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BIOLOGICAL RESEARCH; THE VALUE AND THE DANGER[1]

I SEIZE with avidity the opportunity furnished me as your retiring president to discuss a subject which I am anxious should have your earnest consideration. I am aware that the title which I have announced is ambiguous, but I think that before I am through there will be no lack of understanding as to what I have in mind. *Biological research* includes many things. I mean to limit myself to those phases of it which require the experimental use of living animals. And I grasp this opportunity because I feel that our colleagues in other fields of scientific effort do not always fully perceive the value of the knowledge attained by this means; and that they do not at all appreciate the danger that freedom of research in these lines may be seriously hampered by hostile legislation or misdirected public opinion.

You who are engaged in very various lines of research will appreciate the fact that the immediate application of a discovery is no fair measure of its value; the ultimate results of the knowledge obtained may become extremely far-reaching. It is in the creation of a background of knowledge and experience that the greatest good is to be obtained. Often we point to certain noteworthy achievements and at the same time fail to perceive that they have become possible only through the accumulation of a multitude of small details, the results attained by the humdrum plodding of patient mediocrity.

The creative imagination of genius is

[1] President's address before the California Chapter of the Sigma Xi, April 28, 1915.

creative, after all, only in the ability to make novel combinations of known elements. The successive steps in the progress of knowledge are absolutely essential. The difference between the genius and the common man is not that the former proceeds by longer steps, but that he takes them more rapidly—often so rapidly that he is hardly himself aware of the intermediate positions.

As an example of the results of the experimental method I want to speak first of the progress of knowledge of the circulatory system—the heart and blood vessels and their mode of functioning.

The beginning of definite scientific knowledge on this subject may be said to date from the publication by William Harvey in 1628, of "De Motu Cordis et Sanguinis," "The Movement of the Heart and Blood."

There was not lacking before the time of Harvey quite complete and accurate knowledge of anatomy of the organs of the circulation; the structure of the heart, the arrangement and distribution of the blood vessels, and the valves of the veins were well known. Notwithstanding this there existed in the minds of anatomists and medical men the most bizarre and remarkable explanations of the uses of these structures. I can perhaps illustrate no better than by a few quotations from Harvey showing the kind of notions against which he had to contend in teaching the doctrine of the circulation of the blood. In the Introduction to "De Motu Cordis et Sanguinis":

> Did the arteries in their diastole take air into their cavities as commonly stated and in their systole emit fuliginous vapors by the same pores of the flesh and skin; and further did they in the time intermediate between the diastole and the systole, contain air, and at all times either air, or spirits or fuliginous vapors, what should then be said to Galen, who wrote a book on purpose to show that the arteries contained blood only? . . .
>
> And if the arteries in their systole expel *fuliginous vapors* from their cavities through the pores of the flesh and skin, why not the *spirits*, which are said to be contained in these vessels, at the same time, since spirits are much more subtle than fuliginous vapors, or smoke?

But Harvey, instead of merely *speculating* upon the functions as they might be inferred from appearances in the dead animal, put everything possible to the test of *observation and experiment in the living animal,* and as a result was able to state his reasons for the belief in the circulation of the blood in language which can hardly be improved upon to-day. The different attitude of mind resulting from his practise of observation and experiment is shown in his assertion

> That the facts cognizable by the senses wait upon no opinions, and that the works of nature bow to no antiquity; for indeed there is nothing more ancient or of higher authority than nature.

Contrast with this the views against which he had to strive as shown by another quotation from the same book:

> Medical schools admit three kinds of spirits; the natural spirits flowing through the veins, the vital spirits through the arteries, and the animal spirits through the nerves. . . .
>
> Farther, besides the three orders of influxive spirits adverted to, a like number of inplanted or stationary spirits seem to be acknowledged; but we have found none of these spirits by dissection, neither in the veins, nerves, arteries, nor other parts of living animals.

It was never permitted Harvey to know the exact method by which the blood passed from the terminations of the arteries to the beginnings of the veins; for no microscope suitable for the observation of the capillaries had then been invented. This final step was reached by Malpighi in 1661 just four years after Harvey's death.

After the *fact* of the circulation had been established, it began to be possible to investigate the mode of working of the circulatory apparatus. The first important step in this direction was taken by the Reverend

Stephen Hales, a Church of England clergyman, who tied into the femoral artery of the horse a glass tube nine feet high and noted the height to which the blood rose. He was able to report an average pressure of the blood in the artery sufficient to support a column of liquid eight feet three inches in height, while the blood rose at the same time to less than one foot in the corresponding vein. He observed also fluctuations in pressure due to the individual heart beats, to the movements of respiration and to other causes. The details of his experiments were communicated to the Royal Society of which he was a fellow and were published in 1733 in a work entitled "Statical Essays, Containing Haemostaticks."

The method employed by Hales was extremely inconvenient on account of height of the tube. Moreover, it introduced a greatly disturbing factor, namely, the loss of blood from the vessels of the animal into the tube. These inconveniences were overcome by the use of the mercury manometer by Poiseuille (in 1828). But the careful and detailed study of blood pressure dates from the invention by Ludwig (1847) of an exact method of recording blood pressures. From that time onward, not only in Ludwig's laboratory where many of the generation of physiologists just passing were trained in the methods of their science, but in all the physiological laboratories of the world has the study of blood pressure been continued.

It is impossible here to summarize all the facts of importance that have been the outgrowth of these investigations, and of others, connected with the functions of the circulatory system, and which could have been learned in no other way than by experiments on living animals.

The heart is a pump driving an incompressible liquid through a completely closed system of branching elastic tubes, the terminal connections of the outflow and inflow portions of the system being all of capillary size. The study of this system presents a series of difficult problems in *hydrodynamics,* in which all the relations of force, rate and output of the pump, the heart, and the pressure, and friction conditions in the arteries, veins and capillaries must be considered.

But this machinery is all composed of living tissues which are interacting and self regulatory to an extraordinary degree.

The discovery by Claude Bernard, and others, of the existence of vasomotor nerves through which the caliber of the arteries may be changed, regulated and controlled, thus adjusting the resistance to the ability of the heart, and also providing that the heavier flow of blood may be shunted from one set of organs to another according to the needs of the body, is of prime importance; so also was the discovery by Weber of the inhibitory action of the vagus nerve upon the heart, which, acting like a brake on that organ, keeps its action always under definite control; and the discovery by v. Cyon of the accelerator nerves whose function is in direct opposition to that of the vagus. Further, v. Cyon found that a special nerve, the depressor, carrying impulses from the heart and the great blood vessels to the brain, causes, when excited, a dilatation of the peripheral vessels and consequent reduction of the pressure against which the heart must work. None of these things could have been guessed from the study of the anatomical structures, nor could ever have been found out in any other possible way than by experiments on living animals.

But it may be asked, Has this knowledge any value? Has it any practical application? Is it useful only for the gratification of mere curiosity?

Putting aside for the present the implication in the expression "mere curiosity" which we hear so often in this connection I may answer that it is now possible to measure the blood pressure in man without resort to the method of Hales; no blood vessel has to be opened and no pain has to be inflicted. Blood pressure determination forms a part of every examination for life insurance, and of the routine of nearly every present-day medical examination. In certain conditions its measurement is of the most extreme importance. It gives exact, quantitative information on the state of the heart and blood vessels that could be obtained in no other way. And the usefulness of this information so far from being confined to diagnosis of disease of these organs themselves is quite as important in the light it throws on the functioning of other organs.

I have given this rather disproportionately long statement of the physiology of the circulation to make very specific what I mean in saying that the importance of most investigations is to be found not in the direct application of the specific discoveries but in the reflex effect of these on all related work. Antivivisectionists use the knowledge which has been obtained by experiments on living animals. No modern physician can for a single hour free himself from the deepest obligation to vivisection experiments, although he may never himself have made such experiments.

It is quite true that human blood pressure may now be determined without opening an artery and that the principles may now be explained without appeal to animal experiments; but I believe it to be equally true that this would not now be possible, and that neither the method of blood pressure determination nor its significance would now be known if the long series of vivisections had not first occurred.

In this connection it will be appropriate to say a word about surgical shock. Every one realizes that as surgery is practised today the chance of coming out of a major surgical operation is always good, yet it is no light matter; there is usually real danger; and the memory still remains with us of friends or acquaintances who in an otherwise not serious operation succumbed to shock. Shock is a peculiar complex not easy to define. There is not usually the suddenness which the word implies to the lay mind; but there is a great depression of the functional activities; and most marked of all its symptoms is an excessive fall of blood pressure. To discover the real nature of shock and thus to furnish the surgeon the means of its avoidance is no small boon to humanity. With this purpose in view many researches have been carried on. It has not been easy to find the true cause of the lowered blood pressure but much progress has been made. Perhaps no one man has made such untiring efforts to the solution of this problem as George W. Crile, and for this he has been denominated "brute," "savage," "arch fiend," "torturer" and almost every other term which fanaticism can devise. And yet it is to Crile and the system of *anoci-association* which he has worked out that every man or woman who has to undergo a major surgical operation owes a debt of gratitude which he can never repay; for not only does this method, where applicable, reduce the immediate danger from surgical shock, but it also greatly reduces or wholly sets aside the long period of nervous impairment which so commonly follows recovery from an operation in which these principles are disregarded.

I have selected the history of the study of blood pressure on account of its comparative freedom from those details which appeal to the emotional and dramatic side of human nature. I have used it to illus-

trate the growth of knowledge sought for its own sake into knowledge which is applied to the good of man. But I have merely touched upon the latter. Let me emphasize again that the great importance is not in the value of this or that specific detail, but in the great background which has been built up, which enables us to gain and to interpret new knowledge, and to see things in a proper perspective.

The physiology of digestion might have served equally well to illustrate the same truths. We owe to Pawlow and other workers in this line a mass of knowledge of prime importance to man, and this could not have been obtained in any other way than by vivisection. It is true that a few unfortunate human beings have had gastric fistulas formed through accident, and they have been used to study processes going on in the living stomach. But these studies have had no such orderliness as those in which upon animals definitely planned and controllable operations have been made. Indeed, the human observations have been mainly useful to check up the observations on animals and to see whether for some reason conclusions drawn from animals might not be wholly applicable to man.

To experiments on living animals we owe most of what is known of the functions of the various parts of the nervous system. The possibility of diagnosis of the seat of nerve tumors, of injuries, of pressure due to blood-clot and the like, in many instances depends upon knowledge of cerebral localization first discovered by experiment on the brain of the dog.

We are just now at the entrance into a new era in the history of physiological science. The study of the glands of internal secretion is widening and deepening our vision of the life processes, and I confidently believe that the next decade or two will be most fruitful in this comparatively new field of research. Already we have use of adrenalin, and various gland extracts. Nearly all our knowledge is based on vivisection.

It is not the purpose of this paper to go into the enumeration of specific instances of the *value* of biological research; many of them are already familiar; some of them are, rightly considered, among the greatest achievements of the human race. You know that the event celebrated by the great Exposition whose lights are at this moment blazing across the Bay could not have been accomplished if malaria had not first been conquered through biological research; you know that Havana by the same means has been changed from a seed bed of yellow fever to a healthy port and has ceased to be a menace to our own southern coast. You know that while occasional deaths from diphtheria still occur, the intelligent use of antitoxin has dispelled the dread and the terror which its presence in any community formerly produced; that a knowledge of the Pasteur treatment for rabies has reduced the death rate from that horrible disease from 15 per cent. to about 0.3 of 1 per cent. These and the like achievements are what the Hon. Stephen Coleridge, president of the English Anti-vivisection organization has eloquently denominated *"The desolating advance of science."*

You know all these things and much more, of the *value* of the achievements of biological research. But you probably do not know or, knowing, do not realize the vigor of opposition to all this effort for the advance of knowledge and the good of humanity. The *danger* of limiting, harmful restrictions is imminent and absolute prohibition is not improbable.

In England for years it has been necessary, if one wishes to perform a single vivisection experiment, to procure a license. It

is much easier to get a license to run a low grogshop. Any man may without a license and with practically no regard for the sensations of the animals rip out the testes from a boar or a dog, merely because it suits his convenience or his whim or his purse to have his animals gelded; but if a physiologist wishes to make the same operation for the purpose of scientific observation on the effects of castration he must secure a license stating with precision the building where this is to be done, and the purpose of the experiment, and he MUST, he has no option, perform the operation under complete anesthesia.

In this country at present the opponents of biological research point to England as the model country. But in England they continue the agitation for further regulation or complete prohibition, and they continue to persecute the licensees with persistent vilification and misrepresentation.

It would be out of place for me to take your time in a statement of the peculiarly extravagant and unscientific views of the opponents of biological and medical research if it were not that there is a real danger of the enactment of pernicious and obstructive legislation. A situation exists in which we who are doing what we believe to be an important work for humanity need your active cooperation, sympathy and support.

1. Practically all antivisectionists agree in the charge that experiments on living animals are necessarily cruel.

Now cruelty implies the infliction of needless or avoidable pain. No one justifies or can justify cruelty in experimentation any more than he can justify cruelty in any other action. But in the question of pain the unbiased individual will see that no one is so well qualified to judge as the experienced physiologist or surgeon. It would require the whole evening to discuss this one subject. Allow me to point out in brief the following:

The experimenter, even if he were really cruel, would usually defeat his own ends by the infliction of pain (*a*) because the pain impulses would cause disturbance of the normal functions which he seeks to discover and (*b*) because the struggles of a suffering animal would disturb the adjustment of apparatus and prevent the desired observation. It is the total ignorance of the real situation that causes so much emphasis to be laid upon this point by the opponents of research.

On the other hand, it is the fact that most vivisection experiments as actually performed, are done under deep anesthesia or narcosis—usually for obvious reasons much deeper than would dare be employed in human surgery. Now the opponents of research insist that anesthetics are not given, or that when given the attempt at anesthesia is a mere blind, and that the animals are allowed to undergo torture. Most of this discussion is by people who never gave an anesthetic, who would not know when an animal could be judged unconscious, and who would be unable to form an intelligent opinion as to whether movements of the animal were unconscious reflexes or purposeful struggles.

But why assume, as every one of the antivivisectionists does seem to assume, that all persons engaged in animal experimentation are necessarily cruel? As one reads their publications he finds that always the experimenter is supposed to delight in torture. In fact he is spoken of over and over again as "arch-fiend," "torturer," "devil in human form" and the like. Can they see no other purpose? No other motive? Has the eminent head of our department of pathology exposed himself week after week to the danger of infection with typhoid, tuberculosis and what not, merely because

he has a fiendish delight in seeing the quivering of flesh and hearing the plaintive squeal of guinea-pigs when he thrusts the hypodermic into them? Why would not a plain needle serve equally? The point of view is so absurd that it should require no discussion among intelligent people.

It is charged, however, that the practise of vivisection tends to induce a disregard for the sufferings of animals and brutalizes the mind and conduct of the experimenter. Now it happens that I have a pretty wide acquaintance among physiologists, and I have known some of the most accused vivisectors rather intimately. Of course they are not all alike, they differ as other men differ. But on the average in point of humane, kindly sympathy they stand above their colleagues. And the reason for this is clear to him who will listen to reason. They have gone into this work because the higher human sympathy has appealed to them; they have sought earnestly for those things which will relieve or prevent suffering; their lives are given to the solution of problems the ultimate end of which is found in the very things about which they are charged to be wholly indifferent.

Not only is it not true that vivisection experiments tend to make the experimenter callous; the reverse is actually the case. I can testify from my own experience that it is harder to make the fiftieth experiment than the first; that one's sympathies are more and more awakened rather than destroyed. There is no doubt that abuses are possible—are even probable. Yet most of the stories told to illustrate the brutality of vivisectors in things aside from the experiments themselves are highly improbable. As, for example, the statement that Dr. Sweet, of the University of Pennsylvania, kicked across the basement floor a poor emaciated dog on which he had operated. An operated animal is too valuable to be used in this way.

Were I to descend to the methods of our detractors I might use the following from my own experience to prove that antivivisection doctrine induces brutality.

I was once teaching in a small college the president of which was an ardent antivivisectionist. One day I received by mail a large poisonous centipede, carelessly enclosed in an unlabeled box. I made haste to get it into a wide-mouthed bottle. I had just succeeded when the president came into the room followed by a stray dog. There was a rule that dogs were not to be allowed in these rooms. The president took me roughly to task for allowing the poor centipede to suffer for lack of air in the bottle. Then, seeing the dog, he asked if it was mine? When I told him it was not he ordered it out of the room. The poor animal instead of obeying crouched on the floor and the president kicked it brutally and cruelly across the room and through the entance. Yet he could declaim with tearful voice upon Llewellyn's faithful hound Gelert!

It should be emphasized here that the lower animals themselves gain immensely from the results of vivisection and of experiments on living animals. The same advantages of protective serums and antitoxins are made available for them as for the human. The Agriculture Department of the University of California at the present time makes and distributes hog cholera serum. The Report of the College of Agriculture for the year 1913–14 states that when a herd of hogs becomes infected and is not treated with serum forty to eighty per cent. of the animals die. I am told by experienced and unprejudiced stock raisers that this estimate errs on the side of conservatism. The report shows further the following figures for a diseased herd treated with the serum:

Died before vaccination	92
Sick when vaccinated	123

Number vaccinated	1,656
Died after vaccination	233
Per cent. of loss	19

That is the conservative statement of the report. There should actually be deducted the 123 sick when vaccinated, for vaccination does not help those aleady sick with the disease. That reduces the percentage to 15 as compared with 40 to 80 per cent. when unvaccinated.

Now the vaccine can not be prepared without operation on living animals; and the method and the underlying idea could never have been reached except through animal experimentation.

This may serve as a near-by example of what is done and as a forecast of what will be done for the animals themselves. The very beginning of Pasteur's famous work was for the conservation of animal health. *To this really great end none of the opponents of vivisection has contributed an iota.*

2. It is affirmed by most antivivisectionists that experiments on animals are useless in that no knowledge of any real value has ever been attained in that way. This attitude is well illustrated in a recent circular entitled "Claim Everything" issued by the American Antivivisection Society. This circular is intended to be a rebuttal to an article by Dr. W. W. Keen in the *Scientific American* of June 20, 1914. The statements in the circular are on the authority of the president of the British Union for the Abolition of Vivisection. The circular says,

> Brain surgery owes nothing to animal experimentation. In brain, above all, the animal differs from man.

This appeals to a multitude of voters who do not know that motor localization was discovered by Fritsch and Hitzig on the brain of a dog. Dr. Keen had referred to the new and highly successful methods of direct transfusion of blood. The circular states,

> The direct transfusion of blood needs no experiments with animals, nor is the operation itself necessary.

The curious psychological twist in the reasoning of the opponents of progress in scientific medicine is shown in the following quotations from the same circular, copied verbatim, except that to save the space of comment I have inserted the italics:

> Operations for goiter, again, depend upon the *aseptic treatment.*
>
> Diphtheria has been reduced solely by *sanitary measures.*
>
> Malaria has been abolished by *sanitation.*
>
> Yellow fever can not have been abolished by any means based on experiments on animals, *because the germ has never been found* to experiment with.
>
> Discovery of salvarsan. This had better never have been made.

Every one familiar with the history of hygiene and sanitation knows how much of our knowledge and our point of view has been obtained through experiments on animals. Prohibit animal experimentation and progress in hygiene and sanitation would be practically brought to a standstill. Yet the opponents of research reiterate the statement that hygiene and not experimentation has enabled us to advance, and hence that experimentation is useless. Where a forward step has been made which is not attributable to "hygiene," as in the case of direct blood transfusion, its usefulness is flatly denied.

In most literature of this kind you will find expressed or implied a denial of the whole range of scientific knowledge as to the relation of microbes to disease. They refer to serums, vaccines and antitoxins in terms of profound contempt. A favorite expression is one which I have heard used by a California legislator, who calls vaccine "rotten animal pus" and who would make it a criminal offense to introduce any vaccine into the human system.

3. *Another argument is based on the so-called "rights of animals."* As a question of theoretical ethics I am willing to leave that for the present to the philosophers. I can not argue with the man who insists that his dog and his hog are as good as he is; that he has no right to restrain the one or to eat the other. If he refuse to eat meat, or eggs, drink milk, use leather, wool or other animal products for clothing or shelter; if he refuse to make counter attacks against the lions or serpents which attack him, he is consistent; I can not argue with him; I can merely watch him go his way in the procession with the trilobite, the ichthyosaurus and the dodo. But intensely practical questions arise and must be met. And the life of a relatively few animals is placed against the life and health and comfort of the human race. The antivivisectionist insists that even if you grant that the injury to the guinea-pig or the rabbit or the horse will save the life of a child you have no right to save it in that way. If there is not room in the life-boat for the woman and the dog you have no right to push out the dog to make room for the woman.

But here I want to take issue squarely with the claim that we have no right to make experiments which cause pain—that is a fatal admission which some of the English physiologists have made. We have a right to perform painful experiments if the knowledge that we seek can be obtained in no other way. Ordinarily it can be obtained better without pain, or can only be obtained in the absence of pain, but the principle remains. So long as man lives in the same world with other animals, eating to some extent the same food, subject to a large extent to the same diseases, it will be necessary for man either to maintain the mastery or to become one of the beasts of the field himself.

But especially I can not see why experiments for the good of humanity and for the benefit of the animals themselves should be prohibited on the ground of cruelty and the absence of right, in the light of the permission of many other things. The castration of an animal as performed on the farm by far exceeds in cruelty and callousness of performance anything which I have ever witnessed in a laboratory. A few hundred animals are used in all our laboratories for all purposes. The census report shows that in California in 1909, there were born 163,728 bull calves. It is fair to assume that 150,000 were castrated. There were born 41,927 colts. Of these approximately one half were probably males, and making deductions for those kept as stallions, there were here at the lowest estimate 19,000 geldings. There were 283,741 pigs born, which means probably 135,000 males to have their testes ripped out. A total each year in California of 304,000 operations. Comparing these in number and violence with the work in biological laboratories and medical schools, the latter becomes wholly insignificant. But the gelding of the boar does not have the emotional appeal in it and we hear little about it. Dehorning of cattle is a painful operation, but it saves vastly more pain which would result from the injury which, without it, they would inflict upon one another.

4. It is urged that certain results of undoubted value (or from the standpoint of the opponents of research, of possible value) could have been reached by some other way. This is a line of reasoning which has been used with a great flourish of apparent candor and show of plausibility. A biologist having by a long and painstaking series of experiments found the solution of a problem, a pettifogger takes that solution and shows by a play on words, how he could, without experiment, have de-

rived the same conclusion from certain given data. This is the basis of the constant appeal to hygiene, as the means of prevention of disease; while the very principles of hygiene are based throughout on animal experimentation.

I have read recently with great interest two books, accounts of journeys over practically the same ground, the journey from Mombasa on the East African coast to the great lakes at the source of the Nile. The one is by Lieutenant Speke, the other by Colonel Roosevelt. Speke traveled in constant danger and discomfort, beset with discouragements and the opposition of treacherous natives, in an unexplored, unknown land. Roosevelt made the trip by railroad. Our antivivisection opponents continually upbraid us for traveling like Speke in the difficult, uncharted territory, when we might wait and go *de luxe* in a Pullman: Will *they* build the road while *we* wait?

5. A further charge is urged against vivisection, that it leads to a state of mind which will not hesitate to make similar experiments on man. Human vivisection is held up as the acme of the fiendish impulses of the biologist, physiologist or surgeon. A hospital is a place of unspeakable horrors.

Now on this I must make two remarks. (1) That any thinking man will see that certain observations may be made on a patient without injury or pain to the patient, and that if these observations or experiments furnish useful knowledge, there can be no possible objection to them, and (2) every surgical operation is a vivisection experiment in one sense. A surgical friend has vivisected me, and yet I do not call him a fiend and an arch torturer.

Of course there are all sorts of men among physicians and surgeons as in all other professions. Abuses and outrages do occur, no doubt. There have been wicked doctors who have abused their trust; and there have been clergymen with whom the virtue of a young lady boarder was not safe; but we need not say for this reason that all surgeons are arch torturers and that all preachers are arch-lechers.

And this brings me to a point I wish to insist upon, that just as you do not need to pass a special law against adultery by ministers of the gospel, but that if you did so you would put an imputation on the character of a large body of earnest, sincere and unselfish men, so you should not pass laws which would put on men in biological research the imputation of bad faith and cruelty. Make the general laws against cruelty to animals as strict and far-reaching as may seem necessary for the good of the human race; but do not single out the men who are devoting their lives to the search after that knowledge which is for the best good of the race, and make them the special objects of unnecessary, restrictive limitations. If experiments on animals must be prohibited let the same law prohibit castration of animals and the dehorning of cattle. If the English law requiring all operations by a scientific man to be done under anesthesia be adopted, then require that the operations on the farm be performed in the same way.

You will perhaps say that the arguments mentioned are unworthy of attention; that it is beneath our dignity to answer them. It will not do to take that attitude. The opponents of research are too strong and too well organized to be neglected. They have enormous sums of money at their disposal. They have been able to subsidize newspapers and are prepared for a campaign of persecution and prosecution. The opponents of research are not easy to classify. They represent widely varied types of mind, but the following are usually recognizable:

1. The fanatics. This type is represented by the man who states over his signature that he would prefer to have his own child die of diphtheria than to have it saved by the torture (?) of a single guinea-pig. These are perhaps the only thoroughly consistent antivivisectionists. They are often so much in earnest that they do not hesitate to mislead the public through publication of untruths.

2. The cultured ignoramuses. A large class of people highly educated along certain lines of language and literature, but profoundly ignorant of the most simple and fundamental facts of natural law. They are the Clara Vere de Veres of both sexes and all ages.

3. The financially interested. Great fortunes are accumulated by the sale of patent nostrums. The business makes headway in proportion as medical knowledge and medical practise can be thrown into disrepute. Thus the *Journal of Zoophily*, January, 1915, quotes the following with no word of disapproval.

Medical Freedom says in its October number:

"Only recently Mrs. Catherine E. Mercer and her two children were vaccinated against typhoid in Brooklyn, N. Y. All were made ill. Mrs. Mercer died and the two children suffered for weeks. In Iowa a perfectly healthy guardsman was vaccinated against typhoid, became ill and died. In Camp Dodge, Des Moines, Iowa, Conrad Liljeberg died soon after vaccination. Also Clarence Pantzer, Thirteenth Coast Artillery, National Guard, New York."

4. Religious cults. It must be said to the credit of the majority of those who profess a religious philosophy which ignores disease that they are not inclined to put obstacles in the way of medical progress. Nevertheless, in a recent number of the *Journal of Zoophily*, a column headed Anti-Vivisection Notes is entirely occupied by a long tirade against the medical profession by the senior senator from California.

5. Demagogues. These are not wanting and in California have been not unsuccessful in securing legislative position by masquerading as benefactors and reformers.

The above are strange bedfellows, but they seem to agree well among themselves. They have this more or less in common that they desire to throw the efforts of the earnest, honest physician into disrepute; his loss is their gain. Anything does for a pretext. It can be vivisection or vaccination or quarantine or what not. Their method is always that of the pettifogger or the demagogue. They publish accounts of experiments done under anesthesia and of experiments done before the introduction of anesthetics as if they were all alike and now all in vogue. They describe vivisections done in the days when men were hanged and quartered as if they were the common practise of to-day. And in it all the appeal is to sentiment and prejudice, not to reason and common sense. By these methods they reach and may yet more effectively influence large numbers of honest and conscientious voters too busy to inform themselves as to the real issues, and unable to unravel the tangle of sophistry, sentiment and misrepresentation, with the result that there is great danger of hostile and harmful legislation.

In the face of all this opposition I feel justified in calling for support from you who are working in the various fields of science more or less remote to that of biology, not only because as co-workers in the effort to enlarge the sphere of human knowledge as men of open mind and enlightened sympathies your support may rightly be expected by those whose researches are primarily concerned in the discovery of those truths that are directly applicable to the diminution of pain and suffering and disease. But I would also place before you the importance to all of

you in your various fields of that which I have called the larger background of knowledge. It is only by this that we can see things in their true perspective. Our respective sciences and our special fields of research become of value only when their wider relations are apprehended. And may I without unduly magnifying mine office as a biologist call your attention to the fact that biology has contributed no unworthy share to the means of progress in the sister sciences. The contributions of biologists, especially the workers in physiological chemistry, to the general advance of chemical science does not require to be mentioned; nor do I need to refer to the usefulness to physical chemistry of the fertile ideas of Pfeffer and De Vries in the explanation of osmotic pressure. The physicists do not need to be told that by far the most sensitive galvanometer for the measurement of minute currents of short duration is the device of the physiologist Einthoven, designed primarily for use in the study of living organs. The engineers will recall that the method of recording progressive changes on a revolving drum is the application of the kymographion invented by Ludwig for the recording of blood pressures; but now employed in securing graphic records of a great variety of natural phenomena.

Or let me reverse the picture and remind you that the physiologist, the pathologist and the physician are laboring to apply the results of your researches in the explanation of the normal life processes, and to use them in the discovery of the causes of pain and suffering and disease, to the end that these causes may be overcome. Toward this result all lines of scientific effort are contributory.

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THE ERRORS IN PRECISE LEVELING DUE TO IRREGULAR ATMOSPHERIC REFRACTIONS[1]

Very accurate determinations of elevations above some datum have been made possible by the great improvements in the wye or spirit level which have taken place during the last half century. In 1867 the International Geodetic Association defined precise leveling as that which has a probable accidental error of not more than 3 mm. per kilometer. The leveling run to establish the controlling or fundamental elevations in the interior of the countries, during the decades which followed, showed these limits to be too liberal. In 1912 the International Geodetic Association adopted a resolution calling for a still higher grade of leveling called "leveling of high precision." This is defined as leveling in which every line, set of lines or net is run twice in opposite directions on different dates, as far as possible, and whose errors, computed by prescribed formulas, do not exceed ± 1 mm. per kilometer for the probable accidental error and ± 0.2 mm. per kilometer for the probable systematic error.

This class of leveling is easily secured with the modern instruments and methods. In fact the greater portion of the leveling done with the older instruments and methods in the United States by the Coast and Geodetic Survey and by other organizations came within these limits.

The datum or plane of reference which has been adopted in this and in other countries is mean sea level, that is the surface of the oceans with the water assumed to be at rest and affected only by gravity. This surface may be determined with relation to fixed points on land by long series of tidal observations. The mean surface varies in height from day to day, month to month, and even from year to year. Whether there are secular changes is not definitely known. The disturbing influences are the sun and moon, prevailing winds and varying atmospheric pressures. The configuration of the shore may have some

[1] Read before the Washington Philosophical Society, March 13, 1915.