gories. Intensive study is already modifying our idea of the species to a great extent, so much that some are beginning to doubt if such an entity exists; and yet without it we are completely undone and will have to begin over again. The physical and personal limitations of those who do the work must always keep the quality far below the ideal which I have discussed. Criticism is usually a generation behind publication, so that the poorest work may stand, as we often see, for twenty or forty years before it is competently revised. Moreover, the ablest taxonomists are likely to be the very ones to succumb to the higher rewards of administrative and economic work, and so fail to make the contribution of which they are capable.

I wish I could close with a strain of optimism, but the best I can say is this: Taxonomy demands the highest talent, and those who prove their fitness should have every facility and inducement; there is increasing recognition of this fact, and here lies the only hope that this basic science can perform for humanity the service demanded of it.

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THE ELECTRICAL ENGINEERING RESEARCH SITUATION IN THE AMERICAN UNIVERSITIES

PRODUCTIVE research is both the criterion and vehicle of scientific progress. This fact makes university research of especial importance, not only because of the additional knowledge that is obtained, but also because of the close relationship existing between collegiate research and scientific education. In view of the great amount of discussion going on at the present time regarding engineering education it is interesting, and very much worthwhile, to investigate the research situation in the technical schools of this country. The following paragraphs give the results of such an investigation into the field of electrical engineering.

It is a relatively simple matter to determine with satisfactory accuracy the amount of productive research being done in our electrical engineering schools. Practically all researches of permanent value which American electrical engineers perform are reported in the *Transactions* of the American Institute of Electrical Engineers. To obtain a very good idea of the electrical research being done in this country it is merely necessary to count titles in the *Transactions* for a period of years, omitting articles from foreign sources, presidential addresses, and papers of a general nature which do not represent contributions to science. Fortunately nearly all the articles published in the *Transactions* are of a technical nature, and represent research work of some kind, or at least the accumulated experience gained by years of observation of electrical equipment.

During the six-year period from 1920 to 1925, inclusive, 442 technical articles appeared in the *Transactions,* of which 54, or 12.2 per cent., had a college source. This gives an average of nine papers a year as the annual production of our many teachers of electrical engineering and of their students doing thesis work. Considering the results separately by years gives the following table:

Articles in *Transactions* of the A. I. E. E. 1920–25

Year	Total	College	Per Cent. College
1920	60	5	8.3
1921	36	3	8.3
1922	66	5½	8.1
1923	80	13	16.25
1924	113	13½	11.95
1925	87	14	16.1
Total	442	54	12.2

The fractional titles are the result of joint authorships. It is to be noted that while the amount of research being done in America in electrical engineering jumped very greatly as soon as research programs got under way after the war interruption, yet the proportion coming from colleges is substantially constant, and is in all cases surprisingly small.

It might be expected that the remarkable development of the radio field in recent years would absorb much of the creative effort of electrical engineers. Analysis shows that such is not the case. A survey of articles appearing in the *Proceedings* of the Institute of Radio Engineers for the six-year period from 1920 to 1925 shows that 174 articles were published, of which twenty-seven and one half, or less than five per year, had a college source. Furthermore, the radio field goes so far into the realms of the physicist that over half of these five articles per year must be credited to physics rather than to electrical engineering.

The results given above do not include all the research results published by electrical engineers, for the electrical engineer does not always report his researches in the publications of the national radio and electrical societies. From time to time important articles which should be credited to electrical engineering appear in other places, particularly in the magazines of the physicists and mathematicians. However, a glance at the bibliographies of electrical engineering papers shows clearly that the number of such stray articles that should be credited to the American electrical engineer, and particularly to the engineering schools, is relatively small, and can be

neglected without impairing conclusions drawn from the data already given.

In the six-year period considered fifty-four technical articles from a collegiate source appeared in the *Transactions,* and forty-three and one half of these fifty-four are credited to five colleges. The remaining several hundred schools of electrical engineering together produced ten and one half articles in six years. Only one electrical engineering department produced more than two radio papers in the six-year period. The following table gives the universities having productive electrical engineering departments:

Articles in *Transactions* of the A. I. E. E. 1920–25	
Mass. Inst. of Tech.	15
Johns Hopkins	10½
Stanford	9
Cornell	5
Purdue	4
Articles in *Proceedings* of I. R. E. 1920–25	
Columbia	7

The researches reported by the universities cover a very wide range of subjects. The high voltage field is most popular, but articles are found covering practically every phase of the electrical industry except certain of those branches that can only be carried on by national organizations, such as the telephone company.

The number of men with university connections who are active in research work is rather small. Considering a college professor as a productive research worker if he and his students together turn out one technical paper of scientific value every two years, it is found that in the six-year period from 1920 to 1925 there were eight productive research workers on the staffs of our electrical engineering schools, and these eight men and their students produced over half of the university research. Three of these were at Massachusetts Institute of Technology, while the other five were distributed one to a college. Only one of the eight published anything on radio.

The summary of this survey shows that the electrical engineering schools of our country produce about one eighth of the electrical and radio research that is reported in the pages of the national engineering societies. This represents about eleven articles a year. Of these eleven articles coming from the colleges each year, approximately seven come from four universities. Apparently not over a dozen technical schools are making much if any effort in the way of research. Over half of the university research in electrical engineering is the work of eight men.

This is the situation, and it now remains to consider the consequences of this condition. University research in electrical engineering is primarily significant as an indication of the situation that exists to-day in the education of electrical engineers. The laboratories of the big electrical companies make technical progress assured even without any university research, but the country's supply of technically trained young men can come only from the university.

Research means progress, and above all things it signifies that the producer of research must be an authority on at least one subject. It is safe to draw the conclusion that an institution which turns out research work in a certain field of engineering will be able to give its students the best and latest that is to be had upon this subject. This makes it evident that an institution which is performing research work in practically all lines of the electrical industry is best fitted to give its students the broadest and most up-to-date training possible.

While the research worker must be an authority, it is possible to be an authority without being a research man. Possible, to be sure, but not likely, for the university man who keeps in touch with everything and who understands the significance of new developments will be continually getting ideas. It is a very unusual man who will keep up in the firing line of progress and not lift his own hand or direct the hands of his students in an effort to advance the front. Almost inevitably such a person upon reaching the front line will either put his shoulder to the wheel or will stand still and let the rest of the world go on ahead. The electrical industry is so new and is progressing so rapidly that one can lose out completely with new developments in a period of from five to ten years, and a man who received the very best of training ten years ago is entirely out of the running now unless he has kept moving ahead. This makes one begin to suspect that perhaps most of our electrical engineering schools are trailers of the electrical industry in general, rather than leaders of progress, as generally assumed. There are very few colleges that can give as good an answer to a "red-hot" question in electrical engineering, as the engineer in the laboratories of the General Electric Company, Bell System Laboratories, etc.

This is the situation; why does it exist? Lack of equipment can be dismissed at once, for although some electrical researches require expensive equipment, there are many that do not. Pencil and paper constitute the main essentials for the investigation of many problems. There are probably a great many factors that enter into the matter, but the most important undoubtedly are first, heavy teaching schedules which leave little or no time for study and research; second, lack of adequate training of teachers

of electrical engineering; and third, the fact that research is often much more poorly rewarded than other activities in which the engineer may engage.

The overworked instructor is met on all sides. His plight is unfortunate, but the fact that he has no time for research between his lectures explains but does not remedy the situation. Excessive burdens imposed on the teaching staff do not directly stifle original investigation, for students do a large portion of the time-consuming part of the university research. The effect of overwork is principally to make it impossible for the harassed individual to do the studying that is necessary if one is to keep up with industry. The inevitable result is that students are often taught by men who are unable to keep up-to-date, and these same students do thesis work which is inadequately supervised and is usually on antique problems.

Inadequate training of teachers is perhaps the greatest handicap under which electrical engineering education suffers. The general ideals of what constitutes a well-trained engineer are very low. A great fraction of the young men on the instructing staffs have received only the bachelor's degree and are not planning to go beyond this point. Some possess a master's degree, but extremely few have gone so far or ever expect to go so far as the doctorate. Compare this with chemistry or physics, for example, where the best schools will not give permanent appointments to a young man who does not have the Ph.D. degree or who is not very near this point. The low standards that prevail in the training of engineering teachers mean that the young instructor spends many laborious years educating himself to make up these deficiencies as best he can. A couple of years of graduate study would do the job much more thoroughly and leave the remaining years for productive research rather than for self-education.

Most colleges do not expect the teacher of engineering to do research as part of his job. They are pleased if he carries on original investigations, but he is not expected to do so and is usually not rewarded in a concrete way for such work. The able teacher who has a little spare time can more profitably employ it in building up a consulting practice. To be successful in this requires that the consultant possess more technical knowledge than his clients, but this does not necessarily imply a great deal of scientific knowledge. Other teachers write text-books for elementary students of electrical engineering—an occupation that has vicious possibilities. It gives us poorly trained teachers writing poor text-books which will inadequately train future teachers who will write still more books.

The tendency of the research situation that exists in electrical engineering is to create a self-perpetuating system in which a second-rate technical education is considered first class because of general ignorance that there might be something better. The student leaves college thinking he is thoroughly trained when he is only acquainted with the shadow of the real thing, and he does "research" work in obtaining an advanced degree that is not research in any sense. Giving a motor a thorough routine test or reworking some problem that was solved twenty years ago is not research in the true sense, even though the process may be new to the student.

All the facts that have been presented are decidedly important in their effects on engineering education. To improve technical training, well-trained instructors having several years of graduate study are essential, and these men should be expected, and should be given the time, to follow closely technical progress. Curricula won't help very much, for a curriculum does not of itself educate. If it did, every college in the country could adopt the curriculum of the Massachusetts Institute of Technology and be able to offer the same brand of training without a change in the instructing staff. It is practically as easy to direct a student's thesis activities on really new problems that are yet unsolved as it is to have him work on some problem that is new to him only—provided competent supervision, backed by original ideas, is available. Practically every thesis investigation should be spent in obtaining evidence and facts that will at least contribute to future published work on the part of some one.

Many of the important aspects of engineering education are not appreciated by the ordinary engineer, who has too often had no opportunity to gain a conception of what constitutes thorough training or genuine research. Questionnaires sent to practicing engineers are valueless as far as such matters are concerned, and the usefulness of the questionnaire anyway is dubious in deciding most of the problems of technical training. The psychologists long ago discarded the questionnaire method of ascertaining *truth* and now use it only where they desire *opinions*. In fact, the educational opinions of most college-trained men are unique. As President Wilbur has put it, the college graduate buys a 1927 automobile, a 1927 radio set and a modern house, but he clings to the college of his youth and wants his children to have the same education he obtained, an 1899 model.

This situation probably exists in other branches of engineering to about the same extent as in electrical engineering, although the writer is not in possession of the detailed facts on this point. There is a common feeling that something is not just right with engineering education, but it will take more than questionnaires and symposiums on curricula to get

us far enough out of the present rut to show that there are better paths within access. At present we are content to pay homage to Steinmetz, Pupin and Tesla, while making no effort to offer at home the thorough training these men obtained elsewhere.

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WHAT IS A PLANT?

A PLANT is a living thing, typically green, possessing a green pigment, chlorophyll, by means of which it absorbs a part of the energy of the sunlight; by means of this energy it decomposes carbon dioxide; it uses the carbon, with water, to form its carbohydrate food; since its necessary food is everywhere, it does not have to have the power of locomotion; and since it does not have to move, it can protect itself with rigid walls of cellulose. . . .

But,

there are animals which during the most of their lives are fixed in one place as securely as typical plants are fixed. Some plants at all stages of their lives, and many plants at some time in their lives, have the power of locomotion, or at any rate are freely moved about. While plants are typically green, it is not impossible that the time will come when more kinds of plants are known without chlorophyll than with it. . . .

Why, then, are they called plants? Not because they have the majority of the characteristics of plants; for they are not green, and can not use carbon dioxide as food, and they may have the power of motion and be destitute of cellulose. Yet they are plants. The reason goes back to the idea that the plant kingdom is a group of creatures which are really related, which have common ancestors. Any living thing which is descended from the ancestor of the plant kingdom is itself a plant, whether or not it has retained the typical characters of plants.

Still farther back, there was doubtless a common ancestor of both plants and animals; and there are living things in the world which are less related to plants than animals are, and less related to animals than plants are.

This is commonplace, indeed; so elementary that it can be quoted from an old text for beginners averaging perhaps sixteen years in age. It is intruded on the—perhaps bored—attention of the professional botanist and teacher, because, as logical as a good lawyer, and hardly less the slave of precedent, he constantly ignores its consequences. Quoting still from the same very elementary text:

The plants and animals which we see about us seem very different indeed. A man or a horse differs from an orchid or a sunflower as widely as the time that plants and animals have existed upon the earth has permitted the difference between living things to become. If we follow the line of plant development backward or downward from the sunflower, we will find the characters which make up our usual idea of a plant gradually to disappear. The first to go is the showy structure of the flower. . . . The seed goes next. No seeds are found among the Archegoniates. Leaves are still present, but if we move downward to the next lower group, we shall lose them also. . . . If we follow the line down to the lowest Algae, we come to plants which no longer show any suggestion of a distinction of roots and shoots. . . . Still, these lowest Algae are plants. . . . If we begin at the top to follow down the line of development of the animal kingdom, we shall see the characteristic structures of the higher animals, hair first, then bones, etc., disappear, as did the flowers, seeds and leaves of the higher plants. At the bottom of the animal kingdom, we come again to organisms each of which consists of a single cell, but this cell still an animal. However unlike the higher animals and the higher plants may be, when we come to the examination of the plants and animals which are single cells, we find that these one-celled organisms, plants and animals are infinitely more like each other than either is like the highly developed creatures which have descended and been developed from them. The animal kingdom, like the plant kingdom, may well be pictured as a tree, and we have come now to the point where it must seem exceedingly probable that the two trunks grow from a common root.

There are many one-celled plants, and many one-celled animals. . . . Some of these share the characters of the two groups so impartially that the question, which they really belong to, is merely one of definition. The definition of a plant may be made to include them, and so may the definition of an animal. Neither is the question, to which kingdom they belong, of any real importance. If two trunks grow from a common root, who shall decide to which trunk the root belongs?

This much we can say: from green flagellates the plants are descended, and from colorless flagellates, the animals. Since the plant kingdom is reasonably spoken of as constituting a vast group of living things for the sole reason that all of these living things have a common descent from the green flagellates, it follows that there can be no possible good reason for calling any living thing a plant, unless it is descended from these green flagellates.

There are alternatives, to which we will return.

There is no reason why other lines of development should not have arisen from the fundamental flagellate stock; and the flagellates themselves are not so primitive, but that they must in turn have had their ancestors; and these ancestors ought not to be included in plants or in animals. There are a large number of organisms known, which, for one or the other of these reasons, must be regarded as neither plants nor animals. . . . For instance, the group of the Chytridineae, which usually have been included among the Fungi, seem very probably to be descended directly from the flagellates, independently of the line of primitive Algae from which the plant kingdom has developed. If this is the case, they are not, in the sense of systematic botany, plants at all, but a distinct group of living things.