matic, comprehending, as tributary departments of itself, the old disciplines of logic, metaphysic, physic and ethic.

And here, after our first problem, two other problems burst upon our view. My belief that these two problems form a program of work well worthy of the attention of a body as learned and earnest as this audience, is, in fact, what has determined me to choose this subject, and to drag you through so many familiar facts during the hour that has sped.

The first of the two problems is *that of our powers,* the second *that of our means. of unlocking them or getting at them.* We ought somehow to get a topographic survey made of the limits of human power in every conceivable direction, something like an ophthalmologist's chart of the limits of the human field of vision; and we ought then to construct a methodical inventory of the paths of access, or keys, differing with the diverse types of individual, to the different kinds of power. This would be an absolutely concrete study, to be carried on by using historical and biographical material mainly. The limits of power must be limits that have been realized in actual persons, and the various ways of unlocking the reserves of power must have been exemplified in individual lives. Laboratory experimentation can play but a small part. Your psychologist's *Versuchsthier,* outside of hypnosis, can never be called on to tax his energies in ways as extreme as those which the emergencies of life will force on him.

So here is a program of concrete individual psychology, at which anyone in some measure may work. It is replete with interesting facts, and points to practical issues superior in importance to anything we know. I urge it therefore upon your consideration. In some shape we have all worked at it in a more or less blind and fragmentary way; yet before Papini mentioned it I had never thought of it, or heard it broached by anyone, in the generalized form of a program such as I now suggest, a program that might with proper care be made to cover the whole field of psychology, and might show us parts of it in a very fresh light.

It is just the generalizing of the problem that seems to me to make so strong an appeal. I hope that in some of you the conception may unlock unused reservoirs of investigating power.

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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE EXPANSION OF PHYSIOLOGY[1]

Looking forward into the far future, we may perhaps dimly discern the day when morphology and physiology will again join hands * * * but that day is as yet most distant.

When Dr. Michael Foster, the eminent physiologist, was writing the lines quoted above, the two grand divisions of biology to which he refers seemed separated as if by a great gulf. In England and America morphology was the reigning favorite and in the higher institutions of learning physiology as such hardly existed. Both zoology and botany had come almost everywhere to mean morphology, and morphological problems were the popular themes of the day. Even in medical schools, physiology was as yet generally denied an independent existence, being commonly appended to or combined with the chair of anatomy, *i. e.,* one of morphology.

Dr. Foster was writing in the early eighties, and those who like myself can recall the conditions of biological teaching and research at that time will testify that his words were justified. It is true that a

[1] Address of the vice-president and chairman of Section K—Physiology and Experimental Medicine, New York meeting, 1906.

full professorship of physiology had been established in the Harvard Medical School in 1876, and that a brilliant young physiologist, one of Foster's own pupils, in the same year assumed the professorship of biology at Johns Hopkins. And yet I distinctly remember how strange and how full of chemistry and physics the first edition of Foster's physiology seemed as it was shown to me in 1876 by my professor of comparative anatomy, and also how two years later I studied physiology in the medical school of one of our leading universities for a whole season, under a young physician of more than ordinary ability and promise, without once seeing a demonstration—still less doing an experiment. The class simply recited,—upon so many pages of Dalton's 'Human Physiology.'

All this was the more remarkable because, according to Dr. (now President) G. Stanley Hall, physiology was at that very time "'The' German Science"—a fact stated and emphasized by Dr. Hall by the title of one of a series of contemporary essays which, re-read to-day, almost cause one to regret that the author abandoned the career of literature for that of administration. (Cf. 'Aspects of German Culture,' by G. Stanley Hall, 1881.)

Physiology, says Dr. Hall, has been characterized as just now preeminently *the* German science. This is probably true, whether it means that German physiologic methods and results are less known in other countries than those of other sciences, or that they reflect more peculiarly the national characteristics. Till Foster's text-book appeared, very little was known in England and America of German physiology, save by specialists who themselves had studied in Germany. * * * Fick terms physiology 'the highest and most fruitful generalization of the collective natural sciences.' Czermak, who devoted his wealth to building and equipping a magnificent laboratory and lecture room and his time to the end of his life to the popularization of physiology, was never weary of insisting that it should be taught in every high school. Once more, evolution in the sense of Darwin or Haeckel is far from being a finality for the physiologist. It is for him rather a morphological assumption that all animals and men belong to one family; and he defines his science with Pflüger as the chemistry and physics of living matter.

Physiology in Great Britain and America had, in fact, so far lagged behind that the publication of Foster's text-book with its revelation of some of the German physiology of the day created a real sensation. In the English-speaking countries morphology was everywhere the fashion and biologists, whether botanists or zoologists, were then, almost without an exception, morphologists. Even ten years after Foster's book appeared, Huxley, who had himself previously defined the grand divisions of biology as morphology and physiology rather than zoology and botany, speaks of zoology, in his Queen's jubilee essay on 'The Progress of Science' (1887), as if this were really morphology when he writes: "It is only in the present epoch that zoology and physiology have yielded any great aid to pathology and hygiene."

When Foster's text-book appeared descriptive zoology and embryology were already rivals in popularity, and the appearance in 1880 of Balfour's 'Comparative Embryology' made this subject for zoologists almost a passion. And yet to-day Balfour's then fascinating work seems strangely descriptive and somewhat overanxious after merely structural homologies. In his 'Introduction' Balfour, while defining embryology as covering "the anatomy and physiology of the organism during the whole period included between its first coming into being and its attainment of the adult state," is careful to add: "The present treatise deals only with the embryology of animals, and the science is moreover treated from the morphological or anatomical rather than the physiological side." So much was embryology the fashion of the day that Foster

himself issued with Balfour a well-known volume on the 'Embryology of the Chick,' and this too as a morphological, not a physiological, treatise. In view of these evidences of Balfour's preoccupation with morphological problems, it is interesting to learn from Dr. A. C. Haddon, one of his students, that Balfour always looked upon this preoccupation as temporary and that he intended to devote himself eventually to comparative physiology. Huxley, again, omitted all reference to physiology in embryology when in 1878 he defined the latter as 'an account of the anatomy of a living being at the successive periods of its existence, and of the manner in which one anatomical stage passes into the next.' And yet he incidentally recognized the equality of physiology and morphology by remarking that "geology is, as it were, the biology of our planet as a whole. In so far as it comprises the surface configuration and the inner structure of the earth it answers to morphology; in so far as it studies changes of condition and their causes it corresponds with physiology."

This supremacy of morphology continued well on into the nineties, but about ten or twelve years ago signs of a change began to appear, and no one who has observed even superficially the progress of biology during the last decade can have failed to perceive an immense and increasing interest in general and comparative physiology, accompanied by a decline of interest, relatively speaking, in pure morphology. Investigations in chemical physiology, mental physiology, embryological physiology, cytological physiology, comparative physiology, and in the general physiology of the response and the behavior of animals, have rapidly come to the front, while the field of vegetable physiology is being cultivated as never before. In its various aspects general physiology is to-day probably receiving from investigators more attention than special or mammalian (including human) physiology, and displacing in the hands of zoologists, to a remarkable extent, more strictly morphological studies of a systematic, phylogenetic or ontogenetic character.

Twenty years ago to be a zoologist meant to be a morphologist, but to-day many professors of zoology are either becoming or have already become veritable physiologists. Most of the 'experimental zoology' and 'embryology' of the present is really general physiology. So also are large parts of physiological chemistry, physiological psychology, cytology, protozoology, microbiology and bacteriology. Hygiene, climatology, experimental medicine, pharmacology, and many other modern branches of biology are also chiefly physiological rather than morphological. Foster's guarded prophecy of 1885 had an almost hopeless tone, for he put 'most distant,' and in 'the far future,' the day when 'perhaps' morphology and physiology will come together once more; and here again, for the thousandth time, prediction touching the future of science has proved to be empty and vain—for scarcely had a score of years gone by before Foster's 'most distant' day was already brightly dawning, and physiology and morphology were again 'joining hands' in experimental zoology. So far, indeed has this movement extended that even the general biologist may now claim the workers in the newer fields as immigrants into his own, pointing with pride to the breadth and depth of their work as justifying that still older idea of physiology in which it was essentially what we now call 'biology'; or even that oldest idea of all, in which physiology was the equivalent of the *ultima thule* of all these sciences, 'natural philosophy'—a term hallowed on its mathematical side by the name of Isaac Newton, and in its entirety reaching back to the pupils of Aristotle.

That the recent expansion of physiology is not really a new departure but rather a return to an older as well as a more normal condition, is another interesting fact. In 1854 there was published in London, and republished in America, the fourth edition of a thick volume of 700 pages by Dr. W. B. Carpenter, on 'Comparative Physiology,' an examination of which shows that the zoologists of that day were fully alive to many of the very problems upon which so many of our modern zoologists are engaged at the present time. The first thing that strikes us in this work is the fact that plants and animals, some high and some low in the scale of life, are equally considered, and always side by side. It is, therefore, really a treatise on general biology. The next is that physiology ordinarily so called, that is to say human physiology, is nowhere much in evidence. We also find that functions, rather than organs, are dwelt upon, and the general functions of organisms—such as alimentation, nutrition, reproduction and the liberation of heat, light and electricity—as well as the special functions of organs—absorption, circulation, respiration, and the like; the general functions always in plants as well as animals. It was therefore truly a *comparative* physiology.

Dr. Carpenter's work was published the year before I was born, but when, as a special student of biology twenty years later, I began the study of physiology, the book was never mentioned and the subject never touched upon,—both being apparently little esteemed if not actually forgotten. It was very likely this work that Foster had in mind when he wrote in the context to the passage quoted at the outset of this article: "In its more general meaning physiology was largely used of old, and is still occasionally used in popular writings, to denote an inquiry into the nature of living beings. * * * In its older sense * * * (it) corresponded to what is now called biology." Recalling the fundamental, original and epoch-making 'Handbuch' of Johannes Müller published in Germany between 1834 and 1840 (and in English from 1837) and Carpenter's textbook just referred to, on 'Comparative Physiology,' published in England and America in 1854, we are compelled to regard the present remarkable development of physiology as not merely an expansion, but also a renascence or revival—a return, as it were, to an earlier normal.

The question naturally arises, How did it happen that general and comparative physiology, after beginnings so brilliant, was virtually eclipsed from the time of Carpenter to that of Verworn—(for Claude Bernard's 'Leçons sur les phénomènes de la vie communs aux animaux et aux végétaux' published in 1878, had at the time very little general effect, and were hardly more than a succès d'estime). Why was it, we may well inquire, that the pendulum of biological research and teaching swung so far over to the morphological side, while mammalian and medical (or human) physiology rapidly advanced—at least in Germany—separated itself from anatomy, a branch of morphology, and secured for itself important and independent recognition with sustaining professorships?

To this question the answer is, I think, extremely simple—the dates mentioned, and the fact that the phenomenon was most marked in English-speaking countries, giving us the proper clue. In all probability the rapid rise of interest in general morphology and the corresponding neglect of general physiology after 1860 were alike due to the almost complete and universal absorption of biologists, and especially English-speaking biologists, in the problem of the origin of species. For getting light upon this all-important problem,

studies in morphological embryology, in comparative anatomy and in systematic zoology and botany were simply indispensable as sources of evidence bearing upon the doctrine of descent, and hence studies ontogenetic and phylogenetic, rather than physiologic, were for the time being enthusiastically and almost exclusively pursued. That medical physiology did not suffer a similar total eclipse by morphology, but rather continued to advance (at least in Germany) until in 1881 Stanley Hall could describe it as "'The' German Science," was obviously because of its technical importance to medicine. That it flourished in Germany and not in England was doubtless due partly to the persisting influence of Johannes Müller's great work and partly to the fact that the struggles over Darwinism were severest and most distracting on English soil.

Whatever the reason, it had somehow come to pass that in the eighties there was nowhere any physiology to speak of outside the medical schools (while that inside these schools was often of the poorest) and that my own generation grew up almost totally ignorant of general and comparative physiology. If the reason, as seems likely, was the rise and all-embracing influence of Darwinism we may perhaps be pardoned if Verworn's innocent remark, that the doctrine of descent has not thus far 'been fruitful in physiology' seems to some of us so far within the truth as not to touch it. But at last, when, after nearly forty years, descriptive embryology and the phylogeny of animals and plants had been well worked out, and when even the noise of the great struggle over the origin of species had mostly died away, opportunity came for that remarkable expansion of physiology which we are now witnessing and which, if I am right, is not merely an expansion, but a renascence. It is a renascence, however, not like the great period of that name in history, preceded by a dark or middle age in general knowledge, for between 1854 and 1894 a splendid development of all other sciences had taken place, theological bonds had been broken, and the freedom of speech and of research enlarged and strengthened. Chemistry and physics had wonderfully expanded and developed and were ready to shed new light upon physiological processes, so that we might say once more, and may to-day repeat with renewed confidence, what George Henry Lewes said before the eclipse —"The hope of science at the present day is to express all phenomena in terms of dynamics."

As for the importance of the revival and of the recent expansion of physiology for biology, making of the latter once more that rounded whole—*totus teres atque rotundus*—which it ought to be, it is difficult to exaggerate. If, as we believe, biology is only the chemistry and physics of living matter, and if our hope 'is to express all phenomena in terms of dynamics,' we cannot but rejoice that having accumulated within the last fifty years a vast and precious store of morphological material we may now pass on to the investigations of questions of the relation, causation and coordination of activities; of processes rather than homologies, of behavior rather than form, of mechanism rather than framework. I am informed by an excellent authority that a similar tendency is apparent in medicine itself, and that to-day the processes rather than the results of disease occupy the center of interest in pathology.

Clerk Maxwell long ago remarked concerning biology, that "sciences of this kind are rich in facts, and will be well occupied for ages to come in the coordination of these facts." Surely it is a matter for rejoicing that physiology is to-day dealing with a wider range of facts than ever be-

fore. It is no longer confined within medical schools, in which mammalian, or at least vertebrate, facts must always be of paramount importance, for, as has been shown above, zoologists and botanists in our universities and colleges are turning their attention to the behavior and activities of the lower forms of life, both plant and animal. It is, however, unfortunate that the beginner still generally finds no physiology, under that name, offered in our higher institutions of learning outside the medical schools, in which physiology is necessarily, and rightly enough, influenced to a great degree by the needs of technical students, since—as Huxley said long ago—"a medical school is a technical school: a school in which a practical profession is taught." For while physiologists have abundantly demonstrated that pure science may thrive in a technical atmosphere, still, it must always be true that in a technical school the applications of science will be most in demand, and hence most influential. Instead of reproving medical physiologists for their failure to cover the whole field we ought, however, to be grateful to them for having stuck to their guns so devotedly after all other physiologists, both general and comparative, had deserted the field and followed after morphological gods, such as embryology, homology and phylogeny. At last, however, the zoologists and botanists are returning to their own and taking up their old work. It is greatly to be hoped that some of these may eventually come to acknowledge themselves physiologists, and that, very soon, students of biology in our higher institutions of learning, whether zoologists or botanists, may have offered to them equal opportunities in general or comparative morphology and general or comparative physiology. (An excellent *résumé* of present tendencies may be found in the various addresses in Vol. V., Congress of Arts and Science, Universal Exposition. St. Louis, 1906.)

Meantime, what is most important is to realize that physiology is still and always will be one of the two grand divisions of biology; that it offers, to-day, especially in its general and its comparative divisions, a field white for the harvest and—what makes it still more inviting—one mostly unworked since the publication of the origin of species. When we realize these facts and also what a wealth of new knowledge the progress of other sciences such as chemistry and physics has placed at our disposal since 1860, it is clear that to general physiology we may probably look in the immediate future for the greatest advances in biology. We have already got from medical physiologists the broad outlines of the physiology of animal organs and from plant physiologists of the organs of plants; we are getting from the experimental zoologists—and particularly the embryologists and cytologists—the physiology of animal cells—including various protoplasms. Our next great advance must come in the physiology of organisms as wholes, and that not merely of the lower organisms, but of the higher also. In this direction studies on nutrition are already beginning to tell, and epidemiology has much to teach. When climatology—a science of rare possibilities—and the numerous divisions of public hygiene shall have 'coordinated their facts,' we shall have at least the groundwork of a complete physiology of the higher organisms.

The discussion which is to follow—a discussion possible indeed only after morphology had cleared the way—should afford in a consideration of the actions and reactions between parasitic protozoa and mankind, an excellent example of the broader general physiology of to-day and to-morrow.

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