americans.

On passing through the entrance hall the visitor will find himself in a lofty rotunda. Here he will see in actual operation apparatus demonstrating certain fundamental scientific facts that hitherto he has had to take on hearsay. A coelostat telescope, mounted on the dome of the central rotunda, will form a large image of the sun on the white surface of a circular table in the middle of the room. Here visitors will be able to see the sun-spots, changing in number and form from day to day, and moving across the disk as the sun turns on its axis. A 60-foot pendulum, suspended from the center of the dome, will be set swinging through a long arc, repeating the celebrated experiment of Foucault. The swinging pendulum will mark an invariable direction in space, and as the earth and the building rotate beneath it, their rotation will be plainly shown by the steady change in direction of the pendulum's swing over a divided arc. Other phenomena to be demonstrated in striking form in the central rotunda are magnetic storms, earthquakes, gravitational pull of small masses, the pressure of light, the visible growth of plants, swimming infusoria in a drop of ditch water, living bacteria, and other interesting phenomena.

In the seven exhibition rooms surrounding the central rotunda the latest results of scientific and industrial research will be illustrated. One room will be set aside for the use of government bureaus, another for industrial research laboratories, others for the laboratories, observatories and research institutes of universities and other institutions. The newest discoveries and advances in the mathe-

[1] Edited by Watson Davis, Science Service.

SKETCH OF ENTRANCE TO THE NEW BUILDING OF THE NATIONAL ACADEMY OF SCIENCES

matical, physical and biological sciences and their applications will be shown in this living museum, whose exhibits will be constantly changing with the progress of science. One week there may be displayed the latest forms of radio telephony; the next perhaps a set of psychological tests or a new find of fossils or a series of synthetic chemical compounds.

MEDALS OF THE NATIONAL ACADEMY OF SCIENCES

At the annual dinner of the National Academy of Sciences, April 25, the J. Lawrence Smith Medal was bestowed upon Dr. George P. Merrill, curator of geology at the United States National Museum. This is a gold medal of the value of $200, from a fund established in 1884, as a reward for "original investigation of meteoric bodies." But because investigators in this field are so rare it has not been given since 1888. Dr. Whitman Cross, in his speech presenting the medal, pointed out that Dr. Merrill had continued to carry on the work of his predecessor, J. Lawrence

OTHENIO ABEL
Professor of Paleontology in the University of Vienna.
From a photograph presented by him to Dr. Henry Fairfield Osborn.

Smith, on meteorites by the application of modern methods of analysis. The earlier analyses of meteorites were not always to be relied upon, and Dr. Merrill in his long years of research has been able to show that some of the elements previously reported as having occurred in meteorites are absent and, at the same time, he has extended the list of elements and compounds that do exist in these bodies. Among other minerals he has found a calcium phosphate similar to apatite, which has been named in his honor Merrillite. Dr. Merrill also has discovered evidences of metamorphism in meteorites, cases where a mineral structure has been broken up and the fragments later fused together like the conglomerates found in igneous rocks in the earth's crust.

Dr. Merrill in receiving the medal said that meteorites had in all ages attracted a great deal of popular interest. In the earliest times they were worshipped as divine and nowadays the newspapers give great atten-

PROFESSOR H. A. LORENTZ, OF THE UNIVERSITY OF LEIDEN, AND PROFESSOR DAYTON C. MILLER, OF THE CASE SCHOOL OF APPLIED SCIENCE

Professor Lorentz gave the principal address, entitled "Problems of Modern Physics," at the meeting of the National Academy of Sciences.

tion to any meteoric fall. Yet few scientists have made them the subject of concentrated and long-continued study. In his work, Dr. Merrill said he had tried to keep his feet upon the earth as though his shoes had leaden soles and to leave to others premature speculation as to the origin of these bodies. It is evident from their composition that they come from regions where there is no air, for they contain iron, both in a free state and in compounds that are not stable in the presence of oxygen. From their structure it is evident that some have undergone secondary igneous changes. In conclusion, Dr. Merrill quoted the verse, "All my dreams come true to other men," and said that he would leave the developments and deductions from his work to future investigators and "may all my dreams come true to other men."

The address bestowing the Daniel Giraud Elliot Medal was made by Dr. Henry Fairfield Osborn. This medal is intended to be awarded every year for contemporary contributions to zoology. Previous awards were made to F. M. Chapman, C. W. Beebe and Robert Ridgway. Dr. Osborn sketched the history of paleontology from the time when Cuvier first announced the law of correlation. The great American paleontologists, Leidy, Cope and Marsh, limited themselves mostly to description. But now again the time has come when general principles and relationships may be founded upon a more substantial basis. Among the young investigators who are taking up this work is Professor Othenio Abel, of Vienna, who has undertaken a general study of the causes of evolution. His guiding thought is that morphology depends upon physiology and that to understand a form we must know its function. Professor Abel pursued his studies even during the war when his family was in such distress that he had to send out his children to friends for food, and in 1920 he produced an inspiring work, entitled *Methoden der Paleobiologischen Forschung.*

The medal was received by Edgar L. G. Prochnik, Austrian chargé d'affaires, who said that all Austria would rejoice over this honor done to one of her citizens. Conditions in Austria are exceedingly hard at present on account of the curtailment of Austria's resources and it is felt that the future of Austria lies in the mental power of her sons. The Austrian scientists are determined to bring their country to the rank which she occupied in science and art previous to the war. The disposal of this medal was another proof that science was not limited in its scope to creed or nationality. Professor Abel serves in the ranks of science, the peace maker. President Walcott, in handing over the medal to the representative of the Austrian Legation, said that the award would carry with it an honorarium which was to be forwarded to Professor Abel.

THE SALT LAKE CITY MEETING

The summer session of the American Association for the Advancement of Science to be held in conjunction with the sixth annual meeting of the Pacific Division of the Association at Salt Lake City, June 22 to 24, 1922, promises to be a very successful meeting.

Salt Lake City offers many advantages as a meeting place. The center of a rich agricultural and mining section, it has large and important commercial and manufacturing interests. But it is perhaps chiefly famed for its scenic attractions drawing every year thousands of tourists by auto and railway from all parts of the country. The opportunity will be seized by many who will wish to combine a pleasure trip to one of the most interesting sections of the west with the advantages of a scientific meeting.

The hosts of the Salt Lake City meeting will be the University of Utah, the Utah Academy of Sciences, the Utah Agricultural College and the Brigham Young University. Arrangements will be made for the comfort and entertainment of visitors. The meeting will be held under the auspices of the Pacific Division of the Association. Dr. Barton Warren Evermann, the president of the Pacific Division, American Association for the Advancement of Science, will preside at the general sessions and will deliver the presidential address at the opening session on Thursday evening, June 22. He will speak on "The conservation and proper utilization of our natural resources."

An outstanding feature of the meeting will be a symposium on "The Problems of the Colorado River." The great reclamation project which has for its object the utilization of the waters of the Colorado River has already attracted wide attention. It is proposed to consider in this symposium the scientific aspects of the problems involved. The arrangement of the symposium is as follows: 1. General description of the Colorado River: Mr. E. C. La Rue, hydraulic engineer, United States Geological Survey, Pasadena, California. 2. Archeology of the Colorado River Basin: Professor H. R. Fairclough, Stanford University, California. 3. Geology of the Colorado River Basin: Dr. Frederick J. Pack, Deseret professor, department of geology, University of Utah, Salt Lake City, Utah. 4. The conservation of the waters of the Colorado River from the standpoint of the Reclamation Service: Mr. Frank E. Weymouth, chief of construction, United States Reclamation Service, Denver, Colorado. 5. The interstate and international aspects of the Colorado River problem: Dr. C. E. Grunsky, vice-president of the Pacific Division, American Association for the Advancement of Science, San Francisco, California.

The evening address will be given by Professor James Harvey Robinson, head of the New School of Social Science, New York City, the distinguished historian of human evolution.

While none of the sections of the national association will arrange to hold sessions at this summer meeting the various fields of science will be represented in the meetings of the affiliated societies of the Pacific Division. Those scheduled to hold meetings at Salt Lake City are:

The American Physical Society.

The American Meteorological Society.

The American Phytopathological Society, Pacific Division.

The Ecological Society of America.

The Society of American Foresters.

The Cooper Ornithological Club.

The Pacific Coast Entomological Society.

The Pacific Slope Branch, American Association of Economic Entomologists.

The Plant Physiologists.

The Utah Academy of Sciences.

The Western Psychological Association.

The Western Society of Naturalists.

AN AMERICAN ANTHROPOID PRIMATE

At the recent meeting of the National Academy of Sciences in Washington, Dr. Henry Fairfield Osborn announced the discovery of a tooth giving evidence of a pre-historic and unknown species of anthropoid intermediate between the ape and the earliest man. This discovery made by Harold J. Cook, of Agate, Nebraska, in the middle Pliocene formations of that state, in addition to being important scientifically, has a timely interest because of the attacks that during the past few months have been launched at the ground work of science through the zeal of opponents of the facts of the evolution of man, and has a dramatic or comic aspect in that it comes from the home state of William Jennings Bryan.

Worn by use when its owner was alive, and worn by water in the centuries since, this tooth matches no known tooth of ape or man, modern or extinct. It is very different from the tooth of the gorilla, the gibbon or the orang. It is nearest to that of the chimpanzee but the resemblance is still remote. Nor does it resemble very closely any human molar, although it is nearer to the human than to the ape type of tooth. Consequently Dr. Osborn classifies it as a new species and genus and names it *Hesperopithecus haroldcookii*, which being translated back from the biologist's Latin means "the anthropoid from the west discovered by Harold Cook." The fossil was found in the upper phase of the Snake River beds, associated with remains of the rhinoceros, camel, Asiatic antelope and an early form of the horse, now extinct.

In 1908 the American Museum of Natural History received a similar tooth but it was so water-worn that it could not be safely identified. But the new specimen looks so much like the other that it may belong to the same species and gives hope that other parts may be found in this field.

The remarkable feature of the discovery lies in the fact that hitherto no specimens of anthropoid primates, ancient or modern, have been discovered in America, although they are common in the Old World. It is possible that this Nebraska tooth will open a new chapter in geological history which may throw light on the vexed question of the origin of man.

According to Dr. Osborn, the animal is a new genus of anthropoid, probably one which wandered over here from Asia with the large south Asiatic element which has recently

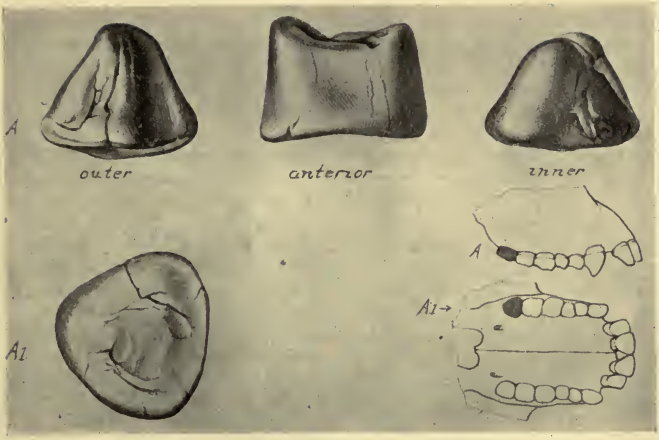


FIG. 1. MOLAR OF *HESPEROPITHECUS*

been discovered in our fauna by Drs. Merriam, Gidley and others.

Dr. Osborn and Dr. C. A. Reed, of the American Museum of Natural History, also presented evidence to the academy that man existed before the great Ice Age, which is a new and very remote date for the antiquity of man. The recent discovery of Tertiary man near Ipswich, England, known as the Foxhall man, led Professor Osborn to visit the locality and to make a very careful study of the animal life which surrounded this man. Unlike the now famous "Cave Man" of the mammoth and reindeer period, the Foxhall man was surrounded by relatively primitive mastodons, rhinoceroses, and saber-toothed tigers, also by two kinds of elephants, the straight-tusked elephant and the southern elephant. This was long before the Ice Age, when England, even in latitude 53°, was enjoying a

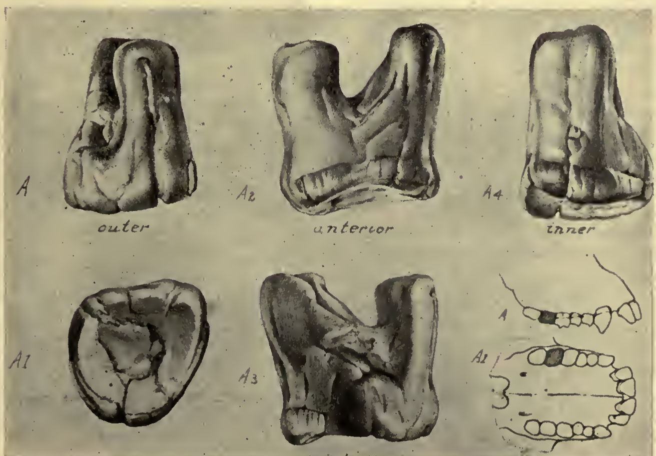


FIG. 2. MOLAR OF AMERICAN INDIAN

very mild climate. Since it is known that the Foxhall man was capable of making ten or twelve different kinds of flint implements, of providing himself with clothing, and of building a fire, he sets a new and very remote date for the antiquity of man, because he is separated from the Recent period by the whole stretch of Quaternary time, or the Ice Age. Scientific men have estimated the duration of the Ice Age from 100,000 to 700,000 years, but Professor Osborn is inclined to adopt the intermediate estimate of 520,000 years made by the German geologist, Albrecht Penck. The Foxhall man is at present known only by the flint instruments that he has left behind. Unlike *Pithecanthropus erectus,* the Heidelberg man, the Piltdown man, and the Neanderthal and art-loving Cro-Magnon races, parts of his skeleton have not yet been revealed to modern eyes.

SCIENTIFIC ITEMS

We record with regret the death of George Bruce Halsted, formerly professor of mathematics in the University of Texas; of J. T. Merz, author of *The History of European Thought in the Nineteenth Century;* of Ansel A. Tyler, professor of biology in James Millikin University; of Harris Graham, professor of pathology and practice of medicine in the American University of Beirut, Syria; of W. B. Bottomley, professor of botany in King's College, London; of Phillippe Auguste Guye, professor of physics at Geneva; and of Robert Wenger, director of the Geophysical Institute of the University of Leipzig.

At the meeting of the National Academy of Sciences, held in Washington on April 26, members were elected as follows: Edward W. Berry, professor of paleontology, the Johns Hopkins University; George K. Burgess, Bureau of Standards; Rufus Cole, director of the hospital of the Rockefeller Institute for Medical Research; Luther P. Eisenhart, professor of mathematics, Princeton University; Joseph Erlanger, professor of physiology, Washington University Medical School; Herbert Hoover, secretary of commerce; George A. Hulett, professor of physical chemistry, Princeton University; Charles A. Kofoid, professor of zoology, University of California; George P. Merrill, curator of geology, U. S. National Museum; C. E. Seashore, professor of psychology, State University of Iowa; Charles R. Stockard, professor of anatomy, Cornell Medical College; Ambrose Swasey, president of the Warner and Swasey Company; W. H. Wright, astronomer, the Lick Observatory, University of California. Dr. Albert Einstein, of the University of Berlin, was elected a foreign associate.

At the meeting of the American Philosophical Society, held in the city of Philadelphia, on April 23 and 24, the following officers were elected: *President,* William B. Scott; *vice-presidents,* Arthur A. Noyes, Hampton L. Carson, Henry Fairfield Osborn; *secretaries,* Arthur W. Goodspeed, Harry F. Keller, John A. Miller; *curators,* William P. Wilson, Henry H. Donaldson; *treasurer,* Eli Kirk Price; *councillors,* Lafayette B. Mendel, Herbert S. Jennings, William W. Campbell, Robert A. Millikan, Felix E. Schelling. Members were elected as follows: Charles Elmer Allen, Madison, Wis.; Rollins Adams Emerson, Ithaca; Worthington C. Ford, Cambridge, Mass.; Frederick E. Ives, Philadelphia; Irving Langmuir, Schenectady; Roland S. Morris, Philadelphia; George William Norris, Philadelphia; Charles Lee Reese, Wilmington; Harlow Shapley, Cambridge, Mass.; Henry Skinner, Philadelphia; James Perrin Smith, Palo Alto; Charles Cutler Torrey, New Haven; Robert DeCourcy Ward, Cambridge; Henry Stephens Washington, Washington; David Locke Webster, Stanford University.

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