In the purely thermal processes of Professor Wilson, liberation of hydrogen is not assumed. This alone would appear to make his mechanism the more probable. But neglecting this hydrogen difficulty, if we calculate the amount of petroleum in the earth's crust that would correspond to the present total of helium content of the atmosphere, on the basis that each atom originated in the crust as an alpha particle, a large total is arrived at. This calculation has been made by Farr and Rogers[13] on the basis of 100 per cent. efficiency in the utilization of the alpha-ray energy in producing petroleum and assuming the same yield per ion pair as found by Lind and Bardwell experimentally. The estimated total of two billion tons for the Petrolia Field of Texas is so huge that even after making large allowances for overestimation of energy utilization, yield, etc., the balance could still exceed the actual production.[14] Corrections in the opposite direction, such as possible loss of helium from the atmosphere leaving the present total content too low, and helium in natural gases still remaining in the earth would raise the total possible. The calculations of Farr and Rogers also have the advantage of being independent of any time factor. It may be mentioned incidentally that some recent analyses of natural gases in New Zealand by the same authors report as much as 4 to 20 per cent. of hydrogen in ten out of eighty-two samples, though the helium content in none of them exceeded 0.02 per cent.

To sum up, it may be said that we now know processes either thermal or ionic by which progression both up and down the hydrocarbon series is effected, starting from any member in the series. This leads directly to the complexity found in natural petroleums, as is also found in the electrically synthesized ones. Consequently, the starting material, whether of vegetable, animal, or mineral source, does not need to be a complex mixture, but may be a single chemical species, from which a high degree of complexity is obtained by steps which appear simple and natural when the chemical and thermodynamic properties of hydrocarbons are taken into account. The simplicity of such a mechanism may lend indirect support to the old idea of an inorganic origin from one or a few hydrocarbon gases such as might be produced by the action of water on metallic carbides in the earth's interior. On the other hand, it does not preclude animal or vegetable origin, but strongly suggests that the primary material, whether gaseous, liquid or solid, is later subjected to thermal (or ionic) agents (or both) which produce the complexity found in nature.

SOME RECENT ASPECTS OF NEMATOLOGY[1]

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ZOOLOGICAL text-books give nemas inadequate treatment—treatment altogether disproportionate to their scientific and practical importance; the space devoted to nemas is insufficient, while many of the statements are antiquated and erroneous.

In judging this defect about 250 zoological and biological text-books printed in English were examined, including text-books proper and books often recommended to students for collateral reading.

A review of these books arouses the suspicion that the text-book treatment given the nemas instead of improving has retrograded. Certain text-books of fifty years ago, now no longer used, give this phylum better treatment than is often the case with texts of to-day.

To cover recent practice it was decided to examine carefully only latest editions. These were grouped, 32 of zoology, and 28 of biology. As a definite basis of comparison seemed necessary, it was decided to compare the nemas with the echinoderms and with the protozoa—a selection determined in part by the following consideration. A cursory examination showed that very much more space is given the echinoderms than the nemas. Since both groups are regarded as phyla and since the two groups present something near the same degree of complexity of organization and since both have long been known to science, it was thought they would furnish material for an illuminating comparison. Reasons for comparison with the protozoa will be presented later.

The percentages of text-book space given the phyla were compared, as well as the number and quality of the illustrations. The percentage of space occupied in each case was taken as a basis of comparison in order that the size of the page and of the type might safely be disregarded.

The 32 text-books of zoology devoted, on the aver-

[13] *Nature*, 121, 938 (1928); M. N. Rogers, *New Zealand Journ. Sci. and Technol.*, 11, 389 (1930).

[14] It is also to be remembered that only about 20 per cent. of the oil contained in a structure is actually recovered.

[1] Extract from the 1929 presidential address before the American Society of Parasitologists, American Association for the Advancement of Science, Des Moines, Iowa.

age, over three times as much space to echinoderms as to nemas (3.12 per cent. to 1.02 per cent.). There was a still greater disparity in the matter of illustrations—fully three times as many devoted to the echinoderms—but in addition the figures illustrating the echinoderms often were works of art—large, attractive and showing much detail, while those devoted to the nemas were sometimes the very reverse.

A moment ago the text-book treatment of the nemas was characterized as not only inadequate but antiquated. It is sincerely to be wished that criticism might end there; unfortunately it can not. In the space devoted to nemas an almost unbelievable number of misstatements occur in this series of 30 odd zoological texts in use at the present time in colleges and universities. The errors, both of commission and omission, are almost incredible, sometimes an average of 5 to 10 serious errors per page. In one or two cases there are no misstatements of fact, but in these cases, unfortunately, the nemas are almost wholly ignored.

At what may perhaps be some risk, *e.g.,* the risk of being thought a scold, I venture to point out some of these errors—about ten errors of a serious character, a dozen or more of a somewhat less serious character and errors of a minor character.

"J'ACCUSE"

(1) I accuse the authors, almost without exception, of failing to state the long-established fact that nemas moult. That all nemas moult has never been proved absolutely, any more than it has for insects, but the nemas known to moult are sufficiently numerous and varied to justify the assumption that all nemas moult, and that this is a most significant and fundamental feature of their development, which, as its details become fully known, will, in due time, doubtless aid in determining the relationship of nemas to other phyla.

(2) I accuse them, almost without exception, of failing to note the very highly significant fact that nemas do not present ciliated tissue.

(3) I accuse them of failing even to mention the spinneret, one of the most peculiar of organs, as characteristic in its way as the spinnerets of spiders. In fact a parallel omission would be a chapter on spiders ignoring their spinnerets. When this exceedingly characteristic nemic organ is absent or obscure, it is usually for the same reason as in certain groups of arachnids—degeneration due to parasitism.

(4) I accuse them of failure to note the absence of typical striated muscular tissue.

(5) I accuse them, with very few exceptions indeed, of either stating or creating the impression that Ascaris is a typical nema. This is very far indeed from the truth; it is hardly more true than that certain wingless and legless parasitic bugs are typical of all insects, or that the turtles are typical of all reptiles, or the monotremes of mammals. We know at the present time as many free-living nemic genera as parasitic, the number of known free-living species being the greater and very much the more varied. As might be expected under such circumstances, the parasitic forms show a marked degeneration of many features characteristic of the free-living forms in their own phylum—the very forms from which, according to accepted doctrine, they must have evolved. Now Ascaris partakes in this degeneration. There are very many important characters belonging to, and widely distributed in, the free-living forms of this phylum which are so nearly absent in Ascaris that they are no longer noticeable. The domination of Ascaris in this section of zoological text-books is so complete as to be something of a catastrophe in the teaching of this phylum.

(6) I accuse them—in fact they accuse themselves, for "qui s'excuse s'accuse"—I accuse them of so little knowledge of the nemic phylum, with comparatively few exceptions, as to include, nearly always apologetically, in the space devoted to nemas, organisms that do not belong there, and on the other hand excluding organisms that do belong there. There is no sound morphological reason for classing the Gordiaceae, the Acanthocephala or the Chaetognaths in the nemic phylum; yet this is still a common procedure. It is equally erroneous to exclude from the nemas the groups Chaetosomatidae and Desmoscolecidae. It would be just as reasonable to exclude the turtles from the Reptilia as to place Desmoscolex outside the nemas. Desmoscolex (and Chaetosoma) are typical nemas in a comparatively strict sense of the word; their internal organization is strictly nemic, but is masked by a modification of the exterior that has, unfortunately, led to error on the part of even noted zoologists. But these errors are of long ago and have since been again and again shown to be such.

(7) I accuse them of leaving unexplained the simple and fundamental fact that the cuticle of nemas, being non-compressible along the lateral lines, constitutes an exoskeleton, acting on which, two antagonistic systems of muscles, one ventrad and the other dorsad, effect all ordinary body movements in the dorso-ventral plane. Nemas do not, can not, move as do eels, by bending laterally.

(8) I accuse the great majority of them of omitting even to mention free-living nemas; so far as many of the text-books are concerned, the student might remain practically unaware that free-living nemas exist, and yet they constitute quite half of the known number of forms, and most undoubtedly, in many respects,

the more important half, for it is certainly correct that the true character of nemas will be fully disclosed only by a study of their more highly developed free-living forms.

(9) I accuse the majority of them not only of giving to students the impression that nemas are parasites mainly, if not entirely, but accuse them, even in presenting *this* point of view, of omitting to mention the very important fact that plants are parasitized by nemas. To show how important an omission this is, one has only to call attention to the well-known fact that the gall nema, a nemic parasite of the roots of over 700 species of plants, including most of our crop plants, is one of the worst pests known to agriculture, the annual losses from which to the world are measured in hundreds of millions of dollars. And yet this is only one of many species that infest plants. True, it is the worst of its class, but many of the others are very serious—so much so sometimes as to have ruffled international relationships and to have been the subject of laws regulating international and interstate commerce.

(10) I accuse them of misleading statements concerning the excretory system of nemas. It is regularly stated that the two lateral "lines" (meaning lateral chords) *contain* the excretory vessels, the inference being that the chords are excretory. Now it is true that in *Ascaris megalocephala* the excretory vessels lie in the lateral chords, but this is not true even of all the species that have been classed as Ascaris, for in some of them one of the lateral chords has nothing to do with the excretory vessels. In a large number of other parasitic forms the statement would not be true, while for almost all free-living forms the statement is utterly untrue. Probably the excretory vessels are not physiologically connected with the chords in any case whatever—even among parasites. The reason that the excretory system is sometimes imbedded in, or attached to, the lateral chords, particularly in some of the larger forms, is a mechanical one. This is the region in which these long tubular organs can be stowed with least inconvenience, and this is the main, and in fact probably the whole, reason for their occasional association with the lateral chords. These facts were published about forty years ago.

(11) There is no mention made of longitudinal chords or fields other than the two lateral ones, in the face of published observations to the contrary that are half a century old, observations that have been corroborated over and over again and have long been common knowledge among nematologists, and in one very large group have even long been used as characters for the separation of genera. These chords are a basic feature of the nemic anatomy—wellsprings of the cuticle.

These are serious errors. Could any one be seriously blamed for asking whether teaching them does not come too near being an imposition?

ADDITIONAL THOUGH SOMEWHAT LESS SERIOUS ERRORS

Point one. Refers to the text-book statement that hermaphroditism is rare in nemas. Hermaphroditism is not uncommon among free-living nemas—relatively as wide-spread as in insects—and it is becoming known among the parasitic species. Numerous and widely varying genera of free-living nemas present species, sometimes a considerable fraction of the species of the genus, in which the males are rare or non-existent. Under such circumstances, the females develop their own sperms and these sperms are efficient, at least to the extent of inciting development of the eggs.

Point two. Either the statement is made, or it is assumed, that nemas have no locomotor organs.[2] You have already been shown the nature of the locomotor organs of numerous nemas. There no longer exists the slightest doubt that well-developed locomotor organs are present on hundreds of species of nemas belonging to a variety of genera.

Point three. Influenced no doubt by a limited knowledge of the organization of Ascaris, the statement is made that the only sense organs of nemas are papillae on the lips. Here and there, it is admitted, eyespots exist in a few forms. Now the formerly so-called "lateral organs" have been taken for chemical sense organs for a quarter of a century. They are universal in free-living nemas, and it is now becoming very evident that they are universal in parasitic nemas. It is more than twenty-five years since these organs were designated sense organs, and this idea is now so thoroughly established as to need no further comment. Phototropes of very considerable complexity, probably in some cases entitled to be regarded as organs of vision, exist in not a few of the free-living nemas—a score or more of widely varying genera. As you have been shown, these may be so complicated as to possess image-producing lenses, pigmented receptors and special nerves connecting them with the central nervous system. In addition there are tactile organs in various parts of the body, supplied with special nerves and existing in both parasitic and free-living forms, and beyond doubt universal. There are special ganglia connected with the sexual functions and these ganglia are associated with special organs, long interpreted as sense organs. There is no lack of sense organs in the nemas. How could there be?

[2] This part of the address was preceded by a lantern-slide review of the morphology and physiology of nemas.

Point four. Mainly a point of omission. The student is given very little idea of the complexity of the nemic organization. By direct statement and by omission the text encourages him to consider the nemic organism as of a simple character. Now the structure of nemas is so complicated that it is in reality one of the marvels of living organization that so many different systems of organs can be packed into a slender microscopic speck only a fraction of a millimeter long, as some are. It will be readily admitted that the late Jacques Loeb was a penetrating observer. He repeatedly said to me, "It is amazing—the complexity of the nematodes. . . . The variety of specific organization in so small a space is marvelous."

Point five. The statement is made that the life history of nemas is usually very complicated. It has become the fashion to describe briefly a few nemas that cause disease in human beings. Trichinella is often selected as an example, and, as its life history appears somewhat complicated, the assumption is made that this is typical of nemas. As a matter of fact, the life history of the vast majority of nemas is about as simple as it could be for organisms of their degree of complexity, no more complex than the life history of rotifers, or that of many animals of other groups of similar complexity. This error undoubtedly is a part of the misinformation connected with the assumption that Trichinella and other parasitic nemas are typical of the nemic phylum.

The dissections of Ascaris made in most zoological laboratories are very limited in their extent, and apparently are usually carried out by those knowing so little of the structure of nemas as to perpetuate the errors that the structure of nemas is simple and the life history complex.

Point six. An important error of omission is failure to recognize the historical significance of nemas and to use the facts of history to implant in the minds of students the historic and scientific importance of the phylum they are studying at the moment. History tells us that in the early eighteen seventies it was in a nema that the male and female animal gametes were first seen to approach each other and "coalesce" (observations of Bütschli) to form the single "pronucleus" from which alone a new individual can arise, speaking broadly. It was in the eggs of nemas that it was first shown that the "chromatin" of the two gametes after thus coming together divided in such a way that chromatin from both gametes (both parents) is distributed to each cell during segmentation, thus pointing out *for the first time* the physical basis of heredity in animals as conceived to-day (discovery of Van Beneden). Following these statements by calling attention to the classical researches of Boveri connected with the eggs of Ascaris and other nemas (the early segregation of the gonadic elements—thus disclosing the continuity of the germ-plasm, etc., etc.) is sufficient to show the extraordinarily important rôle nemas have played in the development of the science of heredity. Most important and fundamental biological discoveries were made through the instrumentality of nemas.

Point seven. It is said that the specific and generic differences among nemas are slight, in other words that those who have spent years studying the nemas are prone to make much of slight differences. As a matter of fact there is no essential difference—no difference worth discussion in this connection—between the principles guiding nematologists in ranging the nemas into species, genera, families, etc., and the principles that guide naturalists in other phyla. Nemic species are as different from each other as lions and tigers, their genera as different as cats and dogs, and so on up the taxonomic scale.

Point eight. Why continue the use of that antiquated word "worm," with all its looseness of meaning, and by its very use leading the student, perhaps unconsciously, into the assumption that things called worms have a scientific resemblance to each other—that tapeworms and roundworms and flatworms, all of them worms, have some sort of organic resemblance, justifying some sort of assemblage?

Why call any of them worms at all? We are well rid of the old subkingdom Vermes; why retain worms?

Why call nemas roundworms? They are no rounder than what are very often alluded to as worms belonging to other phyla.

Leading students even remotely to associate nemas with trematoids and cestoids may lead them to think that the structure, life history, etc., of nemas are similar to those of these other groups, when as a matter of fact there is very little real resemblance; the differences are very, very great. No doubt the statement made in more than one of the texts that the life history of nemas is usually complicated comes from this very association of nemas with other more purely parasitic groups, under the misleading denomination worms, whose life history *is* entitled to be called complicated, in that it involves regularly in all species the passage of a parasitic form through two or more conditions, forms or hosts.

Point nine. Contrary to well-established chemical knowledge it is common to state that the cuticle, egg shell, etc., of nemas is chitinous—composed of chitin. While there is a superficial resemblance between the cuticle of nemas and that of other phyla, chemists have long since established the fact that the substance mainly composing the cuticle of nemas is not chitin, and that its properties are very different from those of chitin. Among other things it quickly disintegrates in water when once it is out from under the influence of the living nema itself. Hence the unfortunate fact that we have no fossil nemas to speak of, while fossil insects are known, sometimes in considerable detail, and from ancient strata, owing to the relative insolubility of their exoskeleton.

Point ten. Why give book room to such statements as that nemas live mainly on the juices of living hosts, when as a matter of fact nemas have learned to ingest and digest food of almost inconceivable variety? Within reasonable limits it is hardly possible to make the statement unduly strong.

Point eleven. Why harbor the thought, let alone permit its proclamation in our classrooms, that parasitic nemas show little degeneration in comparison with free-living nemas, when as a matter of fact their degeneration in this respect is practically on a par with the degeneration of parasitic forms in other phyla?

Point twelve. Authors state that nemas are entirely devoid of segmentation, in face of the fact that for a decade or more it has been established beyond peradventure that very many of them, probably the majority of the free-living forms, bear appendages that must be denominated segmented. This matter is incapable of full discussion here, but it is, to say the least, incautious to deny nemas all trace of segmentation.

Point thirteen. In these texts all the free-living forms are still placed in one or only a few families, *e.g.,* Anguillulidae, when as a matter of fact it has long been common knowledge among nematologists that they belong to a wider range of families than do the parasitic nemas.

Most of these additional thirteen errors are also serious ones.

MINOR ERRORS

One text at least continues the mistake of regarding the esophageal swellings as stomachs, or organs for trituration, and even on occasion of calling them "gizzards."

At least one text places the central nervous system at the anterior end, instead of around the esophagus.

The longitudinal chords are called "thickenings of the epidermis" at the same time that they are said to *include* the excretory system, whose embryonic origin is entirely different from that of the epidermis.

Not infrequently the texts treat the nemas as constituting a group of lower order, instead of, as they do, constituting one of the most outstanding phyla of which we have knowledge.

I have come across other misstatements which, though they are not common, are worthy of mention. Nemas are said to be cylindroid and to taper at the two extremities. Among the free-living forms, which, as before remarked, constitute at least half the present known forms, this description of Ascaris applies but poorly. While it is true that they often do taper more or less toward the extremities, not infrequently this is not at all a marked feature, especially in front, and one which in a general description would be ignored. Furthermore, there are large numbers of nemas to which the term cylindroid is totally inapplicable; some are spherical or nearly so, many are much wider toward the extremities than they are in the middle. No doubt those who derive their idea of the form and motion of nemas from Ascaris alone think that all nemas have a serpentine motion. Their movements are *always draconic,* never serpentine. A large number of nemas, hundreds of species, numerous genera, creep after the manner of the caterpillar popularly known as the inchworm or measuring worm, as shown in some of the slides exhibited.

I note a good many misapplications of generic and specific names, but we know so little about the details of this phylum as yet that it is premature to attempt any final or even fairly satisfactory philosophical classification. The classifications necessarily proposed must be looked upon as matters of more or less ephemeral convenience, and usually not as adequate expressions of zoological philosophy. Probably the total number of species now described does not much exceed 5,000, belonging to from 900 to 1,000 genera, distributed about equally among the free-living forms and the parasitic forms. When we consider that those who have given the closest attention to the matter believe the species of nemas existing must be numbered in at least hundreds of thousands, and when, in addition to this, we consider that the great majority —fully nine tenths at least—of the forms that have been seen, studied and named are inadequately known, it becomes evident how futile it is, at the present time, to make strenuous attempts to institute a philosophical classification. Inasmuch as nematologists themselves have come to no very satisfactory conclusion in regard to the more comprehensive taxonomic groups, it is quite forgivable to writers of zoological text-books that errors of this sort occur.

I am not unaware of the difficulties in teaching nematology as it should be taught, nor inexperienced in the matter, having as a teacher actually used nemas in courses in school and university. The difficulties are mainly connected with their small size and the fact that their organs, highly varied though they are in function and form, are reduced to extremely small size and packed into extremely small space. Their study and demonstration therefore require skilful use of the microscope. At one time this would have been a serious matter. Microscopes of the quality and number necessary for the purpose would have been expensive and difficult to procure. This difficulty has been largely decreased, and we now find microscopes used with more skill than formerly in zoological laboratories, especially in conjunction with protozoology and cytology.

It is for this latter reason that a comparison is now drawn between the treatment given in these same text-books of zoology to nemas and to protozoa. Not because the two groups are morphologically comparable; the comparison is much less apt than the comparison between nemas and echinoderms. It is made for the purpose of showing, among other things, that it is impossible for teachers of zoology longer to plead that it is the small size of nemas and the necessity of using microscopes skilfully that have brought about the condition criticized. If these difficulties can be overcome in connection with the protozoa, there would seem to be no reason why they can not be overcome in the case of nemas. The comparison will show—particularly through the nature of the forms selected by authors to illustrate respectively the nemas and the protozoa—that such an excuse will no longer hold.

As might be expected, the average space given the protozoa is more than five times as great as that given the nemas, and the illustrations outdo both in relative number and quality those devoted to nemas, that is to say there are more than five times as many illustrations given under the head of protozoa as under the head of nemas, and they are better.

A careful examination of the illustrations shows that the microscopy necessary for the production of these particular protozoan illustrations is practically of the same nature as that required for a study of the nemas. Hence if we assume that along with the zoological texts, corresponding laboratory work is done, and done satisfactorily, we must assume that in protozoological laboratories microscopes are used with that degree of skill and painstaking care necessary in connection with nemas.

The twenty-eight text-books on biology gave figures very closely comparable with those obtained from text-books on zoology.

The figures and facts presented indicate an opinion on the part of those who prepare text-books of zoology and of those who teach zoology that there are stronger reasons for acquainting students of zoology with echinoderms than with nemas. Let us compare these two phyla (1) with respect to their economic importance, (2) their historical importance, (3) their importance as furnishing suitable material for teaching purposes.

Economic importance. We have already seen, in connection with the lantern slides shown, something of the great importance of nemas as causing diseases of man and his domesticated animals and plants. It is quite impossible to go into detail here, but a few items will be mentioned that show the enormous importance of this phylum in this respect.

For example, I am authoritatively informed that of the approximately twenty-one and one half million dollars the Rockefeller Foundation has spent on public health activities, excluding buildings, equipment and endowment, over one fourth has been spent on what is known as hookworm control. Many government agencies in many lands have contributed cooperatively large additional amounts to the same end at the same time. I leave you to calculate the probable losses to mankind through this single nemic disease, to cause such a huge, world-wide expenditure in an attempt to ameliorate it. In doing so it is well to remember that this is only one of over a hundred distinct species of nemas known to infect the human body.

My colleague, Dr. M. C. Hall, estimates the live-stock losses in the United States through the attacks of nemas to be not less than one hundred million dollars per annum.

You have already heard of the huge crop losses to agriculture due to the attacks of the gall nema.

The oft-repeated statement is amply justified, that nemas are responsible for annual losses aggregating very many millions of dollars, and for death, suffering and inefficiency on a large scale among human beings and their domesticated animals and plants.

To offset all this I am glad to say I know of no echinoderm causing a serious disease of human beings, or of a domesticated animal or plant. The economic losses due to echinoderms are confined to the depredations of predatory forms, and even here the list is not very impressive. The marine shellfish industry, or at any rate the oyster industry, suffers locally, at times severely, from the attacks of starfish, but if the entire marine shellfish industry were thus wiped out, the loss would not be equivalent to any one of many single items connected with nemic diseases.

Let us now consider the balance on the other side. It is not so widely known as it should be that there are beneficial nemas, that is, nemas beneficial to mankind because they are active enemies of other organisms which on their part are injurious to mankind. We are only at the beginning of these important lines of research, and yet investigations have already shown that the prevalence of a number of very injurious insects is largely dependent upon whether or not they are parasitized by certain nemas. The nemas are such an important factor in the prevalence of some of these insects as to appear second only to the reproductive powers of the insects themselves, and in some cases it is becoming rather difficult to see how human beings could live in comfort in certain regions now thickly populated were it not for the beneficent effect of certain nemas.

Benefits from echinoderms are practically confined to one item, the value of trepang, or bêche-de-mer, a food—more or less of a luxury—used in the East. The total value of the trepang industry, which is said to employ hundreds of vessels, is a figure I have been unable to obtain with exactness, so I resort to liberal estimates. If we place the entire fleet engaged in the industry at a thousand vessels, which I believe too high, and the average annual value of the catch of each schooner at $10,000 per annum, which is probably in excess of reality, the total annual valuation of the catch would be $10,000,000. The trepang actually fished from the Great Barrier reef, by far the largest fishing ground, is given by the Queensland government as about 33,000 pounds sterling per annum, say $155,000, and from this I am inclined to think the estimates given above too large. The trepang fished on the Pacific Coast of the United States, 1927, is given by the Bureau of Fisheries as 5,355 pounds, valued at $268.

Historical and scientific importance. In comparing the relative historical and scientific importance of nemas and echinoderms, I can hardly do better than refer to that classical work, Wilson's "The Cell in Development and Heredity," a work of broad scope dealing comprehensively with what constituted the main biological work of the late nineteenth and the early twentieth centuries, a work by general consent placed in the very first rank.

If the reader of this work will consult its index to authors, he will find that few if any authors are more frequently and extensively quoted than Van Beneden and Boveri. Remove from the text the passages and illustrations derived from these particular researches of these two authors, and the very heart would be taken out of the work. If now one inquires what were the organisms used by these men in their epoch-making discoveries he will find that they were very largely, in fact in many cases almost exclusively, nemas. It would be difficult to conceive more convincing evidence of the great historical importance of nemas as contributory material for some of the most fundamental biological researches of the last 50 years.

Very many important researches, and many of a basic character, have been carried out with the aid of echinoderms, but the conclusion seems unavoidable that up to the present, in fundamental biological research, they have not been as important as the nemas.

Relative importance of nemas and echinoderms as a source of laboratory material for teaching zoology. Many echinoderms are of large size and are readily collected, preserved and shipped. In their living condition they are interesting and often attractive objects. Where running sea water is available, the study of their gametes, fertilization and early development is fascinating and highly instructive work. A practical disadvantage is that they are marine only.

One can therefore understand why echinoderms have received some of the attention remarked upon in this review of zoological texts.

The nemic laboratory material currently used in our zoological courses suffers severely by comparison. In fact, it is rather difficult to imagine a more uninteresting, not to say disgusting, object to be placed in front of, say, a dainty and refined girl student than *Ascaris,* so stimulative of disagreeable feelings and thoughts, and devoid of a single curious or interesting external feature to attract attention.

Fortunately, however, it is not necessary to introduce nematology to students by way of *Ascaris,* although at present any other course is little heard of in our schools and universities. There is a large assortment of extremely interesting microscopic nemas that can be placed before the student in a living state—nemas both free-living and parasitic—and when this is done with the aid of good microscopy there is in my personal oft-repeated experience never any lack of interest, or even enthusiasm, on the part of students, whether they be new to biology or already considerably advanced.

This successful and attractive way of introducing live nemas to students can be carried out almost anywhere, but necessitates good microscopy and involves certain comparatively simple technique long used in certain laboratories. Through this change in material and methods, the nemas may easily be made so attractive as pedagogically to compare favorably with other organisms.

Whatever the method of comparison adopted, we are unable to come to a conclusion justifying the present relatively small amount of space and time assigned to nemas in zoological texts and courses. The emphasis seems so obviously misplaced as to lead to the following constructive suggestions.

(1) Rectify those egregious errors with regard to nemas. Most of them are no longer excusable.

(2) Cut down the space and time devoted to, say, echinoderms, by 50 per cent. or more and add them to the nemas.

(3) Teach nematology through the instrumentality of living, microscopic, transparent forms, especially the free-living ones, and relegate *Ascaris* to the background so far as morphology is concerned.

These suggestions are brief but comprehensive. Probably the greatest obstacle to their immediate adoption is the fact that so few trained zoologists know anything worth speaking of concerning nemas. It is suggested that trained zoologists can instruct themselves by a perusal of original nemic literature (not text-books—not encyclopedias) available in most large libraries, and by a few weeks study of living nemas with the aid of high-power immersion lenses. The nemas should be under sufficient pressure to prevent active motion, but not sufficient to altogether prevent them from moving.

THE CHALLENGE OF PLANT VIRUS DIFFERENTIATION AND CLASSIFICATION[1]

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For some time there has been no phase of phytopathology in greater need of cooperative thinking and action than that of plant virus differentiation and classification. Much uncertainty and confusion have existed in this field of investigation ever since the first recognition of a virus disease by Adolph Mayer in 1886. Soon after Mayer's work became known, it was claimed by some that his "Mosaikkrankheit" of tobacco included two distinct diseases, one the true infectious mosaic and the other a supposedly unrelated necrotic disease known elsewhere as "Pockenkrankheit." Although much attention was given to the subject, this disagreement has persisted almost to the present time, though it is now quite generally conceded that Mayer was correct in his interpretation that necrosis is one of the symptoms of the ordinary tobacco mosaic virus on tobacco as well as on certain other hosts.

In the meantime, the continued description of virus diseases on different hosts, on the basis of symptoms only, has led to serious confusion even in fundamental research concerning the nature of a virus. It was natural that a school of thought should develop which was inclined to the belief that only one, or at the most only a few, viruses existed in nature, or that a virus was a labile entity capable of adapting itself to various hosts and circumstances. This point of view has only recently been dispelled by those who maintain that many distinct and specific viruses exist in nature and that we have in the viruses a problem of differentiation and classification comparable in complexity if not in extent to that in mycology and bacteriology.

Unfortunately, however, the pendulum is apparently swinging too rapidly in this direction. The tendency to apply new names to a virus disease when only symptom expression is involved, either on an old or on a new host, is leading to new difficulties, the more serious because we are dealing with an unseen entity, the true nature of which may long remain a mystery.

The challenge is clearly before the workers on plant viruses, first, to check themselves and others as far as possible from adding to our present difficulties, and then to clear up as rapidly as may be done the confusion already existing in the literature.

While the reliable methods now available for the differentiation of plant viruses are not applicable in all cases nor entirely satisfactory in others, such methods are yet remarkably useful considering the early stage of development of this subject. New and better methods for the differentiation, determination and description of specific viruses are gradually becoming available, and important advances in this line of technique may be looked for in the future. Many of these methods are already familiar to most of the workers. In connection with a discussion of this kind, it may be well briefly to list the more obvious of these methods and to discuss their possibilities and their limitations.

Four chief types of differential or diagnostic features of plant viruses are recognized at the present time. These are: symptom expression, properties of the virus, modes of transmission and the cytological picture.

Symptom Expression

Comparative symptoms on a single host species or variety have constituted the main diagnostic character relied on up to the present time in the recognition of specific viruses. The best example of the use of this type of differentiation lies of course in the potato virus group. The limitations of this method, useful as it has been in the past, are obvious to any one who has worked with this group of diseases. The symptoms produced may vary greatly with the variety of potato and its stage of development, and with the source and method of infection as well as with the environment. Consequently, descriptions of symptoms of the different viruses often overlap so extensively as to be quite unreliable even to authori-

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