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EDITED BY

HOWARD J. ROGERS, A.M., LL.D.

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A FUNERAL IN THE CATACOMBS

Photogravure from the Painting by Adolf Crafs

The Catacombs of Rome are no longer used as funeral depositories, but in the early period of Christianity they were the common sepulchral places of the dead. The artist, in a famous painting here reproduced, has presented a typical scene of the ceremonial rites performed in the Catacombs about the tenth century. The body of a maid, exposed on a bier, after the custom of the time, is bewailed by nine virgins who attend in the capacity of mourners and recite prayers while the celebrant pronounces a benediction, after which an Epithalamium is sung, and the body is then committed to a vault, as shown in the painting.

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DIRECTOR OF CONGRESSES

VOLUME XII

MEDICINE AND TECHNOLOGY

COMPRISING

Lectures on Obstetrics and Gynecology, Pediatrics,
Otology, Electrical and Mining Engineering,
Civil and Mechanical Engineering,
Technical Chemistry, and
Agriculture

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ILLUSTRATIONS

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SECTION I — GYNECOLOGY

(*Hall* 13, *September* 24, 10 *a. m.*)

Chairman: Professor Howard A. Kelly, Johns Hopkins University.
Speaker: Professor John Clarence Webster, Rush Medical College, Chicago.
Secretary: Dr. G. H. Noble, Atlanta, Ga.

SOME FUNDAMENTAL PROBLEMS IN OBSTETRICS AND GYNECOLOGY

BY JOHN CLARENCE WEBSTER

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Marked as have been the advances during the modern scientific era in our knowledge of woman in respect to her anatomic and physiologic peculiarities, her special diseases, and the treatment thereof, many problems yet await solution, some of which are chiefly of scientific interest, others of therapeutic importance.

In complying with the request of the organizers of this great Congress, I have fully realized the seriousness of the responsibility which I have assumed in restricting myself to the topics which I have selected for your consideration. I have avoided all reference to matters pertaining to the treatment of disease, believing that the presentation of certain fundamental scientific problems would be more in keeping with the aims of this convention. I have also deemed it best to confine myself to a few topics of particular interest or importance, rather than to wander discursively over the entire scientific field open to the gynecologist. Your attention is, therefore, directed to the following subjects:

1. The determination of sex.
2. The structure of the ovary.
3. The functions of the ovary.

4. Antagonism between maternal organism and ovum.
5. Functions of the placenta.

Determination of Sex. From the time of Hippocrates to the beginning of the eighteenth century, about five hundred theories relative to the question of sex-determination had been advanced. During the last two hundred years this number has been considerably increased. At the beginning of the twentieth century, it must be frankly admitted that the problem of sex-determination in the higher vertebrates generally still remains to be solved. The most important observations and experiments bearing on the question have been made during the last fifty years, and from a study of these it would appear that the most exhaustive researches in comparative and experimental embryology and physiology will be necessary before the difficulties of the subject can be elucidated. The data furnished by the study of human beings are scanty and of little value. Most of the statements which have been made are speculative in nature, or of doubtful accuracy. Certain it is also that all attempts to regulate the production of sex in the human fetus in utero have met with failure.

In many countries the belief has long been current that the sex of the human fetus could be modified during a greater or less period of its uterine life. Now we know that the sex is fixed at least by the beginning of the second month, for at that time the microscope can distinguish ovarian from testicular structure. It is, therefore, scarcely credible that any reversal of sex can be brought about after this period by any conceivable combination of influences. We must, indeed, look to conditions existing during the first month of gestation, or at the time of the meeting of spermatozoön and ovum, or to influences affecting either or both of the latter before conception, in order to find explanation of sex-determination in the human embryo. Those who believe that both sperm and ovum share in the production of sex refer to the various statistics giving the relationship of the parental ages to the sex of the offspring. Hofacker in 1823, and Sadler in 1830, independently stated, as the result of an analysis of about 2000 births, that when the father is the older the offspring are preponderatingly male; while if the parents be of the same age, or if the mother be older, there is a larger percentage of female children. This generalization, termed the law of Hofacker and Sadler, has been the subject of much debate, having been upheld by some and denied by others during the last 70 years.

Those who believe that the influences determining sex belong to the ovum entirely find no evidence to support them from a study of the highest forms of life, though there is strong corroboration from investigations made among lower forms. Thus in cases of parthenogenesis it is evident that the influence of a male paternal element must be entirely eliminated in the determination of sex. B. S. Schultze advanced the view that there are two kinds of ovums, one of which may give rise to males, the other to females, but there has been no proof of such a differentiation in the higher forms of life. In several low organisms, however, it appears that these two varieties (of ovums) exist. Thus Korschelt describes two kinds of ovums in the ovaries of the worm *Dinophilus opatris;* one of large oval shape, developing into females, the other small and round, becoming males.

With regard to the determination of sex by influences brought to bear either upon parents, the sexual elements, or embryos, many observations have been made, but trustworthy conclusions may be derived only from the study of comparatively low organisms. The influence of nutrition is thus considered of great importance in determining sex. As illustrations may be noted the variations in the sex of frogs associated with changes in the nutriment supplied to the young tadpoles. Yung found that when the latter were left to themselves the percentage of females was slightly in the majority, but when very rich food was supplied, 92 females to 8 males in every hundred were produced. In the case of bees it seems evident that the influence which decides whether the offspring of the fertilized ovums shall become queens or workers is the nature of the food-supply. Rich and abundant diet develops queens; plain and scanty food leads to the production of workers, in whom reproductive organs are undeveloped. Very interesting observations have been made upon plant-lice or *aphides*. In the warm months when food is plenty they reproduce by parthenogenesis, the offspring being entirely female. When colder weather and scantier food appear there is sexual reproduction and an offspring of males. In the artificial life of a well-kept greenhouse, these phases may be repeated at the will of the observer, by varying the nutrition. So far as the temperature is concerned, Geddes and Thomson state that experiments point to the conclusion that favorable conditions tend to femaleness and extremes to maleness of offspring. As regards higher forms of life, it is impossible to estimate the importance of nutrition, temperature, etc., in the determination of sex, while as regards mammalians this field of inquiry is as yet entirely speculative.

From what is known of the early embryology of many invertebrates and some of the lower vertebrates, it would appear that their early embryonic life is one of indeterminate character so far as sex is concerned, during which various conditions, *e. g.*, nutriment, temperature, moisture, light, may act so as to produce maleness or femaleness according to their abundance or deficiency. Whereas, in the higher vertebrates, the period of embryonic sexual indeterminateness (if any) is very short, and so far as is known no influence can be brought to bear on the ovum which can in any way determine sex. The mammalian ovum developing in the uterus seems to enjoy such a sheltered existence that it is impossible to conceive that changes may be induced in its environment comparable to those which have been experimentally introduced in the study of ovums and embryos of low vertebrate and invertebrate forms of life. Indeed, it would seem that the most satisfactory theory of sex-determination in the higher vertebrates is that which supposes the existence of two forms of ovums — one destined to maleness and the other to femaleness, though it is impossible to establish any such differentiation by microscopic study or chemic analysis. The elaborate work of von Lenhossek, recently published, strongly favors this view that sex is fixed in the ovum before the spermatozoön fertilizes it. If such be the case it is quite futile to expect that any alteration may be brought about by dietetic or other influences made to affect the human female either before or during gestation.

In this connection it is interesting to refer to the question of the occurrence of true hermaphroditism in the human species. Many hold that this has never been demonstrated. Nagel, for example, states that it probably cannot exist, and holds that the ovary is never found with the testes in cases of so-called hermaphroditism. Recently, however, Sarré has described the case of an individual with the external configuration of a woman, who possessed a well-developed imperforate penis. On making a rectal examination, two small bodies, each the size of a pigeon's egg, could be felt in the left half of the pelvis, while in the right inguinal canal an ovoid body was found. An exploratory incision was made over the latter and the swelling removed, along with a smaller mass attached to it. Microscopic examination proved these to be testicular structure and epididymis. Another small mass near the testicle was also examined and found to be ovarian tissue. A Fallopian tube and a structure resembling the vas deferens were also present. Sarré believes that, with the exception of another case described by Ziegler, all other records of true human hermaphroditism are very doubtful, though he thinks it has been clearly demonstrated in some lower mammals, *e. g.*, the pig.

The Structure of the Ovary. In spite of the immense amount of investigation to which this organ has been subjected, many points in its development, normal and pathologic histology, still require elucidation. It is generally agreed that the ovary is developed from epiblast and mesoblast on the inner surface of the Wolffian body. The epiblast, a specialized portion of the celomic lining, very early forms a mass consisting of several layers of cells, the germinal epithelium. In the deepest portions certain of these cells increase in size, giving rise to the primordial ovums. The latter are all formed previous to birth. As the epiblast layer increases in thickness, processes of the underlying mesoblast of the Wolffian body extend outward among the germinal cells, forming a network-like stroma, in the meshes of which lie primordial ovums, frequently surrounded by germ cells. Regarding the formation of the primary follicle, there are differences of opinion. Most believe that the germ cells arrange themselves around the ovum forming the primary ollicle, in later life proliferating to form the membrana granulosa. In 1878, Foulis, of Edinburgh, contended that the cells surrounding the primordial ovums are derived from connective tissue, and lately Wendeler and Clark have advocated this view. The latter has pointed out that the cells are usually spindle-shaped in the early stages and that frequently primordial ovums are found without any special layer of cells surrounding them. Kölliker stated that the follicular epithelium was derived from Wolffian epithelium, but this view has received little support. Regarding the changes between birth and puberty, we do not possess exact information. It is believed that during this period more than half the primary follicles disappear, though the manner and reason of the disappearance are not clear. The period of puberty is characterized by the development of Graafian follicles, which rupture gives rise to the peculiar structure of the corpus luteum. In some cases this phenomenon may be noted months before the external signs of puberty are detected and occasionally years previously. The explanation of these variations is not known. Some degree of development of the ovum seems to be a normal occurrence in the pre-puberty period. Stevens has recently described these as follows: The follicle and contained ovum mature to a certain extent. The single layer of flat cells surrounding the dormant ovum proliferates and becomes somewhat cubical, several layers being formed — membrana granulosa. The ovum increases and is surrounded by a discus proligerus; there is also a zona radiata and liquor folliculi. At its greatest the follicle measures about .8 × .7 mm.; the ovum, .1 × .095 mm. The tunica fibrosa is well marked, and resembles the ovarian stroma, being somewhat more vascular. Sometimes excessive liquor folliculi collects. Retrograde changes gradually develop. The ovum is invaded by cells, which are apparently phagocytes, derived probably from the membrana granulosa. Their protoplasm is vacuolated and they do not resemble leukocytes. Necrobiosis gradually develops, and most granulosa cells disintegrate. The tunica fibrosa gets many capillaries and the connective-tissue cells multiply. On the inner surface a hyaline layer of fibrin forms, in which new connective tissue develops. The follicle gradually shrinks, leaving a small scar area. It thus appears that the pre-puberty changes in the follicles differ from those in adult life in the following particulars: the ovum does not reach such a large size. The wall of the follicle external to the membrana granulosa does not present a two-layer arrangement; there is no rupture of the follicle; there is no formation of a corpus luteum; the ovum is invaded by phagocytic cells. In adult life, also, it is to be noted that, beside the follicles which rupture, there are others which may develop to a certain extent and then undergo retrograde changes before rupture occurs. The ovum may increase, a yellow body may form, owing to the development of lutein cells in the theca interna. Then the ovum and surrounding epithelium degenerate and are absorbed, along with the liquor folliculi. The explanation of such a process is not always certain. In some cases it appears to be due to chronic inflammatory changes in the ovary, but it is probably also due to other causes of which we are ignorant.

Regarding the bursting of the follicle there is a difference of opinion. Most authorities hold that the ovarian tissue, being greatly thinned at the most projecting point, is gradually ruptured by the increase in intrafollicular pressure resulting from the accumulation of liquor folliculi. Nagel, however, holds that owing to an increase in the thickness of the inner layer of theca folliculi, to the swelling of its cells with lutein particles and to its becoming arranged in a wavy manner, pressure is made on the follicle contents from without, and that they are forced in the direction of least resistance, viz., outward toward the surface of the ovary.

Clark holds that rupture is due to changes in the circulatory conditions in the ovary. Owing to the marked engorgement of the organ, tension is increased and the follicular contents are forced to the surface. The vessels lying external to the folicle at the bulging portion are compressed, and consequently necrosis and disintegration of the tissue take place. *Pari passu* with the development of the lutein cells there is fatty degeneration in the cells of the stratum granulosum and in those of the discus proligerus. This enables the ovum to escape easily from the cells surrounding it.

The formation of the corpus luteum has given rise to considerable discussion. Some workers still hold firmly that it is a derivative of the membrana granulosa. The majority hold, however, that it is developed from the inner part of theca folliculi, which is regarded as a cellular layer of the connective-tissue stroma of the ovary.

Of great interest is the observation recently made by Stoeckel, Pick, and others, that, occasionally, corpus luteum cells may not undergo their normal growth and retrogression within the limits of the follicle, but may wander outward into the ovarian stroma and even undergo atypic proliferation. I have occasionally noted this wandering, though not to a great distance; in some instances the cells contained abundant dark pigment apparently derived from blood which had been effused into the cavity of the follicle. The explanation of these irregular phenomena is quite uncertain, and is deserving of careful investigation.

Another interesting histologic appearance has been described in recent years by Pels Leusden, Schmorl, and others, viz., small localized areas of decidua-like cells in the ovary in some cases of uterine pregnancy. I have recently examined ten specimens in my museum, and have found these changes in four ovaries. In one a single area was found in a complete section of the ovary; in the others, two were found at different portions and varying in size. In each instance the areas were situated in the cortex, at or near the surface, sometimes projecting slightly from the latter, sometimes extending some distance into the cortex. The cells in these areas bear the closest resemblance to the uterine decidua in normal pregnancy, presenting similar variations in size and shape. The line of demarkation from the surrounding ovarian stroma is always well marked, giving the impression that the two tissues are distinct. Usually these areas contain dilated capillaries which are not found in the neighboring unchanged ovarian stroma.

I have never found such areas in ovaries removed from non-pregnant women. What is the explanation of these changes? It might be suggested that they are peripheral portions of the theca interna of the ripening Graafian follicles or of a corpus luteum. Serial sections show, however, that this is not the case. The large cells are undoubtedly of connective-tissue origin, but their definite localization suggests some special characteristic which makes the cell capable of undergoing the same genetic reaction which is ordinarily found in the uterine and tubal mucous membrane when pregnancy develops in relation to these tissues.

Tentatively, I advance the view that these areas represent displaced portions of Müllerian tissue, which have become attached to the surface of the ovary in early embryonic life. Occasionally, I have found in the substance of such an area a gland-like space lined with columnar or cubical epithelium. The latter may, of course, be simply a derivative of the surface germinal epithelium, but it may indeed represent included Müllerian epithelium.

It is possible that the special genetic reaction in these areas may sometimes determine the imbedding and development of a fertilized ovum in the ovary, and if the opinion that they are Müllerian in origin be correct, it is not unlikely that all cases of pregnancy in ovarian tissue may still serve to support the dictum which has been widely believed in recent years, viz., that imbedding and development of the fertilized human ovum in the earliest stages can only take place in a tissue capable of undergoing a special genetic reaction, and that this tissue is in all cases Müllerian in origin.

While the proof of this is impossible, all *a priori* evidence is in its favor. Those who attempt to overthrow the hypothesis certainly undertake a heavy task in trying to establish an exception to the uniformity of performance of one of the most complex and highly specialized functions in the human body. The indication of the genetic reaction is decidual transformation, and this is normally found only in the mucosa of the corpus uteri, where indeed it occurs in all cases of pregnancy, whether the latter be uterine or ectopic. In certain cases we know that decidual changes may occur in other portions of the Müllerian tract, most frequently in the Fallopian tubes, a fact which probably helps to explain the occasional occurrence of pregnancy in the latter.

With regard to ovarian gestation, in the specimens which have been most fully studied, viz., those of von Tussenbroek, Thompson, and myself, it is true that no definite decidual layer is found in the wall of the gestation sac. Though von Tussenbroek, in her first description, mentioned a decidual layer, she afterward stated that this was an error, the cells being in reality lutein cells of the corpus luteum. The final account is in the main correct, but she cannot deny the possibility that some of the large cells were decidual. However, admitting that no decidual cells are found in specimens as advanced as those mentioned, we do not know that they were not present at an earlier stage, when the ovum was very small. One of the small ovarian decidual areas to which I have referred would very soon disappear as a result of the outward pressure of the expanding ovum, as well as of the phagocytic action of the trophoblast, if there be no more tissue capable of undergoing decidual changes, and it is quite evident that the ovarian stroma proper does not tend to undergo this transformation.

Even in tubal pregnancy, in which decidual changes are always present in the early stages, there may be a marked disappearance as pregnancy advances, the production of cells being evidently much poorer than in the uterine mucosa in normal pregnancy, though in the latter there is a considerable range of variation. In my own recently described specimen of ovarian gestation I believe that I have demonstrated a few scattered groups of decidual cells in the ovarian stroma, near the inner wall of the gestation sac.

For several years I have held the belief that decidual transformation is peculiar to the Müllerian tract. The occasional finding of the small areas of decidua-like cells in the ovary in uterine gestation has been regarded by several writers as a proof that other tissues may also undergo the change. From what I have already stated it remains to be proved that these areas are not Müllerian in origin. The occasional blending of Müllerian and ovarian tissues has been abundantly proved, both by macroscopic and microscopic demonstration. Take, for instance, the relationships of the ovarian fimbria. In some cases its outer end may not reach the ovary, sometimes it may just touch it; sometimes its tip may be imbedded in the ovary; sometimes a considerable extent of the fimbria may lie against the ovary or adherent to it; in some cases there may be a break in its continuity, so that a small outer portion may lie close to the ovary detached from the main part. Marchand has directed attention to the early close relationship between the tubal epithelium and that covering the surface of the ovary, and has pointed out that they are one and the same surface. He believed that in some cases the line of demarkation, instead of being at the end of the ovarian fimbria, might reach over to the lateral portion of the ovary and that from it processes might extend into the cortex of the ovary. The observations of De Sinety and Melassez, in 1878, seemed to establish the correctness of such a view. Other studies, especially those of Whitridge Williams, leave no doubt as to the occasional extension of Müllerian tissue into the ovary. It need not, therefore, be a matter of surprise that small areas are occasionally found in the ovary of pregnancy, presenting the appearance of decidual changes in the connective tissue of the uterine mucosa.

It must also be mentioned that small localized decidual nodes have also been found in the broad ligaments. I believe that these are also derived from displaced portions of Müllerian tissue, which are quite common, especially in the upper portions of the broad ligaments. Similar areas have also been found under the peritoneum of the pregnant uterus, but this cannot be considered as at all remarkable, since there is no doubt as to the Müllerian nature of the uterus. Rarely they have also been found behind the peritoneum of the pouch of Douglas, and it is not unlikely that even in this neighborhood may be found small detached Müllerian fragments displaced backward in early embryonic life.

In describing these small decidua-like areas it must be remembered that somewhat similar appearances may sometimes result from chronic inflammatory changes in the peritoneum, associated with inclusion of the endothelium and proliferation of the latter. The large cells produced in this manner are usually closely packed and suggest masses of epithelium rather than the looser arrangement of multiform anastomosing cells found in the connective-tissue decidual areas.

The Functions of the Ovary. In addition to furnishing the ovums, it has long been recognized that the ovary exercises an important influence on the body, though the nature of the influence and the changes induced by it have been and still are unknown. Recently, various workers have suggested that the ovaries are ductless glands, whose internal secretion affects general metabolic processes.

Several years ago, it was noted that in many cases of osteomalacia the disease could be checked by removal of the ovaries. Fehling, a pioneer in this line of work, made a careful study of the urine in his cases, but gained no information as to metabolic changes by comparing its condition before and after operation.

In 1894 and 1896, Neumann stated that removal of the ovaries in this disease exercised a marked effect in lessening the excretion of magnesium, calcium, and phosphorus, as well as diminishing proteid disintegration. Later, Neumann and Vas experimented on normal female animals, and found that Merck's ovarian tabloids, even in large doses, did not appreciably alter the quantity of nitrogen or phosphorus in the urine. They found, however, that there was an increased excretion of these when their own preparation of cow's ovary was administered. They also noticed no pronounced alteration in the phosphorus excretion after removal of ovaries from animals. When ovarian tabloids were given to spayed animals, there was increased excretion of calcium and phosphorus, and less marked nitrogenous excretion.

The experiments of Curatulo and Tarulli, in 1895, have attracted a good deal of notice. They fed bitches on a regular diet until there was a uniform average daily excretion of phosphorus and nitrogen. The ovaries were then removed, and thereafter the excretion of phosphorus was much diminished. They concluded that the ovaries produced an internal secretion, of unknown nature, which influenced the oxidation of organic substances containing phosphorus which enter into the structure of bone. In accordance with their view, it has been widely believed that the beneficial influence of the removal of the ovaries in osteomalacia was due to the retention of more phosphorus in the system and its deposition in the bones in the shape of phosphates.

In 1899, Falk repeated these experiments, but did not arrive at the same conclusions. After removal of the ovaries in two bitches, he noticed no difference in the amount of phosphorus excretion.

Moreover, recent investigations regarding the source of the excreted phosphorus tend to lessen the value of these experiments. They appear to show that much of the phosphorus is derived from nucleoproteid in food, and it is possible that the increased excretion after the administration of ovarian tissue or extract is thus explained. Curatulo also holds that the ovarian secretion favors the oxidation of carbohydrates and of fatty substances, and explains the tendency to corpulency when the ovaries are removed in the reproductive period of life, or after the menopause, as due to the loss of the ovarian secretion.

The results of various experiments in the administration of ovarian tissue or extract in the human female have in no way helped to throw light on the subject under consideration, nor have they tended to uphold the theory of an internal secretion. The use of the gland in various diseased conditions of the pelvis has not served to give to it any definite therapeutic value. Neither has its administration at the time of the climacteric served to ameliorate or dispel the troubles incident to that period. Results, good, bad, and indifferent, have been published, leading strongly to the conclusion that in the cases observed only the same variations in clinical features have been recorded which may be recognized when any group of menopause cases is studied uninfluenced by any medication.

Whatever the influence of the ovaries may be, it seems to be established that they affect the organism through the circulation and not through the nervous system, and thus support is given to the theory of an internal secretion. Many experiments have been made in transplanting the ovaries of animals from their normal situation to some other, *e. g.*, the peritoneum, subcutaneous tissue, muscles, etc. While after transplantation some of the ovarian tissue usually necroses, the remainder generally lives and continues to functionate, ovums continuing to develop, ripen, and even to escape from follicles. When this activity continues, no matter where the ovary is placed, the genitalia and mammae remain well developed just as though the organ is in its normal position.

The Rôle of the Corpus Luteum. Recently the view has been advanced that the internal secretion of the ovary is produced by the corpus luteum, and that the latter structure exercises very important functions in the female organism. The late Gustav Born, of Breslau, was the first to bring forward this hypothesis, stating that the particular function of the corpus luteum was to favor the imbedding and development of the fertilized ovum in the uterine mucosa.

Ludwig Fraenkel has recently published an elaborate paper in which he states his belief that the internal secretion produced by the yellow body keeps up the nutrition of the uterus during reproductive life, leads to the phenomena of menstruation, and favors the imbedding and development of the fertilized ovum. Uterine atrophy and amenorrhea are brought about when no corpora lutea are found. Thus are explained the conditions normally found before puberty and after the climacteric. The facts upon which this remarkable hypothesis is based are derived mainly from experiments carried out on rabbits, since in these animals the time of occurrence of the various stages of gestation, following insemination, are fairly accurately known.

In endeavoring to determine the influence of the ovary on implantation of the fertilized ovum, Fraenkel removed the ovaries from thirteen rabbits, one to six days after copulation. Later these animals were killed, and in no instance was an ovum found in the uterus. In another series only one ovary was removed, and this did not interfere with gestation. It seemed, therefore, that implantation had been prevented by removal of both ovaries.

In another series of rabbits the ovaries were removed after implantation of the ovums, and it was found that their development ceased, though they were not expelled from the uterus.

Similar results were obtained when, instead of removing the entire ovarian tissue, the corpora lutea were destroyed with a cautery. It was found that development of the ovum might continue if only one corpus luteum was left in the ovary. When the ovaries were transplanted, destruction of the ovum occurred, though after some delay. After burning the corpora lutea from the ovaries, it was found that the uterus was much atrophied in two weeks.

This physiologic interpretation of the function of the corpus luteum is worthy of the highest consideration. Hitherto, anatomic explanations have been chiefly prevalent. Thus, it has been considered as forming an extra protective covering to the ripening ovum, as a plug to check hemorrhage after bursting of the follicle, and as a kind of splint steadying the tissues during the process of healing. Clark has pointed out that it is evidently associated with a method of repair, which leads to little formation of connective tissue, and has well stated that if the ruptured follicles were healed by the ordinary method, the ovary would be converted into a mass of connective tissue, which would render the escape of ovums increasingly difficult.

On the other hand, Fraenkel and others who adopt the physiologic interpretation, emphasize the well-known structural resemblance of the fully-formed corpus luteum to a ductless gland, since it consists of rows of large epithelioid cells — the lutein cells, arranged somewhat radially, strands of delicate connective tissue containing blood-vessels ramifying between the columns. Fraenkel holds with Sobotta and others that the yellow body is derived from the membrana granulosa, and that thus an epithelial origin is obtained for the cells of the glandular organ. I have already pointed out that many authorities hold that the corpus luteum is derived not from the membrana granulosa, but from the connective tissue external to the latter, while a considerable number hold that the membrana granulosa is itself of connective-tissue origin. If the latter view be correct, and the glandular nature of the corpus luteum be established, such a marvelous transformation of connective tissue is without parallel in any other portion of the human body. But even if its origin be epithelial, it is equally remarkable and unique that a glandular function should be carried on during many years by a continued series of new formations in different portions of an organ.

In considering Fraenkel's hypothesis, various questions suggest themselves for investigation. If the corpus luteum causes the phenomena of menstruation, why is the latter function limited to the primates? Born has pointed out that in all animals in which there is a uterine insertion of the ovum there is a well-developed corpus luteum, whereas in all other animals the latter is either rudimentary or not developed at all. In all mammalians above the monotremes the ovum is implanted in the uterus and the corpus luteum is well developed. The absence of menstruation in the great majority of these must either be due to some peculiarity of the corpus luteum or to other unknown reasons.

If the corpus luteum presides over the implantation of the ovum through its internal secretion, does the latter influence the ovum by passing to it through the maternal tissues (where presumably it circulates) or is the ovum already influenced at the time it escapes from the follicle? Fraenkel's experiments seem to negative the latter hypothesis, for if the ovum reaches the uterus already charged with the secretion, destruction of the corpora lutea in the rabbit might not be expected to affect its implantation. It is therefore more reasonable to suppose that contact with the uterine mucosa in which the ovarian secretion circulates leads to the conditions which determine the imbedding of the ovum. From histologic studies it is now known that the implantation of the ovum in the mammalia occurs after certain changes have taken place in it, that in the vesicular stage there is a proliferation of the outer layer of epiblast forming the trophoblast which has the power of attaching itself to the uterine mucosa, of absorbing the latter and burrowing into it. Is this power dependent upon the influence of a circulating ovarian secretion? Hitherto it has always been believed that these changes were possessed by the ovum itself, for in animals developed from ovums which find no resting-place in the body the development of the ovum does not depend upon the maternal organism.

It must, however, be believed that in the higher mammals, at least, some special complementary characteristic must be found in those areas of maternal tissue on which the ovum grows. In the human female, for example, as I have already pointed out, a particular portion of the Müllerian tract, viz., the mucosa of the corpus uteri, is the normal seat of implantation. The normal occurrence of a decidual reaction in this area has already been noted. Is it possible that this peculiar change is brought about by the ovarian secretion and is a prominent indication that the tissues are favorable to the reception of the ovum?

Recently various authors have suggested a connection between abnormal conditions of the ovary or corpus luteum and aberrant developments of the ovum. Thus several cases have been described in which hydatidiform mole has been associated with disease in the ovary, especially cystic degeneration. Pick has recently made a careful study of a case in which excessive production of lutein tissue was found in the ovaries, and he regarded this condition as the cause of excessive chorionic development, leading to the formation of hydatidiform mole. In chorioepithelioma this author, Runge, and Jaffé have also described excessive production of lutein cells in the ovary, which they are inclined to consider as the cause of the chorionic growth. In several specimens of ovaries examined by Pick, Stoeckel, Runge, and others, in addition to cystic changes in Graafian follicles and corpora lutea, collections of lutein cells were found scattered through the ovarian stroma. Careful study of a larger series of ovaries must be made before any positive statement can be made in regard to the association of changes in them with abnormal development of the ovum. It is certainly difficult to explain the occurrence of hydatidiform mole in a twin pregnancy by the lutein secretion hypothesis. If over-production of the latter be the sole cause, it is strange that both ovums should not be similarly affected.

The Antagonism between Maternal Organism and Ovum. For several years the idea has been steadily gaining ground that the maternal organism during pregnancy is very commonly affected by circulating toxic substances, and that many disturbances, both of major and minor importance, are caused thereby. This view has been chiefly prominent in recent investigations concerning the nature of eclampsia. Though little success has been obtained in the identification of specific toxins, there has been plenty of speculation as to their source and nature. The maternal organism has been considered the chief source of their production, the contribution of the ovum being generally regarded as of minor importance.

Recently, however, a new theory attributes to the latter a much more prominent rôle than has hitherto been suspected. In addition to the passage into the maternal circulation of the waste products of fetal metabolism, it is believed that there is a continual warfare between the chorionic layers of the ovum and the maternal tissues, that the proliferating and invading tendencies of the former are continually antagonized by the latter, and that a toxic chorionic internal secretion is produced which is neutralized or destroyed by maternal influences.

In normal cases of pregnancy it is considered that there is established a kind of equilibrium between the ovum and maternal organism; that in some abnormal cases the ovum suffers as the result of predominant activity of the maternal elements, while in others the maternal organism suffers when the ovum is in the ascendant. In the former instance the ovum may be destroyed and abortion result; in the latter the mother may exhibit phenomena of various kinds, from the minor nervous and alimentary disturbances of pregnancy to such marked disorders as pernicious vomiting or eclampsia. This same theory would also explain the rapid growth of chorionic tissue after pregnancy, giving rise to chorioepithelioma malignum, as mainly due to some defect in the maternal factors which normally counteract the excessive proliferation of chorionic epithelium.

These newer lines of thought have followed close upon the establishment, by recent workers, of the exact histologic relationships between the human ovum and uterus. It has been demonstrated beyond doubt that the early ovum in its vesicular stage is characterized by a proliferation of its outer epiblastic covering forming a layer of cells, distinct from one another, known as the trophoblast, and that through the activity of this layer the ovum burrows into the superficial part of the uterine mucosa, where it becomes completely imbedded. The trophoblast continues to extend outward in all directions, lacunas appearing in it. Into the latter, blood finds its way from maternal sinuses which have been opened by the phagocytic activity of the trophoblast. The entire trophoblast is in this way converted into a sponge-like structure. The lacunas enlarge, and the trabeculas between them become smaller. The former are the forerunners of the permanent intervillous spaces of the placenta, the latter of the villi. The trophoblastic cellular trabeculas are gradually penetrated by the mesoblastic layer of the chorion in which the terminal branches of the umbilical vessels carry on the fetal circulation. As soon as lacunas appear in the trophoblast a change takes place in the cells of the latter lining the lacunas. They appear to become fused into a continuous layer of nucleated protoplasm in which no cell outlines can be distinguished. This is the earliest stage in the formation of syncytium, and was regarded by Peters, in whose specimen it was demonstrated, as caused partly by the pressure of the maternal blood in the lacunas, partly by the influence of the blood-plasma; in some parts, also, blood-corpuscles appeared to become degenerated and to fuse with the trophoblastic cells.

As pregnancy advances, the syncytium rapidly increases so that it covers the entire chorion. The unaltered trophoblast cells subjacent to the syncytium form the layer universally known as Langhans' layer. Wherever the chorion comes into contact with the maternal decidua, evidence of invasion of the latter by the former is found, but it is chiefly noticeable at the site of the placental portion of the chorion, the decidua serotina. Here in the early weeks of gestation irregular extensions of syncytium may be found. They are chiefly noticed in the compact layer of the serotina, but are observed in the spongy layer, and even in the muscular wall. Portions undoubtedly extend into maternal blood sinuses, to whose walls they may become attached. Small portions of syncytium also may be carried away in the venous circulation. That this may take place throughout a considerable period of pregnancy is highly probable. Several authors hold that pieces of villi, comprising both epithelial and connective-tissue elements, may also be deported, though I have never observed this in normal specimens. Whatever be the extent of the process no important anatomic lesions in the vessels of the lungs or elsewhere have been demonstrated to result from them. The chorionic fragments are very small and are probably rapidly disintegrated in the maternal blood. Their destruction is explained according to Ehrlich's now well-known hypothesis. The foreign fragments produce a substance which fixes them to the red blood cells, and which also enters the serum, forming an antitoxin, which tends to destroy the fragments. Veit has termed the latter syncytiolysin. Various experiments have been made in support of the view that the chorion produces a toxin which may cause various morbid changes during pregnancy unless continually destroyed by the maternal organism. Thus Politi injected sterile filtered extract of human placenta into rabbits, producing death in some cases with spasms and marked prostration. He states that the toxicity of the extract was lowest when the placentas of healthy women were used and most marked in the case of eclamptics. Ascoli has also made interesting experiments, in which placental infections produced some of the phenomena of eclampsia. Beside the influence of the blood in counteracting the syncytiotoxin, it is believed by some that the decidual cells also share in this function. Bandler holds, in addition, that the ovary also furnishes an element in its secretion which is antagonistic.

Functions of the Placenta. It has been clearly established that the placenta is entirely an organ of the chorion, consisting of projections of the latter termed villi, which are attached to the uterine mucosa, and bathed by maternal blood circulating among them.

Comparatively little is known as to the nature of the interchange of materials between the fetal and maternal circulations through the medium of the villi. For many years the placenta has been regarded merely as the medium through which nutritive material and oxygen passed from the mother to the fetus, and the effete products of fetal metabolism from fetus to mother; it was considered to be a kind of fine sieve, through which percolation took place, or a diffusion membrane that favored osmosis. It is now almost certain that the transmission of substances between the maternal and fetal blood is not merely a matter of physics. The chorionic epithelium is believed by many to be a highly differentiated tissue, capable of carrying on complex vital processes, possessing powers of selection, elaboration, and even digestion. Marchand has suggested that the syncytium is the chief factor in the absorption of nutritive material from the maternal blood, the Langhans layer being more concerned with the transmission of waste products from ovum to maternal blood. Cavazzani and Levi state that there is no correspondence between the quantity of urea in the maternal and fetal blood, that there is more glucose in the former than in the latter, and that the density of the fetal blood is greater than that of the maternal blood. It appears that there are considerable variations in the transmission of substances through the placenta at different periods of pregnancy. Thus, in the last three months, there is a great increase in the iron, potash, and lime stored up in the fetus. In the early months there is a great predominance of soda over potash.

Various materials may be stored in the placenta. Thus, it undoubtedly fixes glycogen. It is thought that albuminoid material is transmitted as soluble peptones, though this is not definitely known. There has been some question as to the possibility of the passage of maternal leukocytes through the walls of the villi entering the fetal circulation. Varaldo states that there are more leukocytes in the umbilical vein than in the umbilical arteries, there being, on the average, considerably more per cm. in the former than in the latter, and that more of them contain iodophilic granules in the former than in the latter. It has, therefore, been concluded by several that leukocytes normally carry substances (possibly nutriment) to the fetal tissues. This has not been proved, however. In maternal leukocythemia there is no corresponding increase in white corpuscles in the fetal blood.

The placenta acts as a protective barrier against the invasion of the fetus by various poisons. It is more efficacious against some than against others. Porak's experiments on the guinea-pig, for example, show that in this animal copper passes easily, arsenic with difficulty, and mercury, not at all, the poisons being stored to a greater or less extent in the placental tissue. With regard to microörganisms and their toxins, little is known. Many microbes are able to pass from mother to fetus, but nothing is known as to the conditions associated with the transit. It does not appear that any placental lesion is necessary. The placenta appears to be more resistant to some organisms than to others. Thus it is clearly established that tubercle bacilli rarely pass through it; indeed, cases of Lehmann and others prove that though tuberculosis may begin in the placental tissue, the fetus may not be affected. In this connection, however, it must be noted that sometimes tubercle bacilli may be present in the fetus, though no lesions be present, since inoculations of guinea-pigs with portions of the fetal tissues may cause tuberculosis.

It seems certain that in the great majority of cases the placenta is the sole route by which microörganisms and toxins reach the fetus. It is possible that they may pass through the amnion into the amniotic fluid and thence enter the fetus, but this is probably a very rare mode of injection. Charrin and Duclert's experiments on guinea-pigs suggest that the passage of germs through the placenta is helped or retarded by varying conditions of the maternal blood. Thus they found retardation when the maternal system was saturated with corrosive sublimate. When tuberculin, alcohol, lead acetate, or lactic acid were present, the passage of the germs seemed to be facilitated. Neelow has experimented on pregnant rabbits, and states that nonpathogenic organisms cannot pass from mother to fetus.

The placenta suffices to allow the fetus to grow and thrive in many diseased conditions or malformations incompatible with health or life in the adult. Pathologic conditions affecting the structure and function of the placenta endanger the life of the fetus. In many maternal diseases, doubtless, the fetus is destroyed as the result of changes in the placenta, affecting its structure or function, produced by its resistance to the toxic material in circulation.

The placenta also acts as the great excretory organ for the fetus. Savory long ago produced tetanus in a pregnant cat by injecting strychnine into the fetus in utero. The passage of other drugs has been similarly demonstrated by others. Charrin holds that toxins placed in the fetus, either directly or by the spermatozoa of the father, may pass to the mother. This might explain certain cases of immunization in syphilis (Colles' law). By injecting diphtheria toxin into the fetus in utero he has killed the mother animal. Guinard and Hochwelker have shown experimentally that the passage of drugs from the fetus to the mother is stopped if the former is killed, and that if the fetus be injected after its death the drug is only found in its tissues. Baron and Castaigne have found that drugs introduced into the amniotic fluid are also transmitted to the maternal tissues, though much less rapidly than when injected into the fetus. If the latter be dead, the substances do not pass to the maternal circulation.

I have already referred to the theory that the chorionic epithelium produces an internal secretion, which may exercise a deleterious influence on the maternal system. Some hold that it may also act as a destroyer of certain elements circulating in the maternal blood which might be toxic to the fetus if it should enter the circulation of the latter.

SHORT PAPER

DR. JOHN A. SAMPSON, of Albany, N. Y., contributed a paper to this Section on "The Importance of an Early Diagnosis in Cancer of the Uterus."

SECTION J — OPHTHALMOLOGY

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(*Hall* 7, *September* 24, 10 *a. m.*)

CHAIRMAN: DR. GEORGE C. HARLAN, Philadelphia, Pa.
SPEAKERS: DR. EDWARD JACKSON, Denver, Col.
DR. GEORGE M. GOULD, Philadelphia, Pa.
SECRETARY: DR. WM. M. SWEET, Jefferson Medical College, Philadelphia, Pa.

THE RELATIONS OF OPHTHALMOLOGY TO OTHER DEPARTMENTS OF SCIENCE

BY EDWARD JACKSON

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THAT ophthalmology has been given a place in this Congress of Arts and Science may be significant of its wonderful development in the last half-century. But it is still more significant of the new conception of what constitutes a science. There was a conception of sciences that we might compare with the representation of states in a primary geography. Each had a distinct color — pink for Missouri, yellow for Illinois, green for Kansas, with strong black lines separating them. If the color of one passed the black line and smeared the other, it was a grave blemish on the map. Receiving first geographic impressions from such a map, it becomes hard for the child to conceive that these arbitrary political divisions correspond to nothing in external nature. Lines equally distinct, equally arbitrary, equally unnatural, marked off from each other the different conventional divisions of science. To a generation trained in the older conception of separated sciences, astronomy, chemistry, botany, physiology, the failure to recognize the traditional boundaries may seem a loose disregard of valuable landmarks.

But in thought, as in geography, across all conventional lines the streams run, the winds blow, the landscape extends toward the infinite, alluring horizon. Each individual student, from the little hill or the mountain he has climbed, looks out upon a panorama of facts the exact counterpart of which no one else can view. Yet he beholds the same region that others see from somewhat different standpoints; and the breadth of his perception is determined not by busy running to and fro, rather by the height to which he has climbed in his own proper domain for a viewpoint.

The new conception of science recognizes its universal continuity; and laying aside traditional boundaries, assigns to every definite, important human interest, dominion over the territory which lies nearest it. Such is the conception which recognizes a science of ophthalmology.

Ophthalmology centres in the function of vision; a gateway — perhaps the most important gateway — between the objective and the subjective. From this centre of its domain, highways and bypaths go out in all directions, each leading to other domains of science, nearer or more remote. They run for a time fairly in the domain of ophthalmology, they end fairly at the centre of some other science; but where they cross the border lying between, no man shall say. The time devoted to this address is to be used in pointing out a few of the salient features noticeable from this particular centre of knowledge; in tracing the direction toward which the paths that centre here extend, and in indicating a few things of especial value that we are able to offer from our cultivation of the field of ophthalmology, or hope to import from other fields of activity.

The central fact of ophthalmology is the conversion of the light impulse into the nerve impulse, and this not in a single general act but by a myriad of sharply differentiated actions. We receive through the eye not merely a uniform impression of general external luminosity. Through this gateway comes a message from each separate particle of the universe. The number of such messages perceptible is limited only by a most remarkable capacity for differentiating impressions. A thirty-thousandth of a square millimeter of retina is capable of isolating and preserving the identity of a particular sensation, and of appreciating a radically different sensation ten times in each second.

This ability of the retina to differentiate impressions is of value only when connected with a correspondingly minute accuracy in the assorting of the rays falling upon it; and this minute accuracy in the assortment of these rays depends on the perfection of the dioptric apparatus of the eye. Its capacity for successive impressions depends on the rapidity of renewal of physical and chemic conditions — upon the perfection of its nutrition. To supply and maintain by most delicate adjustments and compensations, these two things, the dioptric assortment of rays and the nutritive conditions of vision, are the essential purposes of the eyeball and its appendages.

On the one side ophthalmology extends to include the whole science of optics. Optical instruments are but artificial extensions of the organ of vision, conditioned by its limitations, of value as they serve it. On the other side few processes of human physiology are without important bearing on ocular nutrition; and more distant processes, biologic, chemic, and physical, throw light upon the problems of ocular nutrition. On the one hand we have the mathematic and physical phenomena of light; on the other the physiologic balance of health and the imbalance of disease.

Ophthalmology was developed from both sides. The physicist and the optician with lenses and more elaborate instruments endeavored to correct the imperfections and extend the usefulness of the dioptric apparatus. The physician traced and combated in the eye morbid processes similar to those that he dealt with in other organs of the body. There is still a reactionary tendency to split the field of ophthalmology along the old lines. From the side of the optician the desire for maximum immediate material results with a minimum of science; and from the side of the physician the unwillingness to overstep the traditional boundaries of a medical education, and train the ophthalmologist in mathematic and physical optics, still favor one-sided and partial studies and views of ophthalmology. The real unity of science, and the importance of the sense of vision in the life of our modern civilization will, in the end, compel a view of the whole field from the true standpoint. But the opposing influences of a hasty commercialism, and a blind if not fossilized conservatism, must be met by the assertion and reassertion, clear and emphatic, of the unity of ophthalmology.

Physics and Mathematics. The two halves of the ophthalmic domain have been alluded to. Let us go into the relations of each of them a little more in detail before turning to special lines of thought that lead out toward the other domains of science. On the physical side of ophthalmology the general laws of refraction and the properties of lenses have been worked out nearly to the practical limit of minuteness. The exact changes in the dioptric mediums and surfaces of the eye, which occur with age, and in the act of accommodation, are still uncertain. This point at which physics and physiology come together is one of especial interest. More minute studies of both the physical conditions present in the crystalline lens and the physiologic processes which change them may yield suggestions of wide applicability both in general physiology and in general physics.

That part of the physical side of ophthalmology concerned with the movements of the eyeball, which secure and maintain binocular vision, has of late years attracted much attention. A voluminous literature regarding it has arisen, the bulk of which, to speak frankly, is worth very little. This literature exhibits with painful emphasis the general lack of a broad training among physicians which leaves them unable to grasp and use to advantage essential physical and mathematic conceptions. The same defective training is also seen in the crudeness and inefficiency of physical methods that have been widely resorted to for the correction of imperfect physiologic adjustments. The unknown being always great, the surgeon, painfully aware of the limitations of his knowledge of physiology, seems to have placed a blind faith in mechanical readjustments, of the limitations of which he was still more ignorant.

Fortunately, the importance of physiologic development for the perfecting of the function of binocular vision has been recently emphasized. Binocular vision is, comparatively, a late acquirement in the evolution of the race. The capacity for it is still rather liable to imperfect transmission from generation to generation. The instinctive reactions and efforts of the child in this direction often need to be guided, assisted, and supplemented. A better appreciation of this evolutionary process and its recapitulation in the individual becomes the antidote for blind dependence on crude mechanical remedies.

Physiology. Turning to the physiologic side of ophthalmology, it may be noted with regard to the growth and nutrition of the eyeball that these are strikingly determined by inherited tendency, and are markedly perturbed only by accidental influences of the severest type. The great mass of eyes approach marvelously near to a normal standard, independently of use or of influences affecting general nutrition. This is illustrated in the retinal development of eyes, the seat of congenital cataract; in the full growth of the eyeball among influences that stunt the general body growth, in the maintenance of function in spite of extensive wounds, and in the strong resistance to the extension of suppurative processes.

In view of the slight perturbation caused in the nutrition of the ocular tissues by moderate influences, it seems easy to understand why physiologic experiment upon the eye has thrown little light upon the normal processes of general nutrition. The influences of sugar and naphthalin in causing opacity of the crystalline lens remain after many years phenomena almost completely isolated and not well explained. The opportunity for the experimental study of pharmacology and of processes of nutrition which seemed to be opened by the discovery of the ophthalmoscope has so far proved rather disappointing.

Pathology. The disturbance of the orderly course of nature within the eyeball is, however, only a question of the adequacy of the disturbing force; and causes capable of producing pathologic results may here be studied through the characteristic series of their effects. The transparency of the ocular mediums enable us to watch undisturbed the usual course of pathologic processes within the eye. This has been of highest value in giving exactness and definiteness to some of our ideas regarding pathology. In the way of contributions to exact knowledge of the processes of exudation and resolution that attend inflammation, and of advanced knowledge of vascular and nerve lesions, much must be credited to ophthalmology. Yet the opportunity it affords for the study of pathology, experimentally or clinically, has thus far been utilized by few, and along comparatively narrow lines.

General Medicine. Ophthalmology has the closest relations with all other departments of medical and surgical science. The general tissues which make up the body at large also enter into the eye and its immediate surroundings. They are here liable to the same morbid changes, and in some measure require the same applications of therapeutic forces. The infections, acute or chronic, have their characteristic ocular manifestations. The degenerations may here be traced, many of them with more minuteness and from an earlier stage than is possible in any other organ. It would be easy to spend time in outlining these relations of ophthalmology which have been the subject of treatises on the eye in relation to general diseases. But it was the "Father of Medicine" who pointed out, "art is long and time is fleeting." Omitting any such general survey of matters which have already claimed considerable attention, let us trace, as equally instructive examples, a few of the newer or less commonly noted relations of ophthalmology.

Bacteriology. Great interest attaches to observations that have been made in the region common to bacteriology and ophthalmology. The pathogenic action of microörganisms can nowhere else in the human body be so readily, directly, and continuously studied. Already the known bacterial flora of the eye, both normal and pathologic, is a large one; and the characteristics and relationships of some of the organisms found there have been quite widely observed and commented upon. Valuable studies of the actions of bacterial toxins upon the living tissues of the eye have been made by Morax of Paris, and Randolph of Baltimore. But their observations are so far from being conclusive that they call for additional investigations to reconcile them.

The identity or non-identity of certain related forms, as the diphtheria and the xerosis bacilli, are of equal interest and importance to students of both sciences. The observation that the same clinical types of inflammation may be associated with the presence or unusual abundance of totally different forms of bacteria, as the pyogenic staphylococcus, pneumococcus, diplobacillus and xerosis bacillus, has been made by many different workers in this field. It raises the questions, what is the essential relation of these organisms to the inflammatory process, and is that relation necessary or merely accidental?

In the eye we have admirable examples of inflammation due to nonbacterial causes, like the retinitis following the excessive use of the eyes, or exposure to excessive light; the choroiditis attending myopia; and the inflammations of the conjunctiva and lids due to eye-strain. Have such pathologic processes any necessary relation to bacteria whatever? What other processes resembling reactions to microörganisms may be reactions to unknown causes quite unrelated to bacterial invasion? It may be suggested that certain forms of ocular disease, such as "Parinaud's conjunctivitis" and "vernal conjunctivitis" ought to be carefully studied for a possible connection with microörganisms other than bacteria.

Neurology. The relations of neurology with ophthalmology are so extensive and so intimate that the boundary between them would vary enormously with the taste or training of the individual who undertook to delineate it. *Die Neurologie des Auges*, of Wilbrand and Saenger, has already reached some 1500 pages and promises to extend indefinitely. Of the twelve pairs of cranial nerves, six are distributed partly or entirely to the eye and its appendages. Peculiarly intimate relations and analogies existing between the retina and the brain give to observations made upon the former a unique scientific interest and value. Then, too, the dependence placed upon the visual function in nearly all occupations and amusements gives it a predominant influence upon the general condition of the nervous system.

Fatigue, neurasthenia, excessive irritability, sluggish and defective development of the higher centres are likely to be very closely connected with abuse or defect of the visual function. The term eye-strain may be loose, indefinite, and faulty, but behind it stands an entity of enormous scientific and sociologic importance. Those who have most strongly emphasized its importance may sometimes have betrayed narrowness of view, and a disposition to reason from mere plausible hypotheses; but the known facts with regard to the influence of abnormal use of the eyes upon the functions of the general nervous system justify more general attention than has yet been paid to them.

Psychology. In the motor and sensory phenomena attending eye-use and eye-strain, we have an open path to intimate experimental knowledge of the general nature and relations of nerve actions and states, both normal and pathologic; and may make the closest approach to objective knowledge of the phenomena of consciousness. One need have but a limited knowledge of ophthalmology and neurology to travel this path and bring back results of great value, as did Joseph Le Conte. Other similar investigations would yield additional matter of high interest for its relations to psychology. Close observations of form, as modified by lenses and prisms; and of color as modified by contrast, and preparatory treatment of the retina, are open to all normal-sighted persons. The careful study of these elementary perceptions must furnish an essential stone for the future edifice of mental science.

The ordinary subjective tests of refraction, which occupy so large a part of the time of every practicing ophthalmologist, furnish data which, carefully selected and arranged, would be of much importance in psychology. The response to the simple test of improving or impairing vision by a change of lens shows characteristics constant for the individual, but which vary widely in different persons. The routine which any one adopts in the subjective testing of ametropia furnishes the fairly constant conditions of experiment calculated to best bring out class types and individual peculiarities of reaction. Surely some ophthalmologist interested in this matter will place some of this material at the command of students of mental science.

Laws of Heredity and Congenital Variation. Attention should be called to the fact that ophthalmology offers an important and promising field for studies of the laws of heredity. I have already referred to the tendency exhibited by the tissues of the eye to adhere strictly to type, in their development and in their resistance to accidental influences. Already enough has been observed to warrant the supposition that, in the eye, departures from the normal type are themselves apt to be typical. Take the well-known facts regarding congenital defects of color perception. The similarity of the disability in enormous numbers of cases, and the tendency to descend to grandsons, through the daughters only, are strongly typical. Such typical instances would seem to promise most for an elementary knowledge of the laws of heredity — those laws which have the widest and deepest importance for the sociology of the future. It must be mentioned, however, that this law of descent through the female to the male does not apply universally. We have in ophthalmology enough groups of exceptions to quite limit and define its scope.

The range of ophthalmic observations already available in this direction is a wide one. The congenital anomalies of the eye and the individual peculiarities it may present, as to color of iris, pigmentation of the eyeground, distribution of vessels, and especially anomalies of refraction, as well as the ocular diseases, have been well worked out, and they are capable of comparatively exact notation and record. Statistical studies regarding them, extending over family or race groups, can be relied on as giving facts of definite value. There are already accumulated many observations of great interest in this connection. The reversion to an ancestral type of pigmentation, in retinitis pigmentosa, the striking condition of amaurotic family idiocy, the predisposition of the Hebrew race to glaucoma, and of the negro to phlyctenular disease, and the comparative freedom of the latter from trachoma, lachrymal obstruction, and strabismus, are instances of a long list of ophthalmic facts that will help to reveal laws of congenital variation and heredity.

Education. From the field of ophthalmology we can bring suggestions of radical importance as to methods of primary education. The educative treatment of squint is truly an educational process; and of the simplest and most definite kind. How development of power and skill goes on under it may well claim the attention of the philosophic teacher.

In congenital word blindness, to which attention has been directed of late years by Hinshelwood and Nettleship, we have a suggestion of the obstacles that may lie in the way of the ordinary training of children. A bright, exceptionally successful teacher told me she had devoted three months to the attempt to teach an apparently bright and active boy of over six years the names of the first three letters of the alphabet, and had failed in that time to fix either of them in his memory. I have encountered two of these cases of inability to name the letters seen, although the alphabet could be repeated forward or backward by rote. In both of these cases, as in most of the other reported cases, this disability subsequently disappeared. Evidently there is a time to teach the alphabet and a time not to teach it. In these cases the times varied widely from the normal standard. How many other mental capacities are there the development of which may be exceptionally early or long delayed? How often is the usual order of development reversed? The complexity of the relatively simple act of vision, its inability to render a certain service because of the retarded or imperfect development of a subsidiary power, should be enormously suggestive to the student of pedagogy.

The ophthalmic history of our schools enforces a lesson that needs to be remembered in every application of educational science. By the training given to and through an organ, and intended to perfect its powers, it is possible to render it functionally worthless. The connection of myopia with the educational process of a certain kind is as well established as the connection of choroidal atrophy, retinal detachment, and cataract with myopia. Then, too, the curriculum and conditions of study which leave the eyes of one scholar unharmed ruin the eyes of others. Will not the analogy between eye and brain carry over the ophthalmic observation as another important suggestion to those who study the theory of education, and work out the educational schemes to which young persons are subjected?

Preventive Medicine and Public Health. It requires no stretch of imagination to apply the observed facts regarding the deterioration of the eyes during school-life to the service of preventive medicine and public health. The separate statistical studies of school-children's eyes are now numbered by hundreds or thousands. Some are of much higher value than others. But taken together, they afford a broad and substantial basis for the conclusions: that as schools are now conducted throughout the civilized world, school-life taxes the eye to near its full capacity for active work; that unfavorable influences, like insufficient light, uncorrected ametropia, or impaired general health, render the strain of school-life disastrous, and cause the eye to be permanently damaged. That merely the normal requirements of the body during a stage of rapid development may cause break-down under ordinary school-work, with comparatively favorable conditions; and that when working to near full capacity, individual needs and peculiarities must be taken carefully into account. The enormous aggregate of disability and suffering, brought about by disregard of these conditions of maximum effective work, make these studies of the eye under school-life very important to those who labor in the field of preventive medicine.

These studies of the eyes of school-children also have for those who study abnormal psychology the suggestive value of very definite and accurate observations in a related field. It is chiefly because of the analogies of eye-strain and brain-strain that we cannot admit extravagant claims for the influence of the former in causing all the ills that the nervous system can manifest. If correction of errors of refraction will not prevent all sorts of neuroses and psychoses, the study of eye-strain and its prevention will throw as much light upon the nature and prevention of brain-fag and nerve-strain as any line of study open to the worker for the prevention of such conditions, be he neurologist, teacher, or social reformer.

In another and quite different direction the straight course of the ophthalmologist, working at his daily routine, carries him into the domain of public health. The group of contagious inflammations of the conjunctiva, especially the still indefinite condition called trachoma, are of enormous importance for their bearing upon public health. Social customs, the regulation of immigration, and the economic and educational problems raised by blindness, are all intimately interwoven with the recognition and treatment of these diseases.

Training of the Worker. Finally, an essential relation of each department of science to other departments is the educational relation. This vast accumulation of observed fact and analogy, of connected cause and effect; this mighty web of interweaving generalization, which our Congress of Arts and Science attempts imperfectly to reflect, — this huge phenomena of modern science, — is of value chiefly as it becomes possible to transmit it from generation to generation. It is the application of knowledge to the needs of men.

and the answering of the questions which perplex them, that quickens it and vivifies it — that renders it prolific and immortal. Ophthalmology the science is vitally interested in the training of those who apply ophthalmology the art. The greatest service will be rendered to it and through it to mankind by that institution of learning that will establish a broad, well-planned department of ophthalmology for the thorough training, both optic and physiologic, of those who are to apply its accumulated facts and generalizations. The progress of ophthalmology is to-day seriously impeded by the lack of rounded education in all directions from its essential centre.

Clearly it belongs among the medical sciences. It can continue to grow and prove fruitful only through its connection with their common educational root. But it differs from all other departments of medical science. And that difference, involving a good working knowledge of mathematics and skill in minute observations and delicate manipulations, requires that the specialization in the training for it shall be great, and shall begin early. Difficulties in the way of the required specialization will suggest themselves to any one who has struggled with the problems of medical training. But many of them will disappear as the educational scheme is made to take its proper relation to the peculiar individual needs of each student. As we learn to furnish each growing mind conditions for its best development, the difficulties of teaching a specialty will grow less. When we have given up that barbaric ideal of forcing a living consciousness into a set mold, we shall get away from the notion that an ophthalmologist can be best grown in the region of general surgery, and when ready to bear fruit in that field can be safely transplanted to the outlying clearing of ophthalmic science, where he seems to be needed.

The process of obtaining educative material must be broadly selective. There must be selection on the part of the teacher and selection on the part of the student. We must learn the lesson that the achievements of the race outrun the possibilities of the individual. Even in the free atmosphere of thought, if we take some, more must be left unbreathed. Not that what is taken is of any better quality, simply that it is nearer and can be utilized by less waste exertion. So for each student certain things lie near at hand, within the easy reach of his interest. They may be no better in the abstract, and yet they are better for him. To drag him away from them to seek more distant mental pabulum is to waste a part of his life. In this matter of education, economy of vital force demands that we respect the possibilities and limitations of the individual.

Upon a thousand fields of discovery eager workers push back the ever-widening margin of the unknown. In a thousand laboratories crude fact, treated in the crucible of experiment, is yielding its gold of wisdom. Analysis opens all doors and probes all secrets. Meanwhile fancied boundaries and limits disappear, systems of philosophy fall to pieces, lie in historic fragments for a little time, and then are forgotten. But there are not lacking higher synthetic movements. On the one side becomes more and more clear, order, eternal and infinite, while on the other rises ever more dominant the developed thinker and worker — his union of knowing with doing, the human expression of a divine synthesis.

THE NEW OPHTHALMOLOGY AND ITS RELATION TO GENERAL MEDICINE, BIOLOGY, AND SOCIOLOGY

BY GEORGE MILBRY GOULD

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The distinction between what may be called the old ophthalmology and the new is one of almost unique clearness, as compared with that of other departments of medicine or science. Especially in medical practice, the modern status has usually grown out of the older and oldest by infinitesimal increments and gradual modifications. In opthalmology it is not so, and this fact explains why there are such profound differences of opinion as regards the claims of the new. Although both are usually practiced by the same men, they may be, and often are, as distinct in origin, theory, and practice, as, *e. g.*, are otology and ophthalmology.

The "old ophthalmology" was, and is, concerned with inflammatory and surgical diseases alone, remaining ignorant of and indifferent to such relations as might exist between the eye and the general system, except as regards those minor and few diseases which arise in the body and then affect the eye. Ocular inflammations, ocular operations, and the ocular results of systemic disease — these were the limits of its interests. Even in recent text-books on medical ophthalmology, there is no thought of any other relations of general medicine and ophthalmology than those morbid ocular ones originating outside. That the eye is the starting-point of systemic disease was unsuspected. In the latest, greatest, best, and most official text-book on general medical practice, that of Allbutt, there is not a word, from the first page to the last, which hints at the ocular origin of any systemic disease, not even of headache. In the text-books of general medicine by Continental authors there is the same official ignoring of the claims of the new ophthalmology. In America also most of the text-books either ignore entirely, or, what is worse, list the remote causes of one or two systemic symptoms as possibly due to the eye, but so mechanically and inattentively as to turn the student aside more effectively than the silence of the utter ignorers. The "praise" is very "faint" indeed, with which they condemn.

The new ophthalmology finds its objects of study and interest precisely in these systemic results of ocular conditions. I do not mean in such ways as the circulatory or metastatic transfer of inflammatory or infectious diseases from the eye to other organs, nor to the extension of localized inflammations to adjacent or even distant ones. That is another matter, and of it the old ophthalmology took sufficient cognizance. The field of study of the new ophthalmology is topographically well defined, its title clear, its methods, instruments of culture, the seed, and the crop itself, distinct, both genetically and evolutionally.

The abnormal conditions of the eye which set up morbid systemic results may in strictness scarcely be called abnormal except by a strain put upon the word. At least they are *per se* not morbid. They might better be called physiologically aberrant or variant. They do not originate in inflammatory or pathologic conditions, but simply in optical ones. But for us all physical optics leads to physiologic optics. Primarily and fundamentally it pertains to the eye as an optical instrument, but as a living one, a physiologic camera obscura. If the photographer's camera had an elastic lens instead of a rigid one, and if its refractive power were spontaneously governed by the desire of the camera for an accurate focus of the picture, the analogy would be almost perfect. But the photographer's camera can neither direct itself, nor renew its own sensitive plate, so that in spontaneous choice of scene, change of focus, and renewal of sensitive plate, the living camera is superior to the dead one. The natural difficulties of the choice of scene and of the resensitization of the plate have been beautifully overcome in the eye by the God of evolution, but other obstacles have not been overcome. The ocular camera, for instance, is double, and stereoscopic, and accurately to superpose the images of both cameras is frequently impossible even after ages of workmanship. As all physiology leads to pathology, so, for physicians, all physiologic optics ends in pathologic optics. The twelve ocular muscles have a highly complex and skilled task; hence heterophoria and strabismus. Moreover, the spontaneously elastic lens grows inelastic in forty-five years, and presbyopia, at least before the days of spectacles, was a frightful tragedy. Lastly, the transparent lens could not formerly retain its transparency in old age, and the blindness from cataract at the end of life has not yet been entirely prevented.

But the chief difficulties of the mechanic of the living camera were to secure to 1,500,000,000 human beings, and to their successors in each generation, eyeballs which did not vary more than about $\frac{1}{300}$ of an inch from a given diameter, and to make all corneas of the same radius of curvature in all meridians. These difficulties have been so great that there has probably never been such a mathematically perfect and optically exact pair of eyes in the world. Those chosen by natural selection, the elimination of the unfit, and the mystery of heredity to survive and to repeople the earth, have been such as were not so widely variant as to disqualify their possessors for work and service; and the majority of their children, those now living in the world, have eyes so near accuracy in optical dimensions as to render their owners at least partly functional in the evolution process. This almost infinitesimal variant of $\frac{1}{300}$ of an inch, the thickness of a sheet of paper, in eyeball measurements may throw the unfortunate possessor out of the struggle for existence, so far as perpetuation of the race goes, at least in civilized life, and for some occupations, or it may render him a most pathetic sufferer. I say it may do so, not that it does do this invariably or generally. The simple law is that the greater the ametropia the greater the certainty that it will do so, and the more limited the range and choice of occupations. The lower, not the positively lowest errors of refraction, however, in civilization are those which in moral persons cause the greatest personal pain and suffering. The high errors brutalize, immoralize, and exclude the owner from most occupations; the lower cause pain and illness.

Eye-strain is the unfortunate and inexpressive term that has come into use for the results that follow the attempt of the eyes, brain, and corelated organs to neutralize the defective function of the optically imperfect eyeballs and mechanisms. The optical defect is not morbid; it is at best pathogenic, secondarily or indirectly, not primarily. Its secondary effect, the straining of physiologic muscles and nerve-centres, is not in itself necessarily pathologic. But it illustrates, and best illustrates, the great truth which textbooks, teachers, and medical science itself, are sadly prone to forget, that abnormal physiology is the origin of most pathology. Unnatural action and over-action start the morbid function which finally lands the physiologic upon the post-mortem table. To ignore this truth is itself pathologic pathology; to scorn it is to add unscientific sin to the symptom-complex of the scientist's disease. It is gratifying to find a reaction taking place — the beginnings of it at least. The magnificent paper of Dr. Putnam of Boston, read at this Congress two days ago, is a hopeful sign of progress. I am sorry he omitted the most striking illustrations of his thesis at his hand, the production of headache, migraine, nervous, mental, digestional, and scoliotic diseases, by eye-strain. The etiologic agency in these cases is both organic and functional, according to the point of view, but — and for this he contended most warrantably — it is preeminently physiologic instead of anatomic, — at least not in the sense given that word by the pathologist of the past. The pathologist of the past has, indeed, completed his work. The great need of the future is physiologic pathology.

It should be noted that as eye-strain is itself simply functional,

— if the word, as I think, is still permitted, — not organic, so its results are at least primarily the same. Headache, the paroxysmal neuroses, many nervous and psychic disorders, epilepsy, chorea, migraine, sick headache, gastric, digestional, and pelvic disorders, dermatoses, influenza, anemia, denutrition, etc., when due to eye-strain, are at first and essentially purely functional. Even those more severe diseases, such as spinal curvature, appendicitis, pulmonary diseases, exophthalmic goiter, etc., which are sometimes directly and indirectly the results of eye-strain, are at first characterized by a peculiar stage of functional and remediable disorder, preceding the organic, inflammatory, and incurable one. There are valuable and practical lessons to be gleaned from the fact of the origin of eye-strain in optics at once historic, physical, and physiologic. There is the observation that medical science and pathology did not discover it. The science of physiologic and pathologic optics came to medicine almost entirely from without. It is the gift of students of physics. Even when physicians busied themselves with it they did so purely from their interest in vision and clear-seeing, not from that of pathology. Astronomers, physicists, and opticians presented their gift to medicine. Even Donders had little or no thought of the extension of the practical science made by the practical American ophthalmologist. The earliest refractionists — we must use the word — more or less accidentally and incidentally discovered the facts of the relief of systemic diseases by their spectacles. The patients made the discovery that their headaches and nervous symptoms disappeared when they wore their astigmatic lenses, and they came back and told the astonished and delighted oculist about it. Mitchell, not an oculist, heard the story from Thomson, and he told the profession about a little of it. The profession would not listen and utterly ignored it. For several hundred years the official profession would not even have anything to do with the spectacles which the non-professional invented. It allowed Franklin to invent the bifocal lens and failed to adopt it for a hundred years. There are to-day neurologists, diagnosticians, and physicians of international renown who wholly deny that eye-strain causes systemic reflex diseases of any kind. In 1904 a special meeting of the New York Academy of Medicine was held in which great neurologists and ophthalmologists vied with each other in ridiculing the absurdity. It is no wonder therefore if the stone which the medical builders refused should become the corner-stone of the temple of the opticians. These gentlemen naturally think they have a right to practice the art and science of refraction. Those who scorn the new ophthalmology would in fact reduce the refractionist to an optician. It is a costly blunder which the profession will resent and unlearn. Because refraction is medical art and science in the strictest sense of the term, one indeed requiring the highest intellectual qualities and hence their claim can never be allowed; the profession must therefore now wage a hundred year war which it might have prevented against an enemy which it might have made a friend and ally.

What are the relations of the new and old ophthalmology? They are most intimate sociologically and clinically. In a word, the scientific correction of ametropia prevents almost all inflammatory and surgical diseases of the eyes, — I should say about nine tenths of them. It will not, of course, prevent the few ocular results of systemic disease, such as albuminuric and diabetic retinitis, optic neuritis, toxic amblyopias, etc., but such things are uncommon, and not seldom the systemic trouble had its individual grounding in morbid ocular function. The greater proportion of ocular diseases are those of the extrinsic muscles; inflammations of the lids, conjunctiva, cornea, and iris; glaucoma; high and increasing myopia; and cataract.

As to the external muscles, there is now an almost exceptionless agreement that heterophoria is due to uncorrected or miscorrected refraction anomalies, and that the plunge made into tenotomies, graduate, undergraduate, or postgraduate, was into a blind alley of error and waste which has done irreparable harm to true ophthalmology by making the professional and lay world suspicious and even contemptuous. The heterophoric trouble is innervational in nature and refractional in origin.

As to strabismus, the same truth is at last becoming manifest and admitted. A recent English book, Browne and Stevenson, on the *Squint of Children*, is a striking proof. Get glasses on the child early enough and there will be no squint. Even when the fatal delay has been negligently permitted, the operation does not do away with the necessity for the spectacles, and there are some of us "extremists" who contend that the operation is of little or no good even at the late date.

With the exception of relatively few cases, due to trauma, infections, malnutrition, etc., blepharites, conjunctivites, and keratites, are of eye-strain origin. When one sees a few thousand cases of spontaneous recovery after the patients get proper glasses, the truth needs no further mention.

As to iritis and glaucoma, did any skilled refractionist ever see these diseases appear in eyes which for years previously had been outfitted with right correcting lenses? It may be that such cases occur, but observation shows that the eye which is morbidized by eye-strain has such low resisting power that only a slight inciting cause is needed to develop the otherwise powerless hint.

Concerning retinal and choroidal diseases it is also a truism that they are usually caused by the ciliary strain of uncorrected ametropia. The "woolly," hyperemic, and suffering retinas, the "pepper-and-salt," unhealthy maculas, the abnormal pigmentations, noted ophthalmoscopically as the result of long-continued eye-strain, are suggestive and characteristic.

There is one refraction anomaly, high or malignant myopia, which is the direct consequence of disease of the eyeball. Does any one now doubt that this, the stretching or stretched eyeball, is the result of ametropia? If so, he should go to Germany to live. And why does the lens so often grow opaque in the old? Why, it would be better asked, does it grow opaque toward the end of presbyopic failure? The suggestion comes that it is at least partly because of the denutritive conditions set up by the severe strain of presbyopia added to that of preëxisting ametropia. This theory derives clinical support from the fact that cataract does not arise when the eye has been kept in an optically correct, healthy, and physiologic condition for twenty years before the cataract age.

And thus the good American motto, *e pluribus unum*, applies to ophthalmology as well as to statesmanship. In these many diseases of the eye there is often at last but one disease. There was plainly an over-hasty recourse to surgery when the surgical disease could have been prevented. As has been well said, an ancient hunger for the miraculous has come down to our times and to our medical science, and operation is the modern medical miracle. At last we have begun to see that prevention is better than cure, and the ophthalmic surgeon is becoming the refractionist. In the same way the ophthalmic therapeutist is disappearing to return immediately as the preventer of disease, the keeper of good eyes good. Therapeutics is fast merging itself into prophylaxis, and the practitioner of medicine is becoming the hygienist. It is a sort of benevolent suicide of the old ophthalmologist for the benefit of his heir, the well-insured new young man. It is fortunate that the new and the old science are in reality carried on in America by the same practitioners so that no rivalry or ill-will can take place. For a time, to be sure, the dual ophthalmologist may privately discuss with his conscience the question as to whether he will undertake to prevent the strabismus of the little one, and the cataract of the presbyope, or operate later, etc., but in this and many other similar instances I do not contend that the old ophthalmologist is Mr. Hyde, although I am sure that the new one is Dr. Jekyll.

The unity of the organism and the interdependence of all functions is the dominating and molding truth of medicine, the monism of physiology, the evolution-principle of medical science and practice. No organ lives to itself alone; there is no function that does not influence every other. This is the truth which disallows a narrow specialism, prevents the exaggerater from becoming an extremist, and forbids the extremist from becoming a hobby-rider. In obedience to it, the specialist must always be on the sharp lookout for all the lines of cause and effect which may subtly run back and forth, either way, between the diseases of his chosen field of study and that of all the other specialists. We are, in truth, all of us specialists nowadays, the general physician fully as much so as any other. While knowing profoundly one specialty, as willy-nilly we now must do, it is our common duty to maintain a keen outlook over the work of others and preserve a large sanity of mind, and a genuine sympathy of feeling with our colaborers in all other fields. The direction to speakers at this meeting is to choose out and emphasize the relations running between their specialties and those of others, between one science and the other sciences. We are to bind into unity, or preferably discover the number and nature of the existing bonds which make the organism one, and its parts interdependent, and which resolve all organisms into a universe.

The relations which exist between refraction anomalies and general medicine are almost solely of one kind, — those, namely, in which the ocular condition is causal. There are very few bodily conditions or diseases that influence the ametropia.[1] Large changes in general body weight, I have demonstrated, do so, a decided increase of fat tending to lessen the anteroposterior diameter of the globes; an extensive decrease of fat, conversely, lengthening the eyeballs. I have also noticed that after a severe illness refraction changes will probably be found. Other illustrations may be omitted.

The eye and ear have extremely few, if any independencies, and they are relatively unimportant. And yet an expert might write an interesting monograph on the subject. One would say that the dentist and oculist had little in common, and yet I have had more than one patient who had violent toothache in sound teeth whenever he read or wrote five minutes.

The specialist in diseases of the upper air-passages must never forget the oculist. It is a significant fact that eye-strain patients locate their headache directly in or behind the frontal sinuses. We list them as frontal, but understand thereby that the forehead is the location of the pain. For many years I had noticed that there was a suspicious relation between eye-strain and frontal-sinus disease, and in several patients I had definitely traced it. Dr. Phillips of Buffalo has made a close study of ten such cases in which the

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[1] Although one well-known neurologist and one orthopedist have said that the eye-strain is a result of the systemic disease rather than the reverse, — an amusing betrayal of a lack of knowledge of what ametropia is!

sinus disease was clearly due to eye-strain.[1] Reflex congestion of the upper air-passages, pharyngitis, laryngitis, aphonia, common colds, and influenza, may be, and more frequently than supposed, due to eye-strain.

In general surgery nothing, a short time ago, would have seemed more absurd than to say that eye-strain could at least prevent surgical disease and operations. Yet Dr. Robert T. Morris of New York,[2] whose character and professional standing need no setting forth, writes as follows:

"A very large group of cases of intestinal fermentation is dependent upon eye-strain. These cases are perhaps quite as often overlooked as any others, but as soon as we have all become familiar with the external signs of eye-strain, fewer cases will get to the surgeon with the diagnosis of abdominal disorder. The ones that I see are sent to the office most often with the request to have the appendix examined, because the distension of the cecum is apt to cause more pain than distention of other parts of the bowel and attention is attracted to this region. If there are external evidences of eye-strain, these cases are referred to the ophthalmologist, along with my cases of nervous 'dyspepsia' and 'gastric neuralgia,' and some of the most brilliant results that I have observed in any kind of medical practice have come out of the treatment that was instituted."

If an oculist had first made such a statement, the grin of derision would have extended across the face of the Continent. Because the general surgeon thus annually turns away from his office thousands of dollars' worth of operations, it derives at least the merit of unselfishness.

There is no truth in medicine more certain and demonstrable, although the gastrologist has not heard of it, than that eye-strain produces anorexia, denutrition, intestinal fermentation, constipation, and many disorders of the digestive organs, including, especially, the liver, although in no book on stomachal and intestinal diseases is the subject mentioned. If so, it is, of course, admitted that the surgical diseases secondary to such disorders may be ocular in remote origin, and the warning may not in future be safely unobserved by the appendicitis specialist, the gastrologist, the gynecologist, etc. Within a year a famous medical journal has editorially stated that all obscure gastric symptoms demand the excision of the gastric ulcer. That is, surely, surgery gone mad.

In orthopedic surgery a new causal relation has most recently been discovered between eye-strain and spinal curvature. Scoliosis begins in childhood and adolescence, as spinal curvature,

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[1] *American Medicine*, 1904.

[2] *Medical Record*, December 26, 1903.

and in thousands of patients the spinal disease is unsuspected by child, parent, and doctor. Within a few months I have discovered thirty or forty cases of tilted heads, most of which caused or might cause secondary or compensatory scoliosis, and all due to an axis of astigmatism (about 15° unsymmetric, and to one side of 90° or 180°, in the dominant, that is the dextral eye in the dextromanual) which compelled an habitual lateral inclination of the head in order to see plainly. And the compensatory curvature of the spine induces a score of other systemic diseases. We formerly allowed our patients to tilt the head while making the refraction tests, and so missed locating the astigmatic axis correctly.[1] By keeping the head vertical during the testing we now apply glasses that keep it straight afterwards, and when the spinal curve is still functional we likewise straighten it by glasses alone.

No pediatrist henceforth may forget the eyes in all of his patients over eighteen months old. The chances are high that, without other definite and easily ascertained cause exists, eye-strain is the source of mischief in the child which suffers from night-terrors, breakfast anorexia, tics, chorea, nervousness, disorders of digestion and nutrition, irritability, headache, etc. I have instantly cured nocturnal enuresis in such children by spectacles alone. Alert-minded pedagogists are fast becoming aware of the tremendous rôle of eye-strain in the health and success of their pupils. As every year of school-life passes, the proportion of diseased pupils increases, until in the upper grades it may rise to 60, and even 80, per cent; it is 40 per cent, on the average, in Columbus, Ohio. And the diseases are precisely those which every capable oculist knows are often due to eye-strain. The rule is so certain that discerning teachers know that those pupils who are one, two, or three years behind their classes, have severe eye-strain, and without further inquiry they are sent to the oculist. There is hardly a page of that magnificent book on *Adolescence* by Dr. G. Stanley Hall, that does not need rewriting with this new knowledge — unfortunately and strangely ignored — in the mind of the writer. Its splendid power and truthfulness could have been doubled had its gifted author looked into the vast existing literature, written by capable and scientific minds, confirmatory of the rôle of eye-strain in school-life.

In neurology there is almost no limit to what the refractionist may justly claim. And posterity will allow it, although the neurologist of to-day may often be unconscious and contemptuous of the truth. Neurasthenia and hysteria he claims as his exclusive possession. Private sanitariums or rest-cure establishments may

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[1] An excellent rule of ophthalmic office-practice is that when we fail to cure eye-strain results by our glasses, it is perhaps because we have allowed the head-tilters to hold their heads as they pleased during the tests.

be of limited and infrequent service for chronic patients whose vitality and resisting powers have been worn to a thread by a half-life of torture for which no therapeutics availed. But even the ordered rest-cure could often be avoided by correction of eye-strain, and in perhaps 75 per cent of cases the neurasthenic break-downs and chronic hysterias could have been prevented by attention to the matter in adolescence. Not infrequently it is plain that the resting is curative because the eyes are rested. With reading and writing interdicted there are often astonishing cures: with resumption of reading and writing, relapses and returns to the sanitarium are required.

Every sensation and its every correlated motion is an example of reflex action, and yet there are those who airily scoff at the very possibility of reflex neuroses and other diseases due to reflex action. There are those who speak scornfully of mysticism and mystery in medicine, while satisfied with a practice which reduces itself to diagnosis and naming unknown mysteries as migraine, neurasthenia, hysteria, psychosis, etc.

Psychiatry seems to have reached the goal of its ambition, — theoretic classification, nomenclature gone mad, and therapeutic nihilism. Diagnosing and naming a morbid mental condition as "a katatonic state," "major psychosis," "melancholia of involution," "psychical tonus or contracture," "dementia precox," "*forme fruste*," "manic depressive insanity," "confusional psychosis," "psychoneurosis," "pseudoneurasthenia," "mysophobia," "topoalgia," "neurasthenical syndrome," etc., — all of which terms are culled from one short article, — seem to end in the air so far as bettering conditions.

Who has examined the refraction of the insane? What patient with extreme eye-strain or migraine has not feared insanity? The sanest of men, Parkman, was pronounced insane, and so was Wagner and others, by great authorities, at the climax of their sufferings. Was not Nietzsche's "atypical paralysis" intimately connected with his most evident eye-strain? A competent oculist finds the majority of the young criminals of the Elmira Reformatory afflicted with so high a degree of ametropia as to make study, reading, and writing, and ordinary handicrafts, impossible. What else could many of the poor boys do but play truant and steal? The statistics showing the relation of crime to truancy indicate that some of both may be due to bad eyes. In 232 cases of suicide, 187 were due to ill-health. About 50 per cent of chronic epileptics have unsymmetric astigmatism and anisometropia, — a surprising ratio of a defect especially prone to upset the cerebral health and balance. And the peculiarity of the diseases of eye-strain is their tendency to produce psychic and emotional disorder, despair, melancholy, etc.

There is scarcely any disease which the general physician or internist is called upon to treat that may not be, and that frequently is not, due to or influenced by eye-strain. The commonest is designated by that silly and meaningless word, migraine. The term has little or no significance nowadays. It is in fact the vulgarization of a misnaming and meaningless designation of a malobserved and trivial symptom, which in the majority of cases is not present, of a widely prevalent and ingravescent disease, with indescribable symptoms, which may, in extreme cases, wreck life and morbidize the mind, the etiology and pathology of which are unknown, the location or organs affected being also unknown, and of which no treatment avails. It is made to cover the conditions indiscriminatingly called scotoma scintillans, headache, sick headache, gastric and intestinal disorders, insomnia, melancholy, etc.; in a few severe cases such patients have all of the symptoms. One symptom, dermatosis, the French physicians learned long ago, is not recognized by modern dermatologists. Severe skin-disorders are not infrequently an indirect result of eye-strain. Migraine is almost always due to eye-strain, and, except in the rarest worn-out chronic cases, it is almost immediately curable by extinguishing eye-strain. It is the commonest of all affections, the great manurer of the ground for other and terminal diseases, the supporter of quacks and patent medicine syndicates. At least 10 per cent of Americans suffer from it, under one alias or another, recognized or unrecognized. The larger number of these, taught by sad experience, have given up the hope of cure, and they are neighbors of the person who says migraine has no relation to eye-strain, and who does not know that thousands are now being cured by two little pieces of glass. Eye-strain effects have a peculiar tendency to periodicities and waves of better and worse. The nervous centres can endure for a time the burdens and irritations laid upon them, but at last give way. This is so of mental states and diseases, and the eye, as psychologists know, is the chief creator of intellect. Hence those diseases or symptoms, when not dependent upon organic disease, like headache, sick headache, fickle appetite, the paroxysmal neuroses, cardiac palpitation or irregularity, chorea, epilepsy, neuralgias, insomnia, colds, etc., which exhibit such waves and troths of exacerbation and depression, may be due to ocular irritation.

A key to many mysteries of disease might be found in a careful classification of such as have increased with civilization as compared with those conditions outside which have been changed during the progress of civilization. Among these changed conditions none can be more noteworthy than the new kind of labor, and the tremendous addition of the amount of it, thrown upon the eye by the printing-press, schools, sewing, clerical, and urban life. No other organ has been subjected to such a change of work and stimulus, and in all other functions the same kind of work is now demanded as before. The eye, however, was brought into function to use in distant vision, and if for near, for but an instant. Osler says that dyspepsia is the besetting malady of this country, due to improper diet, etc., although modern food is many times more certain in amount and good in quality than ever before. It is certain that stomachal and nutritional diseases seem to have recently increased inordinately. What is the cause of this contradiction? One, surely, is eye-strain, which is extremely prone to upset the digestive function. See several thousand cases of nausea, "dyspepsia," loss of appetite, constipation, etc., relieved at once by glasses; see the disease return at once when the glasses are broken, a lens reversed in a frame, or when the refraction changes, and one recognizes the fact of the interrelation.

Allied to this class of cases are those in which the keen ophthalmologist detects more than hints that renal affections, hepatic ones surely, including gall-bladder diseases, may possibly be set up or aggravated by severe reflexes from the eyes to the secretory and eliminative organs. Some day it will be established that eye-strain is a large factor in the production of diseases of the kidney.

One of the more subtle but still easily recognizable methods in which eye-strain works perniciously is by a slow and general denutrition and reduction of mental and physical vitality whereby the resisting powers of the system are reduced to such a degree that it becomes the easy prey of infections and of general and terminal diseases. This makes eye-strain a factor in the tuberculosis and pneumonia crusade. The life-study of patients and their diseases — the biographic clinic — will make such a connection more often manifest. The sad story of the life of John Addington Symonds is in this way suggestive.

The age-long superstition, whereby almost all the diseases of women were traced to the sexual organs and functions,[1] is fast giving way to a new view more in correspondence with facts. That puberty and menstruation should inaugurate a host of terrible evils, and the menopause another legion, is at the least contradictory. The proper name for the cause of many supposed disorders of menophania and puberty is study with astigmatic eyes; that for supposed menopausal woes, is presbyopia. In a large number of instances ὀφθαλμός may replace ὑστέρα as the organ primarily at fault. The oculist and gynecologist should be good friends. The connection between eye and sexualism is known of old, and is a deep and profound one. Love of any and all kinds dilates the pupil, the designation of the grand sympathetic system itself arising from the fact.

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[1] A sad error that much mars the large sanity and lessens the benefits of Dr. G. Stanley Hall's great book.

A certain profound relation of vision and sexualism will some time be established which as yet is unsuspected.

Justly motived, therefore is the question: why has this great truth been so long ignored, and why now do so many reject it? Some of the answers are these:

1. The progress of science has not yet reached the stage that will enable certain minds to see its truth.

2. The conditions of life and professional evolution have made surgery of supreme importance.

3. Organic diseases had first to be studied.

4. The laws and status of infectious diseases had first to be made definite.

5. A mere habit of neglecting the eye and its all-important function and diseases has with some grown into a blind dogmatism.

6. The theory of optics and the elaboration of mathematic formulas satisfied too many minds, and there was no proceeding to the practical application in clinical work.

7. Specialists in medicine, other than ophthalmologists, have overstated the effects of the diseases of special organs.

8. The ophthalmic tenotomist has made unwarranted claims, and so made the profession blind and deaf to the warranted claims of the refractionist.

9. The commercial medical journal plays to the galleries and flatters the prejudices of its readers.

10. Patent medicine venders, drug-sellers, and quackery within the profession carry on the irrational tendency.

11. Suffering and pain are positive, relief and cure negative. The patient therefore is prone to forget the former misery, nor does the physician recognize the cause of the cure by glasses, which is ascribed to fate, *gale répercutée*, the doctor, his drugs, etc.

12. The method of eliciting symptoms and of clinical note-taking is so faulty that the very existence of the chief symptoms of eye-strain is not recognized. The patient thinks the vomiting, the abdominal symptoms, migraine, headache, dyspepsia, insomnia, loss of energy, etc., have no possible connection with the eyes, does not allude to them, and they are thus wholly ignored. Thousands of such cases have been cured by glasses and the fact unsuspected by either physician or patient.

13. The desire for consultation practice, referred cases, professorships, hospital positions, and "success" make the cunning silent, or conservative. "Faddism" and "hobby-riding" charged to a budding reputation are ruinous.

14. Poor refraction work on the part of oculists is the greatest cause of skepticism. Those who do accurate refraction know perfectly well that, broadly speaking, the ophthalmologists of the

world have done their refraction work badly. The logical and pathological conclusions of the labors of Donders, Helmholtz, and others have been practically made only by some American, and one or two European, refractionists. "I sent my patient to the oculist and glasses had no effect on the disease," means utterly nothing. "Is not my oculist a man of the highest renown and ability?" may mean as little. Does this man of renown and ability teach, and in the persons of his patients demonstrate, that so-called "migraine," headache, sick headache, dyspepsia, spinal curvature, insomnia, neurasthenia, anemia, the blues, and the rest of the list, are often, very often, due to eye-strain? Belief in the truth is a prerequisite of ability to cure; and it is absolutely essential to a rigid attention to at least "78 reasons why glasses fail to give relief." From 50 to 75 per cent of glasses prescribed in the world are inaccurate and cannot relieve eye-strain. Then it is also true that fully 75 per cent of the adjusting of opticians is so bad that any possible therapeutic result is not obtained. To be entirely frank, one should add an argument which is, indeed, a two-edged sword, but which needs occasional use to keep it from rusting. It is this : Those who deny that migraine and the many other diseases mentioned may be due to eye-strain have not of course cured such patients in their own private practice. That is a self-judgment which is most severe. Those on the other hand who claim that such diseases are curable by ametropic correction, unless utterly unprofessional, must have cured such patients. If they do not cure they would surely be soon found out and their reputations and practices ruined. They seem to prosper! I heard one astute oculist say that if this absurd skepticism continued a few years longer his fortune would be made. He is very "successful" and is conducting his work in an honorable manner. The enthusiasm and gratitude of a patient permanently relieved of the tragedy of "migraine" or "neurasthenia" are irrepressible.

A corollary is that refraction is not taught, there is not a single adequate and thoroughgoing school wherein may be taught, or wherein there is any outfitting, or attempt to teach, this most skilled, most infinitely subtle and difficult art and science. Two years at least of study, daily, exclusive study and practice, —after the general course in medicine, under expert teachers, and on the part of the best type of student minds, is a too short period to introduce him to the work, and legally to justify him in entering on such specialist practice. An endower and maker of such a school would do the world a far greater service than either Carnegie or Rockefeller have dreamed of doing.

Again the critic may justly ask: Have none, then, recognized and spoken out this much unrecognized truth? Oh, yes, many and good men have done so. There is a vast body of literature produced by clinicians of the best character and professional standing, and it is astonishingly convincing and cogent. It is unfortunately scattered, and hence in part ignored by too many physicians. The last weighty utterances are Dr. Zimmerman's study,[1] and, especially since they are from England, the excellent papers of Dr. Snell,[2] and Dr. Pronger.[3] Hundreds of others might be cited, the testimonies, *e. g.*, of such good professional journals as *The Cleveland Medical Journal, The St. Paul Medical Journal, The Lancet, The Pacific Medical Journal, American Medicine, The Maryland Medical Journal, Colorado Medicine, Science, Mind, The Harvard Graduates' Magazine, Bulletin of American Academy of Medicine, Canadian Journal of Medicine and Surgery, Dublin Medical Journal, Medical Press and Circular, Bulletin of Chicago Health Department, The Practitioner, The Nation, Wisconsin Medical Recorder, Quarterly Medical Journal, Treatment, California Medical Journal, Medical Bulletin, Medical Council, The General Practitioner*, etc.

Of individual opinions a page of names could be easily cited, of men with good professional reputations acquired and to be preserved, such as, for instance, Drs. Jackson and Bates of Denver, Edes of Boston, Southard of San Francisco, Hurd, Reik, Welch, Murdock, and Halsted of Baltimore, Senn, Walker (J. W.), and Westcott of Chicago, Baker and Sherman of Cleveland, Cheney of Boston, Alleman and Prout of Brooklyn, Carmalt and Swain of New Haven, Coggin of Salem, Mass., Bennett, Starr, Pohlmann, and Phillips of Buffalo, Risley, Pyle, Thorington, Hansell, Reber, Zimmerman, Solis-Cohen (S.), Thomson, Fenton, Murphy, Talcott Williams, Hollopeter, etc., of Philadelphia, Callan, Ranny, Carhart, etc., of New York, Van Duyn and Marlow of Syracuse, Taylor of Wilkes-Barre, Würdemann and Black of Milwaukee, Roberts of Pasadena, Ellis and McBride of Los Angeles, Hale of Nashville, Matas and Souchon of New Orleans, and especially the dean of American ophthalmologists, Dr. Green of St. Louis, who for nearly fifty years has been refracting patients and observing the results. I append in a footnote[4] extracts from a personal letter written by Dr. Green, because of its peculiar appositeness.

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[1] *New York Medical Journal*, Nov. 21, 28, 1903.

[2] *The Lancet.*

[3] *Slight Errors of Refraction and their Influence on the Nervous System*, Harrogate: R. Ackrill, 1903.

[4] Dear Dr. Gould: I have read your two volumes of *Biographic Clinics* with great interest, and have gained much instruction from them. I regard them as a very important contribution to a just appreciation of the distinguished men and women whose lives you have so sympathetically studied.

The fact that the commonest ocular defects may give rise to morbid states such as you have depicted has impressed itself upon ophthalmic specialists before it was recognized and urged upon the medical profession in the classical essay of Dr. S. Weir Mitchell, *American Journal of the Medical Sciences*, April, 1876. In the nine illustrative cases reported in that paper, the trains of distressing and disabling reflex symptoms clearly parallel those analyzed by you in the fourteen

But as optics grow into physiology, and physiology into pathology, so must our pathology merge into biology. How is eye-strain related to the evolution process of living things? The test of the validity

Biographic Clinics, but with this difference: In his cases the dominant etiological factor was discovered before irreparable damage had been done, and relief followed the timely prescription of appropriate glasses; in the lives which you have discussed, relief came only in advanced age, when accommodation ceases from troubling.

To me the central and very significant fact is that the protracted sufferings, always alleviated by rest from eye-work and always recurring with the resumption of studious pursuits, as portrayed in the several biographies from which you have culled, are such as ophthalmic practitioners recognize as dependent, in many persons, on common ocular defects, and as preventable or curable by properly directed optical treatment.

It cannot be too strongly impressed on all intelligent persons, whether physicians or workers in other fields, that the demands made upon the eyes in modern life are much greater than the visual apparatus, when of only average structural perfection, can meet effectively and safely. The lesson which I have learned from forty years of continuous study of the anomalies of accommodation and refraction is precisely in the line of your teaching, namely, that no degree of anisometropia or of astigmatism can be regarded as too small to demand accurate correction in persons compelled to use the eyes continuously, or in patients suffering either from so-called asthenopic symptoms, or from headache or other reflex disorders induced or aggravated by eye-work. Neither can I accord any measure of assent to the notion that a short term of attendance at a postgraduate school, or any period of apprenticeship in selling eye-glasses and spectacles, can qualify an uneducated or, at best, a crudely educated man to do work which often taxes my own powers to the utmost, and in which I find that the continued coöperation of the patient, by returning promptly for further advice when anything goes wrong, and by permitting the necessary periodical revision of his optical correction, is indispensable.

It is surely not an extravagant contention that eyes which do not perform their function perfectly in all respects and under all conditions, or whose use is attended or followed either by local disturbances or by headache, nausea, insomnia, or other reflex manifestations, ought, without exception, to be promptly and critically examined. That such examination will very often bring to light a previously unrecognized ocular defect, and so point the way to urgently needed relief through wearing properly chosen and properly adjusted spectacles, needs only to be stated to command assent. The knowledge that relief from headache may come through wearing glasses is becoming more and more widely diffused; but comparatively few physicians have learned as yet to recognize the protean forms which reflex disorders of ocular origin may take on, or to estimate at its true value the service which a wise and conscientious ophthalmic specialist may be able to render.

The investigation and treatment of functional disorders dependent on structural imperfections of the visual organs call for the exercise of the minutest care, and often of almost infinite tact and patience. That these essential qualifications are sometimes conspicuously lacking in men eminent for their achievements along other lines is also true. Careless or perfunctory refractive work by an ophthalmic specialist will yield no better results than similarly defective work done by persons of inferior scientific attainments and of vastly less reputation. The intelligent and painstaking pioneer work of Ezra Dyer; the invention and employment of new aids to diagnosis by William Thomson; the frank recognition and just appreciation by S. Weir Mitchell of the far-reaching benefits rendered in his reported cases, by William Thomson, William F. Norris, and George C. Harlan; and lastly, the continued devotion to the cultivation of accurate methods by a long line of careful investigators down to the present day, make up a sum of achievement by Philadelphia men which may be regarded as more than sufficient to justify the recognition of a distinctive Philadelphia School.

The personal sufferings of Ambroise Paré and of Percivall Pott were the means of enriching surgical literature by two illuminating chapters on compound fracture. Your early experience of the torments and disabilities incident to a too long delayed diagnosis and correction of a complicated ametropia gives you, also, the right to speak forcibly and with authority.

Were not the Hebrew prophets decried, in their day, as enthusiasts?

John Green.

of all medical truth, and distinctively of that we have been emphasizing, is its function in the great incarnation process summed up in the Bible verity, "The word became flesh," and in the consensus of doctrine in the term, Darwinism.

A truth none can deny, but one which all biologists have ignored is this: Vision is the dominant condition of self-motility. Wherever there is an animal that moves in the light, there are eyes. *Ubi motus, ibi visus.* There could not have come into being any except the very lowest animalian organisms unless through the visual function. All nutrition, all safety, all attack and escape, all free-moving and effectual doing, were utterly and wholly by means of seeing. Thus the evolution process was dependent upon and made possible only through the evolution of the eye, both as a precedent and conditioning *sine qua non.*

And few have the most dim notion of the complexity of the organ of vision in man, or of the amazing difficulties of "Biologos" in fashioning and perfecting it. Millions of finger-tips are bunched together in the one-inch cup of the eyeball, from whence run about 425,000 nerve-fibrils to a topographic mechanism of sensation in the occipital lobe. The eye can see an object of $\frac{1}{1000}$ inch in diameter. The cones and rods are only $\frac{1}{10000}$ or $\frac{1}{14000}$ of an inch in diameter, and a million cones at the macula occupy the space of only $\frac{1}{10}$ of an inch space. These crowded finger-tips perceive the shape of the picture and the intensities of the light stimuli of all illuminated objects, of a millionth of a millionth of the kinetic energy of any other physiologic force, and of so short a duration as the 0.00144th part of a second. And out of these infinitesmal waves the sensations called light and color are created. The mechanism which creates them must be in intimate and instant connection with the centres initiating and controlling every other sensation, of every motion, of every muscle of the body. Imagine for an instant what takes place in every animal and human being every day of its existence: a traveler tells of a monkey pursued by another, and running over and through the tops of the trees of an African forest faster than a deer could run on open ground. The flashing repetitive momentary glances of the eyes, before, back, and all about a hundred objects must be coördinated with a mathematical precision to accurate unity and brilliant action of every muscle of the body. Similar perfection of eye and motion has been evolved in every higher animal of the world, and in every savage, and in every child. Your horse avoids all stones and knows, unconsciously, every inequality of the ground before and beneath him, by the like mechanismal unity. Watch little children in play barely missing obstacles and dangers which would mean injuries and perhaps death, with swift unconsciousness. The history of savagery and of civilization is all there and is of the same nature. See with unbelievable accuracy if you would succeed, is the first verse of the biologic decalogue. That is the physiologic Logos which became the biologic flesh.

But see inaccurately and you die, is the antithesis, and the animal which failed to obey perished, inevitably and quickly. The savage did the same; your horse that stumbles is useless; your playing child that hits its leg or trips becomes, at least, a very different child, and a very different man or woman from the others who do not make these visual and coördinating blunders. Such are the backward scholars in schools and, in large part, they are your failures in life, society's expensive degenerates, defectives, and dependents. And they are rapidly increasing in number with every step in civilization, because every such step means the entangling difficulty of added near vision.

All of which — and this is the heart of the matter — all of which, Darwin, a martyr to bad eyes himself, failed to see, and all of which no evolutionist has since caught sight of. And yet it has been one of the large controlling conditions of the evolution-process. For not only has this unity of mathematic optics and physiologic function been the inescapable method of success in the struggle for existence, but it has been one if not the chief mechanism whereby the so-called unfit have been thrown out of the count. Visual imperfection has been and is increasingly becoming one of the dominating causes of the exclusion of the ontogeny from the propagating phylum. This is the fundamental distinction which differentiates the laws of biologic evolution and survival of those with and those without vision. It is the key which will unlock and reveal many of the profound mysteries of heredity and descent which to-day are tormenting the different schools of evolutionists and biologists. Open the door and walk into the long-closed ancestral hall and the mystery of forbear and aftercomer is revealed. How and why we are here is at once plain. None could have been, and we could not now be, the link between the phylum of the past and that of the future, except on the condition of seeing well. Those not allowed to become such parental links were largely those who saw too inaccurately to compete in the beneficent but summary process.

Note well, however, two things: The most perfect organism in the past world of animal and man was useless without, first, this perfection of visual function, cerebral coördination, and muscular response; and, second, the attainment of this optical mechanism was far more transcendently difficult than any other physiologic task. To attain transparency and nourishment of cornea, lens, vitreous humor, and retinal end-organs, to superpose the images of the two eyeballs, to respond to the almost nothing of stimulus, to transmit to brain, to manufacture sensation, to dominate all other cerebral function, instigate and direct all motion — where is the end of the marvelous task! The end is in failure to do any one of these things, and to make that inch-in-diameter eyeball of a spheric perfection which shall not vary by $\frac{1}{300}$ of an inch from the norm. The end is not to have prevented conjunctivitis, traumatism, keratitis, iritis, glaucoma, cataract, retinitis, and other multiform diseases, prone especially to occur in the astoundingly complex and refined organism. The pathology of animalian evolution has therefore been in large part the pathology of vision. The organism otherwise perfect, except as to an infinitesmal visual part, is thrown out by this optical necessity. The mechanism par excellence of the exclusion of the unfit is thus made clear.

And to this now add the consummating and crowning function of vision, — the creation of intellect. Psychology, history, and biology unite to demonstrate that the objectivation of the ψυχή of civilization is almost uniquely by means of vision. The greatest task of all human history was the creation of the letters of the alphabet. It was so difficult that only one race did it, and within one or two millenniums all others have come to a knowledge and use of civilization only through the adoption of the invention. No writing and printing, no civilization. But the letters of the alphabet are conventionalized symbols of pictures or things seen. Add to this that language itself is of identic origin. There has been no speech except to express the result of ocular function. Almost all psychology is summarized as handlings, coördinations, and deductions of visual images, of these and of the motions made possible by sight. Thus every cerebral function, perception, apperception, feeling — most of it, and willing, — that which is effective, surely reasoning and judgment, — all spring originally and constantly, are bound up with, dependent upon, and interdependent with vision.

There is something more than mere imagery and fancy which analogizes the course and phases of these developmental stages to the way of water-flow in the world. Decidedly optical are the sun, cloud, rainfall, and snowfall upon the uplands and mountains whence spring the crystal streams and rivulets of physiology. In them optics becomes function and action, physics becomes physiologics. The lower falling brooks become discolored and morbid when they reach the homes and degradations of man, — physiology becomes pathology. But the stream broadens into the large river of biology with the commerce, the health and unhealth of a continent, until finally the Mississippi sweeps to the mothering ocean of sociology where sail and steam the navies of the world.

Thus all routes and efforts lead to man, and all biology ends in sociology. Our striving is for human betterment: because all medicine is preëminently philanthropic. The beclouded or befogged mariner orients himself by means of an optical instrument, and as the sun and the sun's winds bear the sun-made clouds back to the far-away mountains again, so vision and optical eyes and instruments again complete the morbid and therapeutic circle, the cure which is always beginning and never complete.

My contention is that here is a great means of civilization. It is a profoundly important thing that the hopeful Carlyle of the *Characteristics* should have become the pessimist of *Shooting Niagara and After.* It is civilization's tragedy that Nietzsche should have had havoc played with his mind by eye-strain; that Huxley should have been driven from work at the height of his powers; that DeQuincey should have been an opium-eater; that Darwin should have been able to work but two hours a day with his eyes, and Parkman but a few minutes. Is it not a sad thing that George Eliot and her books, Symonds and his great opportunity, Taine and his great scholarship, should have suffered as they did? Is it not a pathetic source of social misery that 10 or 20 per cent of eyes are incapable of sewing, typewriting, book-keeping, lathe-work, studying, draughting, and a still sadder thing that their owners have no knowledge of the fact, and that they should suffer until "break-down" comes? Is it not an awful thing that from 40 to 60 per cent of all school-children are sickly? That suicide is increasing, insanity and epilepsy incurable, hospitals multiplying, — and taxes, and prisons, and war, and want? A certain, perhaps a large per cent of all these backward school-children, epileptics, prisoners, insane, hysterics, neurasthenics, dyspeptics, have such eyes that glasses correcting their optical defects would bring them much relief, would often have prevented much or all of their tragedy. And the proof is this: put any pair of such spectacles on any one of us, and within an hour there would be headache, giddiness, vomiting, or intense suffering. The cynics and skeptics of "eye-strain exaggeration" can be speedily converted whenever they are earnest enough to try a simple experiment upon themselves. It is a truth awful in its significance that in civilized countries there are millions of people who are good products of the evolutionary mill, who have sound minds and good bodies, but who are partial or complete failures, always with intense personal suffering, simply because of an infinitesimal malcurvature of the cornea, a too long, or a too short eyeball, no greater than the thickness of a sheet of thin paper. It is the little thing that, overlooked by others, makes or mars all undertakings, all sciences, and all cosmic proceeding. The compass guides the ship and without it there would be no civilization as we see it. Without vaccine virus there would be a different world, there could hardly be civilization, and yet it was a generation after farmer Jesty inoculated his family from the teats of the cows in the field before even Jenner dared do the same, and before the best of the profession would have anything to do with it; and to-day there are perhaps a million anti-vaccinationists in America! When Pasteur had demonstrated what Villemin and Davaine had before said was true, the bacterial origin of some diseases, history records that "the doctors, in the great majority, were violently opposed to the germ-theory of diseases. They answered experimental proof with oratory. The less excited among them urged temporizing. The surgeon Chassaignac warned Pasteur that laboratory results should be brought out in a circumspect, modest, and reserved manner, etc." In 1843 our O. W. Holmes conclusively showed that puerperal fever was contagious. We ignored the fact. In 1846 Semmelweiss, of Vienna, independently proclaimed that puerperal fever was due to inoculation by nurse, midwife, or doctor, and that this contagion could be prevented. For this bravery and clinical acumen Semmelweiss was persecuted by his medical brethren, turned out of his professorship, and ruined. In the Paris Maternity Hospital in 1856 64 women died of the disease out of 347 admitted. In 1864 out of 1350 cases 310 died. At last in 1874 Fornier and Budin introduced the "new" views of Pasteur and Lister, and in spite of what Dr. Roux calls the "tyranny of medical education," they were accepted, and puerperal fever disappeared. Would it not have been an inestimable gain not to have persecuted Semmelweiss, and instead, to have examined and tested his theory? In 1888 Dr. G. Martin stated that "migraine" was due to astigmatism, and published proofs. In 1903 and 1904 the *Medical News* likens those who say the same thing to Dowie and Mrs. Eddy, and the leaders of the New York Academy of Medicine call a special meeting in order to snuff out of existence the advocates of such a senseless theory. And yet migraine is due to eye-strain, as any one can prove whenever he wishes, and as thousands of patients will testify whenever asked. Migraine is peculiarly a disease of civilization, increased with every added hour of near-work with the eyes; and civilization is enormously increasing that constant strain of near-work with eyes evoluted during millions of years for a different function.

There is hardly an instance in all history of a great and beneficent medical discovery that was not either ignored or hated and scorned by the official leaders, and by the great part of the entire profession. It was so with vaccination, with anesthesia, the germ-theory of disease, Mendelism, thoracic percussion, ovariotomy, antisepsis in surgery, the etiology of yellow fever and malaria, the serum treatment of diphtheria, Pasteur's anti-rabies inoculations, the humane treatment of the insane, etc.

Now the amazing fact about all of this is its ease of proof or disproof, the passionate hatred with which was rejected a possible source of relief of human suffering, the harmlessness of the trial, the utter forgetting of the patient, the supreme interest in the prejudice. Vaccination is harmless and its protective effect easily demonstrated. To tap the chest with the finger is a very simple proceeding and the sounds elicited are easily recognized. It is not difficult, if so minded, for the nurse, midwife, and doctor to be clean, and thus test if puerperal fever is contagious. The physicians who clamored against railway travel because it would make passengers sick, giddy, or insane, and said if the foolish would build railways board fences must be raised above the height of the cars, — these physicians could have got on the cars and disproved their theory. The opposers of the theory of circulation of the blood might at least have tested the theory by pricking their fingers. The prejudice against rabies inoculation, the diphtheria antitoxin, the mosquito theory of malaria and yellow fever, etc., which resulted in untold deaths and delay of scientific progress, could have been easily tested. It is childishly simple to test the power of astigmatism to produce or cure migraine, and yet many prefer not to make the test.

There are probably not a half-dozen hospitals or ophthalmic clinics in the world fitted with a trial-frame or set of test-lenses that would enable even an expert refractionist to diagnose ametropia with the perfect accuracy which is necessary to cure morbid ocular reflexes. But those set to do refraction work in the public clinics are not expert. They are the students and learners. Hence nine tenths of the glasses prescribed in these institutions are not correct. Ophthalmic surgery and inflammatory diseases are all that interest, and these would be largely preventable by the refraction that is neglected and misdone.

Even in the institutions for the blind, it has been found that some of the inmates are not blind, and that their remnants of vision may be so vastly improved as to make these dependents self-supporting. In every school of the world at least 20 per cent of the pupils are suffering from ill-health due to imperfect eyes, and yet pedagogics, except infinitesimally and incipiently, does not know and does not care. The teachers and professors in preparatory schools, colleges, universities, technical and other schools, pay little or no attention to the ventilation of the rooms, or to the refraction of the eyes of their students. These are constantly breaking down in health, or in study, from migraine, etc., and the general scholarship is vastly depreciated because of the neglect of the eyes. An official and resident expert refractionist would make a university outdistance its rivals more than, *e. g.*, does all its "athletics."

In every asylum for the insane some patients are there because of bad eyes, — and if only a few are curable of the chronic disease, many could be relieved of the headaches, gastric, and other nutritional diseases which burden the attending physicians and the taxpayer. In one great institution for epileptics, a little experiment with glasses, imperfectly executed in many ways, showed a greater percentage of cures, a greater reduction in the number of seizures, than by all other methods of cure combined that had been tried in the institution. And yet the official report characterized the experiment as "disappointing" and sneered and misrepresented it. Epilepsy, it has been demonstrated, is in many cases due to ametropia; many cases could be prevented by proper glasses in the child, or during the early history of the case. In the chronic, severe, and hopeless cases it may not be always or even frequently curable. The conditions of the glass-treatment are exceptionally difficult to carry out, and often cannot be done at all, especially if conscience and sympathy are absent. The improved general health, freedom from headaches, etc., would make it at least a saving of money for the state to pay an expert resident oculist. This, apart from the humane consideration. Nobody can rightly estimate the number of degenerates, paupers, defectives, and dependents loaded upon the producers and taxpayers because reading, writing, sewing, handicrafts, etc., are impossible to a person with disqualifying astigmatism. Neglect of the fact greatly increases the tax-rate and makes the philanthropic miserable.

Why does the truant-boy exist, and why does he so often develop into the young criminal? If the majority of these, as Dr. Case of the Elmira Reformatory finds, have an ocular defect that makes vision impossible for any continued reading, writing, or handwork, does not the fact modify all penology? If the sewing-girl cannot possibly sew or do any such kind of eye-work, what alternative is often left her except crime? Sociology is very frequently another name for ophthalmology.

And if even to-day, in the city, the poor cannot be fitted with a simple device to make their lives happy and independent, how is it with the other half or three fourths of the people who live in small towns and in the country supplied only with the itinerant criminal spectacle-peddler? The farmers and their families now waste most of their evenings and their winters, and then the sociologist blames them for their vile country newspaper and their unprogressiveness.

Philosophers and thoughtless critics bewail the literary pessimism of the age. It is indeed a pitiable and a pitiful fact. In a time when comfort and possibility of education and of enjoyment have suddenly increased an hundredfold, why the strange phenomena of vastly increased skepticism, mental suffering, hopelessness, and melancholy? Who have set the fashion? Certain powerful, but in some respects morbid, literary geniuses. Who were they? Those almost without exception who were great sufferers from physical disease. Of what disease? Simply of "migraine." Without a thought of the class to which they may belong, make a list of the literary pessimists of the last century and another list of the optimists. The pessimistic or gloomy writers and artists were almost entirely great sufferers from eye-strain and from its result — migraine. They were, for instance, Nietzsche, the two Carlyles, de Maupassant, George Eliot, Wagner, Tchaikowsky, Chopin, Symonds, Tolstoi, Heine, Leopardi, Schopenhauer, Turner, Obermann, Thomson (the younger), Poe, and many others. Others that partially or wholly conquered the "migraine" of eye-strain by opium, or by renouncing ocular near-work, by walking, etc., are Mrs. Browning, DeQuincey, Coleridge, Beethoven, Parkman, Whittier, Margaret Fuller, Browning, Huxley, Spencer, Taine, Darwin, Lewes, Hugh Miller, Southey, etc.

The optimists — the cheerful, hopeful, encouraging, loving, and helpful ones — were, a few and at random, Goethe, Mozart, Verdi, Ruskin, Wordsworth, Renan, Châteaubriand, Hugo, Zola, Sainte-Beuve, George Sand, Emerson, Lowell, Longfellow, Kant, Scott, Brontë, Dumas, Voltaire, Gibbon, Macaulay, Mommsen, and a host of others.

In not one of the lives or writings of these last will you find a hint of eye-strain, or migraine, hardly even of ill-health. Note also that the pessimists are mostly atheistic and materialistic, while hardly one of the healthy optimists is so. One may also remember the tendency to despair and even suicide in those who suffered most from migraine. It is exactly so in private practice to-day. Pessimism and atheism are an expensive tax on the national vitality, a danger to the public health, a brake on the wheels of the progress of civilization. If we care naught for the personal and preventable sufferings of these great workers in humanity's cause, nothing for those of the literary and other laborers tremendously increased by the very nature of their tasks, we at least should consider the welfare of the generations that follow us. As the creation and perfection of vision has been the condition of past biologic evolution, so its normalization and the avoidance of its pathogenic results is one of our highest professional duties and ideals.

SECTION K—OTOLOGY AND LARYNGOLOGY

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(*Hall* 7, *September* 21, 10 *a. m.*)

CHAIRMAN: PROFESSOR WILLIAM C. GLASGOW, Washington University, St. Louis.
SPEAKER: SIR FELIX SEMON, C. V. O., Physician Extraordinary to His Majesty the King, London.
SECRETARY: DR. S. SPENCER, Allenhurst, N. J.

RELATIONS OF LARYNGOLOGY, RHINOLOGY, AND OTOLOGY WITH OTHER ARTS AND SCIENCES

BY SIR FELIX SEMON

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WHEN Professor Newcomb's extremely flattering invitation reached me to deliver an address before the Section of Laryngology and Otology of the Congress of Arts and Science held in connection with this wonderful Exhibition, my first feeling was naturally one of sincere gratitude for the great honor done to me. This feeling was enhanced by the information contained in Professor Newcomb's letter that the invitation was extended on the nomination of a number of American representatives of medicine, whose names are household words on the other side of the Atlantic. I am deeply sensible, believe me, of the exceptional distinction thus conferred upon me, and my pleasure in accepting it is only marred by the consideration that I cannot pretend to be an aurist, and that the otological part of my task would no doubt have been infinitely better fulfilled by many European representatives of that branch. I dutifully mentioned this fact to the organizers of the Congress, but it was not considered an insurmountable obstacle to my undertaking the pleasant duty conferred upon me. Needless to say, I will do my best to do justice to the otological part of my address as well, but it will be intelligible to my hearers, and will, I trust, be pardoned by them that the lion's share of my remarks will be devoted to subjects rather of which I can speak from personal experience than to questions with which my work is less intimately connected.

If my first feeling on receiving your invitation was naturally and properly a sense of gratitude for the high distinction conferred upon me, this feeling was run very close by the sincere pleasure I experienced in thinking that I should have been selected to coöperate in a work so entirely sympathetic to me as is this great undertaking. It was stated in Professor Newcomb's invitation that the object of this Congress was "to discuss and set forth the uniformity and mutual relationship of the sciences, and thereby to overcome the lack of harmony and relation in the scattered special sciences of our day."

I do not know whether I was selected as having upheld throughout my scientific career this leading idea, but I can say without fear of contradiction — and in proof thereof, I may point to my literary work — that I have consciously and intentionally striven, wherever opportunity offered itself to me, to maintain the principle which animates the organization of this Congress.

I should not be a specialist if I did not firmly believe in the necessity of specialism in medicine. The immortal aphorism, "Life is short, art is long, technique is difficult," applies to-day with even greater force than when it was uttered two thousand years ago by the Father of Medicine. Whilst the span of life has since his time remained very much what it was then, his art has been and is making giant strides. Economical considerations stand in the way of indiscriminately prolonging the time of medical study, and more and more work has to be compressed within the span of the few years which serve to prepare the future medico for his professional life. No wonder, then, that it has become extremely difficult, nay, almost impossible, to equip our students so thoroughly that they can enter practical life with full knowledge of their craft in every branch of medical thought and work. Even the few who, endowed with good health and strength, with exceptional abilities, and with equally exceptional industry, succeed during their students' career in mastering all the details of current medicine will, with very rare exceptions, find it practically impossible, when once they have plunged into practice, to keep abreast of the rapid progress which is the signature of the times in which we live.

Under these circumstances division of labor has become a logical and unavoidable necessity. The old line of demarkation between internal medicine and surgery, to which, at a somewhat later period, gynecology and midwifery were added as independent branches, no longer suffices to carry on investigation and practice within their formerly strictly defined limits. Gradually one recognized specialty has developed after another, partly owing to the necessities of special training in a certain technique, partly because only men trained in that technique could promote further investigations.

The International Medical Congresses bear testimony to this unavoidable development of contemporaneous medicine. Their organizers desire nothing more than to limit the number of the Sections of the Congress, yet time after time is it found indispensable to create new sections. Thus, whereas at the International Medical Congress of Brussels in 1875 eight sections sufficed to carry on the work, which was truly representative of the state of scientific medicine at that time, that number had been more than doubled twenty-five years later, when no less than seventeen sections had to be formed at the International Medical Congress of Paris of 1900. Seeing the unexpected rise of so many branches formerly undreamed of within the memory of our own generation, he would be a bold man indeed who would dare to assert that the limit had been reached of further specialization of our science.

This progressive division of labor — the outcome, not of individual caprice, but of stern necessity — has certainly resulted, within the last fifty years, in greater progress of medical knowledge and power than has taken place at probably any corresponding period in the history of medicine. If we middle-aged men remember what medicine was when we entered upon our studies and see what it is to-day, and if we further reflect how much of all the progress achieved meanwhile is due to the labors of specialists, we have every reason I think to be grateful to the division of labor which has brought forth such splendid fruit.

But while this must be readily and ungrudgingly acknowledged, it cannot be denied that, as in almost every movement of a similar character, thus in this development of modern medicine there is one great and real danger, namely, the peril of over-specialization. Well do I remember, when I first selected a specialist's career, how incensed I was at the reproach then currently leveled at specialism, namely, that it engendered narrow-mindedness, and how ill-founded and unjust that reproach seemed to be to me. With longer experience and riper judgment I have learned that the danger of narrow-mindedness, accruing from too exclusive a devotion to specialism, is more than a mere phantom. Whether by natural turn of mind, or by want of steady connection with broader aspects of pathology, there is no gainsaying that the enthusiastic specialist is apt to see a local trouble everywhere, and to overlook disturbances of general health and other organs which in reality require the chief attention. The tendency which has become particularly marked during the last decade, namely, to confine research and discussion in special subjects to special societies and special journals, has materially increased that danger, the reality of which was foreseen nearly twenty years ago by my great teacher Virchow when in the address he gave at the jubilee meeting of the Berlin Medical Society on October 28, 1885, he spoke the memorable words, to which I have more than once referred, and which in verbatim translation are as follows:

"Amongst us has arisen the large army of specialists, and it would be useless, or at any rate fruitless, to oppose this development; but I think I ought to say here, and I hope to be sure of the consent of you all when I say it, that no specialty can flourish which separates itself completely from the general body of science; that no specialty can develop usefully and beneficially if it does not ever and ever again drink from the general fount, and if it does not remain in relationship with other specialties, so that we all help one another, and thereby preserve for science, at any rate, even if it should not be necessary for practice, that unity on which our position rests intrinsically, and, I may well say also, with regard to the outer world."

Under these circumstances it was certainly a happy thought to remind us again of the unity of Sciences and Arts, and to try thereby to overcome the lack of harmony and connection between the scattered special sciences of our day.

And I look upon it as a particularly characteristic sign of the times, and as a hopeful augury for the future, that the reminder should have come from the scientists of a country so eminently progressive as the United States of North America. If they, who are untrammeled by many of the traditions, formalities, and prejudices which so severely handicap us on the other side of the Atlantic, have found that it is high time to raise a warning word against the ever-increasing disruption of the unity of Science, surely this ought to make those pause, who with a light heart consider every further step on the road to so-called "independence" as a practical gain to specialism. If to-day by placing before you in rapid succession the intimate links which connect us with other arts and sciences I should succeed in convincing some of the more ardent protagonists of such independence, that laryngology, rhinology, and otology can only flourish and healthily progress by never for a moment losing sight of their close relationship with other often enough apparently remote branches of human thought, I conceive that I shall have contributed my mite towards the excellent object of this great Congress.

It is not a mere figure of speech when I say that the more I advanced in the preparation of this address, the more did I become impressed with the magnitude of my task and with the intimacy of unexpected or hardly-thought-of connections between laryngology, otology, and rhinology and other sciences and arts. These specialties have developed so much along characteristically independent lines that theoretically one might be inclined to think that they had comparatively little in common with other branches of medicine, let alone other sciences and arts.

Nothing could be better calculated to destroy such mischievous belief than the results of my inquiry. At every step during the preparation of this paper has it become clearer to me how much we owe to apparently remote lines of human thought, how much we have been and are benefited in our special work by progress made in other distant fields, and how much more good we may expect to accrue to us from the advances achieved in territories of human thought which a few years ago even the most fantastic visionary could not have brought into useful combination with our own occupation.

It will be my endeavor in this address to justify the foregoing statements by rapidly surveying the intimate connection of laryngology, rhinology, and otology — in addition to their relations with other branches of medicine — with physics, chemistry, mathematics, philosophy, history, biology, technology, and music, and I only regret that within the limit of time allotted to me it will be quite impossible to do full justice to my task.

I. *Physics*

(*a*) *Light.* Let us first take physics. The connections of that science with laryngology, rhinology, and otology are as manifold as they are interesting and important. The branches of medical science named have it in common that they deal with the investigation of the physiology and pathology of deep-seated cavities. Hence the question of their illumination for purposes of examination is of the greatest importance, and thus the chapter of physics dealing with the properties of light is a subject of immediate and pressing interest to us all. This applies with particular force to laryngology. Although of late, through the work of Kirstein, direct inspection of the larynx by means of depressing the tongue with suitable spatulas has been rendered feasible, this method of examination is only applicable in a certain fraction of cases, and examination of the larynx is still carried out universally by means of reflecting mirrors. The very foundation of laryngoscopy, as ordinarily practiced, depends upon the principle of physiological optics: that when rays of light fall upon a reflecting surface placed in a certain inclination towards the source of light, the angle of reflection is equal to the angle of incidence. Thus, if a small mirror be held at an angle of 45 degrees to the horizon just below the uvula, whilst a powerful beam of light is thrown horizontally into the throat of the person examined, the part just underneath the mirror, that is, the larynx, becomes illuminated by reflected light, and its image is in turn thrown back upon the mirror, and hence reflected into the eye of the observer, which is parallel with the rays thrown upon the reflecting surfaces. Exactly the same principle applies if, instead of the larynx, the nasopharyngeal cavity has to be examined, and the law of physiological optics just described is as all-important for posterior rhinoscopy as it is for laryngoscopy. But in order to obtain a really good image of either the larynx or of the nasopharyngeal cavity it is necessary that the light which is thrown upon the reflecting mirror should be a powerful one. Hence every progress which is made in concentrating and intensifying the light used for illumination of these parts is of the greatest interest for my branch of science. It sounds nowadays almost like a myth that the progress of laryngology in its infancy should have been retarded for almost half a year, and that Professor Türck of Vienna, who first utilized Manuel Garcia's epoch-making discovery of the laryngoscope for the investigation of pathological processes in the larynx, should have given up his studies for the time because the winter of 1857 in Vienna was a very dark one, and because sufficient light for illumination of the larynx could not be obtained from the direct rays of the sun. Yet such was actually the case, and it was only, as Morell Mackenzie has tersely stated, through Professor Czermak's substituting artificial light for the uncertain rays of the sun, and using the large ophthalmoscopic mirror of Reute for concentrating the luminous rays, that the initial difficulties were overcome. Thus already at this early stage lenses, another achievement of physiological optics, were employed to help our young science. Ever since, every improvement in the way of light has been a subject of the keenest interest for laryngology and rhinology. What progress have we made from the *Schusterkugel* — a large glass globe filled with water, originally employed by Türck and Stoerk — until we have been actually enabled to introduce a small electric lamp into the cavities of the body themselves to illuminate them properly for purposes of diagnosis and operation, or to throw light into the esophagus or the bronchial tubes, or to transilluminate the face for diagnostic purposes, as, for instance, for the diagnosis of disease of the maxillary antra or the frontal sinuses.

The employment of gas, recently followed by its new incandescent modification; the introduction of hydro-oxygen light, and, above all, that wonderful source of light, now in general use, the electric, have formed so many steps in the way of improving our powers in laryngology and rhinology. Quite recently the invention of the Nernst lamp has proved a great boon to us, enabling those who had been accustomed to the, if excellent, rather cumbersome use of hydro-oxygen light, to get illumination almost equally good at infinitely less trouble.

As if this had not been progress enough within the comparatively short span of a quarter of a century, Professor Roentgen's great discovery of the penetrating power of the ultra-violet rays, which now go by his name, has, at its very inception, been most happily utilized for the purposes of laryngology. When the extraordinary properties of the X-rays were made known I expressed a hope that by their help it might become possible to distinguish, owing to their different density, between benign and malignant growths. Although this hope has, unfortunately, not been realized so far, yet the medical attainments of these rays are surely wonderful. They enable us to discover the presence of metallic foreign bodies in the larynx, the lower air-passages, the nose and its accessory cavities. When it is doubtful whether paralysis of a vocal cord is due to the presence of an aneurism, or of a solid new growth in the chest pressing upon the pneumogastric or recurrent laryngeal nerves, the X-rays again come to our aid and help us to make a differential diagnosis. A further very ingenious application of the Roentgen rays has been made by Dr. Spiess of Frankfurt-am-Main, who has suggested that the delicate and by no means dangerless probing of the frontal sinus may be controlled and thereby rendered innocuous if during the act of introducing the probe the picture of the patient's head be thrown on the screen, the operator being thus enabled to see whether the instrument is really on the right way into the frontal sinus.

Who will be bold enough to say that with such discoveries the resources of physics have been exhausted, and that possibly at some near future some other even more powerful source of light may not be introduced? Those who are unwise enough to believe in the finality of scientific progress need simply be reminded of the possibilities, quite recently introduced through the discovery of radium with its as yet imperfectly known properties.

Before leaving the subject of light I must refer to some other methods in which that branch of physics has been rendered useful to our specialties.

The Microscope. The first of these is the use of the microscope. On this point I need say but little. The enormous value of the microscope in medicine is so universally recognized that it would mean carrying coals to Newcastle if I were to enlarge upon it. Our specialties have been benefited as much in the understanding of the finer processes of normal and pathological anatomy of the throat, nose, and ear, as any other branch of our mother science. It suffices to mention the help which the microscope gives us in the differential diagnosis between benign and malignant growths, in the recognition of tuberculous and diphtheritic affections, in the differentiation of septic disease in general, to show the truth of my statement.

Stroboscopy. Another, though much more restricted application of light for the use of laryngology, is stroboscopy. By an ingenious modification of the stroboscope, consisting of two rotatory disks, the one perforated, whilst on the other figures are drawn, which are inspected through the perforation of the first disk, the late Professor Oertel has succeeded in constructing an apparatus by means of which the oscillation of the vocal cords can be accurately observed. Very interesting observations on the action of the vocal cords during singing have been made with the aid of this apparatus, as an example of which I may only mention that, according to Oertel, "the sounds of the chest register are produced by oscillation of the vocal cords in their entire length and breadth, whilst the sounds of the falsetto register are caused by the longitudinal division of the surfaces of the vocal cords into aliquot parts, nodules being at the same time formed on them."

Photography. A further method to be mentioned in this connection is photography. I need not say that photographic reproduction of preparations illustrating the normal and pathological anatomy of the ear, the nose, and the throat is no exclusive property of laryngology, rhinology, or otology, but a special interest connects the former of these sciences with photography, inasmuch as by the aid of this method a number of most interesting observations have been made on the physiology of the larynx during the act of singing. The method has proved particularly useful in showing the absurdity of the preconceived ideas of some teachers of singing as to the extent of the individual registers. It has fully corroborated the views held by those most competent to speak as to the enormous variety in producing the singing voice, even in persons whose voices belong to one and the same category. The pioneer in this fascinating territory has been an American, my friend Dr. French of Brooklyn, and to his enthusiasm and perseverance have been due the first reliable results of this most promising method of physiological investigation. Further studies in this direction have been made by Dr. Musehold and Professor E. Meyer of Berlin. The last-named gentleman has just, in coöperation with the celebrated mechanician, Zeiss of Jena, constructed a very ingenious apparatus for demonstrating and photographing the larynx; but having seen the photographs obtained by its use, I am bound to say that the work done by Dr. French has not been so far surpassed.

Stereoscopy. Finally, in connection with light, I must not omit to mention the ingenious application of stereoscopy for purposes of medical teaching made by my friend Dr. Watson Williams of Clifton in the wonderful atlas which accompanies the second edition of his work on Diseases of the Upper Respiratory Tract. It being often extremely difficult to obtain, for teaching purposes, really illustrative preparations of the accessory cavities of the nose, the employment of the principle of stereoscopy in order to substitute photographs, the plasticity of which truly rivals life, may fairly be described as a triumph in utilizing for our special purposes the achievement of an apparently very remote science.

The mention of electricity, the X-rays, and radium naturally brings to our minds the fact that the chapter on light is of interest to laryngologists and rhinologists, not from the point of view of the question of illumination alone. We are privileged to live in a time when the great healing powers of light have been discovered and are utilized in a class of cases in which there is much need for addition to our therapeutic armory. The light of the sun, the electric light, the ultra-violet rays, and the emanations of radium are nowadays utilized with much success for the treatment of lupus, of rodent ulcer, and of some of the more superficial forms of malignant disease; and it may fairly be hoped that further progress may be made in the treatment of these cruel affections even when they occur in parts not easily accessible to the effects of the various rays.

(*b*) *Sound.* Whilst the chapter of physics dealing with light and its powers is, as I have just endeavored to show, of the very highest importance for laryngology and rhinology, the chapter on sound holds an equally high position with regard to otology. I need not elaborate that a science which is prominently concerned in dealing with the troubles of hearing is inseparably connected with the physics of sound. Thus the tuning-fork is one of the most indispensable weapons of the aurist, and the question whether the sounds caused by its vibrations are more easily perceived by aërial or by bone conduction is of the highest diagnostic importance in a large number of ear affections. In the same category may be mentioned Galton's whistle for the testing of the hearing of high notes. Again, the question of the capacity for the perception of tune; the difference in perception according to whether the mouth is closed or open; interference phenomena; the estimation of the hearing capacity for speech; the audibility of different sounds; the differential diagnosis between affections of the sound-conducting and sound-perceiving apparatus — are all questions intimately connected with the physics of sound, and it might be said without exaggeration that otology without constant close relationship with physics is an impossibility.

The Phonograph. Speaking of sound, the phonograph, an invention due to American genius, must not be forgotten, although its possibilities in connection with our triad are still in their infancy. I may remind my hearers that very shortly after its introduction Dr. Mount Bleyer of New York, Dr. Lichtwitz of Bordeaux, and I, independently of one another, conceived the idea of utilizing its recording powers for the purposes of instruction. One does not always have a case of whooping-cough at hand if one lectures on that disease, and although it be easy and true enough to say that the peculiar cough connected with that disease was so characteristic that any one who had ever heard it would never forget it, it is not so easy to demonstrate practically in what the characteristics of which one speaks consist. Here the phonograph comes to one's aid: let the child afflicted with that disagreeable affection cough a few times into the apparatus, and turn it on, when you have to lecture on whooping-cough and have no illustrative case near. The whoop will come out true enough!

It need not be said that the investigation of different forms of cough and hoarseness is only one of the modes in which the discriminating powers of the recording mechanism of the phonograph could be utilized. Attempts have already been made by Dupont to investigate with its help modifications of speech in different forms of delirium, paralysis, multiple sclerosis, etc. More recently Flatau of Berlin has studied the various forms of vocal disturbances by means of Edison's phonograph, and has also utilized it for investigation of the finer mechanism of the singing voice. With further perfection of the apparatus it may justly be hoped that yet more valuable results may be obtained than those so far achieved, although even now they are anything but a negligible quantity.

The Sensitive Flame. Finally, in this connection it should be mentioned that König's sensitive flame has been utilized for the registration of sound-waves produced by the human voice. The apparatus consists of a rapidly rotating cube, the four lateral sides of which are formed by mirrors, and of a membrane in the side of a gas-chamber, connected with which is a small sensitive gas-flame. If a note be sung on to the membrane the flame bobs up and down and the waves seen on the mirrors are not simply up-and-down ones, but the primary large waves are complicated by smaller ones on their surface. The richer the voice the more numerous are the overtones of the harmonics represented on the reflecting sides of the rotating cube. (Halliburton).

(*c*) *Electricity.* The enormous progress of the science of electricity made within our generation has had the most useful effects upon the diagnostic and therapeutic powers of laryngology, rhinology, and otology. In fact, there are probably but few collateral sciences in which our specialty is so keenly interested and the progress of which so greatly benefits us as electricity in all its different forms. It has already been stated that the illuminating power of the electric light is being utilized not only for ordinary but also for trans-illumination of the cavities of the head and neck, and for the inspection of the lower air- and food-tubes. The constant and faradic currents are of the greatest help to us both in diagnosis and in treatment. By means of the reaction of degeneration we are enabled to decide whether paralysis occurring in the mouth, the pharynx, or the larynx is of central or of peripheral origin. By employing both forms of current we succeed in many cases in curing paralytic disorders, more particularly when they are of functional character.

Again, electricity in the form of the galvano-cautery is of practically daily use in the hands of the laryngologist and rhinologist. It has superseded the employment of most other forms of caustics, and few laryngologists nowadays would care to be without it.

Yet another form of employment of electric force, namely, electrolysis is highly extolled by some devoted adherents who utilize it for the treatment of such troublesome affections as ozena, naso-pharyngeal fibromata, reduction of irregularities of the nasal septum, etc. It must, however, be confessed that this method has never met with general adoption by the bulk of laryngologists.

Finally, in recent times the motor power of electricity has been largely used, and I do not think anywhere more than in the United States, as the driving force of such instruments as trephines, saws, drills, particularly in nasal surgery and electro-motor masseurs in aural therapeutics. If the method has not yet met with general acceptance in Europe it is, I think, more from want of acquaintance with it than from any other cause, and I feel confident that the more general the domestic use of electricity shall become, the greater rôle will the electro-motor play in our instrumentarium.

Even as it is now, however, the rapid sketch I have just drawn will suffice, I trust, to show the enormous importance of this branch of physics for our special field of research.

II. *Chemistry*

Whilst it cannot be said that chemistry, apart from its general relations with medicine, is so closely connected in its various branches with laryngology, rhinology, and otology as physics, yet there are points enough of very great and immediate importance which link these two sciences together.

In the first place, synthetic chemistry gains every day in importance for us by enriching us with new and important pharmaceutical preparations. Need I remind you of orthoform, anesthesine, adrenalin, iodoform, sozoiodol, peroxide of hydrogen — to mention a few only of the large number of new remedies which form, so to say, our present stock-in-trade, and for the introduction of which we are indebted to synthetic chemistry? Every day increases our power of doing good, due to the progress made in this collateral science, and we are therefore accustomed to watch constantly nowadays for further help in our therapeutical powers from that source.

Skeptics, it is true, may say with some show of reason that we had lately had and were still having a little too much of a good thing in the shape of new remedies, but I the more gladly leave that undecided, as chemistry comes to our aid not only with regard to therapeutics but also to diagnosis. It is mostly by means of the different chemical reactions of cerebro-spinal fluid, and of the ordinary serous secretion met with in vasomotor affections of the nose that we can differentiate between these two affections.

Finally, although this may perhaps be called "music of the future," I myself look forward to the day when further progress in physiological chemistry will enable us to recognize subtle differences in the composition of nerves and muscles. Should that hope be realized, physiological chemistry will perhaps enable us to solve that great problem, which for the last twenty-five years has occupied the minds of so many of us — namely, the cause of the greater proclivity of the abductor fibers of the recurrent laryngeal nerve, and the muscles which they supply, to succumb sooner than the adductors, or even exclusively in cases of organic disease of the roots and trunks of the motor laryngeal nerves.

III. *Mathematics, including Statistics*

Occasionally the resources of mathematics have to be laid under contribution by our specialties. Thus, for instance, it was necessary when I studied some years ago the position of the vocal cords in quiet respiration in man, to correct, when using graduated laryngeal mirrors, the considerable difference between the actual and the apparent length of the distance measured. This difference could be accurately expressed by a mathematical formula.

Similarly, in a recent paper on the aërodynamics of the respiratory passages, Dr. Gevers of Leuven measures mathematically the permeability of the nasal chambers. On the whole, however, it must be confessed that the connection between pure mathematics and laryngology, otology, and rhinology is only a distant one.

But matters become very different if we look upon the science of statistics as a method of applied mathematics, and consider its employment in our literary work under the present heading.

More and more frequently of late years has the statistical method not merely been laid under contribution, but been allowed to have a decisive vote in questions of the greatest importance for laryngology, otology, and rhinology. It may therefore not be out of place to express on this occasion a devout hope that those who employ this method for the decision of controversial points in our own science, should make themselves first acquainted with the general principles of the method itself. The non-observance of this precaution has led in more than one instance not only to fallacious scientific conclusions but to deplorable practical results.

I will illustrate this by one example only.

In no chapter within the territory of our own specialties has the statistical method of late years been more frequently used than in that of cancer of the larynx. As a matter of fact, the usefulness or otherwise of the individual operations now practiced for the cure of that terrible disease is judged by most surgeons exclusively on the basis of statistics recording the results of various forms of operation. Unfortunately, however, a good many of those who have compiled such statistics have done so in a most empirical manner. They have simply registered under one and the same heading all operations of one and the same type ever performed without taking into consideration such indispensable distinctions as:

1. The period of our knowledge at which each of these operations was performed.
2. The individual and enormously different conditions present in each of the cases which were subjected to one and the same operation.
3. The progress of the technique of these operations as they gradually developed.

The outcome of this, as will be clear to everybody who has paid any attention to the principle of statistics, has naturally been lamentable. Most valuable forms of operation, such as thyrotomy, have been and unfortunately still are persistently discredited, because some compilers of these statistics will not or cannot see that a thyrotomy performed, say, in 1870, was a thing as different as heaven and earth from a thyrotomy performed in 1904 under altogether different conditions of diagnosis and technique. They accordingly put together all thyrotomies ever performed, without taking these all-important differences into consideration, and calmly proceed to register the net result. The natural outcome of such directly misleading statistics has been that the true value of thyrotomy in suitable cases has not nearly universally enough been recognized at the present moment, and those who have practiced it with excellent results in really suitable cases during the last fifteen years have even at this hour of the day to carry on an uphill fight against those who put their faith blindly in the unsatisfactory sort of statistics just described. The hope may therefore be justly reiterated on this occasion that every medical man who wishes to approach a medical question from the statistical point of view should make himself thoroughly acquainted with the standards of his measurements before applying the latter to the question which he intends to study.

IV. *Meteorology and Climatology*

A few words only are requisite at the present state of our knowledge with regard to the connection between meteorology and laryngo-otology. The more we learn of the influence which climatic and meteorological conditions exercise upon certain diseases, the more necessary does it become to study these conditions in order to benefit our patients, and to avoid serious mistakes in sending them to localities which, however suitable in other affections, are not adapted for their particular case. This general rule applied to our specialties comes particularly into force with regard to laryngeal tuberculosis and to middle-ear catarrh. With regard to the former, I need simply mention that at present the opinions as to the suitability or otherwise of high altitudes in cases of laryngeal complications of pulmonary tuberculosis are extremely divided; with regard to middle-ear catarrh, one sees it frequently stated that seaside places exercise a distinctly unfavorable influence upon them. But the relation of meteorology and climatology to our branches is certainly a wider one than indicated in the foregoing illustrations, and well deserves — and will no doubt receive — further attention.

V. *Philosophy, Logic, History, and Literature*

Of the connections of philosophy, logic, history, and literature with laryngology and otology I wish to say a few words jointly, because their relations to our specialties are similar in kind. They are not of that palpable and, if I may say so, tangential character, as those of physics, chemistry, and mathematics, and of the other branches of human intellectual activity to be touched upon hereafter, in that it is impossible to name individual distinct points in which their achievements touch equally distinct and individual points of specific interest for us. But, although more subtle, their relations with the higher aspects of our work are no less intimate, and additionally, if I may say so, are all-pervading. The specialist who is endowed with a philosophical turn of mind will look upon his own work and upon the interests of his specialty from a much broader point of view than the man whose horizon is obscured by the limited and more or less narrow-minded doctrines of one individual school of thought. He will not be swayed by the fashionable currents of the moment, and will be consoled when he sees that not only the public but many within the ranks of his own confraternity periodically lose their heads over the latest sensational development, destined in the opinion of its creator and its disciples to bring about in our own times the millennium, by the remembrance of Ben Akiba's immortal dictum:

Alles schon dagewesen (nothing new under the sun),

and by the reflection that in all probability in a very few years the same faithful ones will bow down and worship another golden calf. The man who has learned to think logically will not, when he writes a paper, be caught, in glaring self-contradictions, and will carry, when following a chain of thoughts, that chain to its only possible conclusion. The author who does not confine his literary studies to the reading of exclusively medical productions, who has been brought up with a knowledge of all that is good in the literary productions of former as well as of our own times, and who has a warm heart for poetical and literary beauties in the literature of all nations, will make his own work attractive to readers, and will know how to give clear expression even to abstruse scientific questions. And, in conclusion, the laryngologist and otologist, who knows something of history in general and of the history of the development of his own specialty in particular, will have an infinitely higher standard of comparison of the achievements of the present day with those of our predecessors than the man for whom all that has been published ten years ago is merely "ancient history" not worth reading. Above all, he will have learned from the lessons of the past the one great truth that, however important a discovery he may imagine he has made, it behoves him to be modest in the face of what has been done before him.

It is extremely tempting to illustrate what I have just said by reference to the writings of some of our *confrères*, whose scientific productions are distinguished by literary charm, by limpidness of expression, by inexorable logic of thought, and by profound knowledge of the history and literature of other subjects, but apart from the question of the length of this address, which hangs over me like the sword of Damocles, the task, although enticing, would be somewhat invidious. Still I hope that nobody will grudge it if, before leaving this part of my task, I refer with admiration to the work done by two American specialists, and illustrating the truth of what I have just said, namely, the excellent historical and literary researches of Dr. John Mackenzie of Baltimore, which give quite a special *cachet* to several of his papers, and the recent magnificent medical history of laryngology and rhinology by Dr. Jonathan Wright, which, owing to a most unusual combination of all the philosophical, literary, and historical qualities of which I have spoken will, I feel sure, ever remain a classic in the literature of our specialties.

VI. *Technology*

A few words must suffice to remind you of the great importance of every technological progress for those whose special practice lies in the treatment of throat, nose, and ear diseases. From year to year these specialties tend more and more to become branches of surgery, and the question of their surgical equipment therefore is constantly with us. Most of our instruments are no doubt invented by specialists themselves, but in not a few cases we are only able to give a leading idea to the instrument-maker, and the success or otherwise of our idea depends upon the constructive talent of the latter. Nor is it rare that patients themselves devise improvements of existing instruments and apparatus. Thus, for instance, the most ingenious and at the same time simplest speaking-apparatus which I have ever seen used by patients condemned to wear for a time or forever a tracheal cannula was constructed by a watchmaker who had the misfortune himself to belong to the class of patients in question. A glance at the innumerable "modifications" of instruments now in general use recommended in the catalogues of various instrument-makers shows the intimacy and importance of our relations with technology, and I desire in conclusion of this reference only to remind you of the quiet revolution that has been going on in our tools of late years in proportion to the greatly increased importance of aseptic surgery, and in the course of which it has become the aim to have all our instruments fashioned out of metal, and to banish wood entirely.

VII. *Music*

Next we come to a most fascinating subject — the relation of the noble art of music to laryngo-rhino-otology. Of the intimacy of this relation there can be no possible doubt; without what is called a "musical ear" music is an impossibility altogether; without the possession of a healthy larynx, singing cannot be thought of. When I speak of a "musical ear" I mean, of course, the control exercised by the ear over the technique of executants; that music in its highest forms is completely, or at any rate nearly, independent of the power of hearing has been shown by nothing more conclusively than by the case of deaf composers, whose "inner voice," to speak with Robert Schumann, elevated them beyond the apparently indispensable faculty of hearing. Beethoven was deaf when he wrote the Ninth Symphony, and nothing more pathetic surely can be imagined than, when his audience after its first performance rose to an indescribable pitch of enthusiasm, one of the singers had to turn the deaf Maestro round in his chair to see

— what, alas, he could hear no longer — the applause with which the public of Vienna greeted this probably the greatest musical composition of all times. But even in this exceptional case the close relationship of the art of music with the physical faculties of sound and hearing is characteristically illustrated. If the musical ear had come to the great composer's help in the final chorus, I cannot imagine that he would have written the soprano parts as he has done — too high to be reached without great effort by the voice and not pleasing in its effect to the tympanum of the ordinary listener.

As to the connection of laryngology with singing, no more significant testimony could surely be adduced than the fact that the laryngoscope, upon which modern laryngology is based, has been the invention, not of a medical man but of a singer, the venerable Señor Manuel Garcia, who has been spared by a merciful Providence to live in undimmed possession of all his mental and physical powers to the patriarchal age of 100, and whose 100th birthday we hope (D. V.) to celebrate in March of next year. The auspicious event will coincide, I may remark, with the jubilee of laryngology, his epoch-making paper, entitled *Physiological Observations on the Human Voice,* which he submitted to the Royal Society of London in 1854, having been published in the *Proceedings* of that Society (vol. XII, no. 13) in 1855. Garcia was led to his discovery by the natural desire of an intelligent singer to study the physiological properties of that most wonderful of all instruments, the human voice, by direct inspection of its constituent parts during the act of singing. Ever since manifold endeavors have been made to let the art of singing profit by the revelations given by the laryngoscope. Candor, however, compels me to say that these efforts have hitherto been less successful than one might naturally have expected. Pretensions have been, and are being made as to the claim of the laryngoscope to lay down the law concerning most intricate questions arising in the production of the singing voice; but as I have stated on a previous occasion, there exists no "superior wisdom" based upon laryngoscopic observations with regard to the teaching of singing. Now, as in bygone days, the teacher who founds his instruction upon the classical traditions of the art of singing and who individualizes in every case intrusted to his care will certainly be more successful than the theorist who, starting from preconceived notions the correctness of which is anything but proven, forces the natural mechanism of his pupils' voices into his unbending formula and thereby in not a few instances ruins them.

This warning is of course not intended in any way to deter both laryngologists and singing-masters from joining forces in determining questions regarding the physiology of the voice, and recent work such as that of Holbrook Curtis, Flatau, Bukofzer, and Imhofer shows how valuable the laryngologist's aid may be in assisting the task of the teacher of singing in such questions as, for example, the method of intonation — a point in which science and art very nearly touch one another. Future anatomical and physiological researches will have to solve the fascinating questions of the mutual interdependency of the centres and paths of audition and sound in the brain. The data at present at our disposal are not sufficient fully to understand through what kind of afferent and efferent fibers impressions are conveyed to and from these centres; how they are changed into volitional impulses, and how they produce the desired note of the voice.

For the purposes of this address the foregoing short remarks will, I trust, suffice to show that no better illustration of the mutual relationship of most various arts and sciences could be imagined than in the territory of music, and more particularly of singing. That noble art is inseparably interwoven with laryngology, otology, rhinology, — for the accessory cavities of the nose are serving as resonators for the sounds produced in the larynx, — anatomy, physiology, and physics.

VIII. *Biology*

If we consider the relation of our branches to biology — excluding from the generic term thus used human anatomy and physiology — the same remark applies to their connection which I have just used when speaking of the relation of music to our specialties; more might be expected from the future than has been achieved in the past. No doubt the study of comparative anatomy and physiology, particularly the developmental part of these sciences, has been very useful in making us understand the origin, the gradual development, and final composition of the complicated organs with which we have to deal, and in not a few questions — more particularly in those relating to the nervous mechanism of the larynx — the lessons derived from experimental physiology have already been of the greatest importance in helping to solve the difficult problems with which we have to deal. Still, I am in no fear of contradiction when I say that a great deal more may be expected for the elucidation of many difficult questions with which we are confronted in laryngo-oto-rhinology from further biological studies.

IX. *Medicine*

Finally — and though last not least — I have to discuss the relations of laryngo-oto-rhinology with other branches of our great mother science, Medicine. The subject is one so large that, to do it justice, not one but a course of lectures would be required. At every step the specialist whose mind is open is reminded of the close connection of his limited field of achievement with other branches of medical art and science.

Anatomy, Physiology, Pathology. He can do no good without an intimate knowledge of the anatomy of the organs intrusted to his care and of their anatomical relations to adjoining and even more distant parts. In order to understand morbid conditions of the nose, throat, and ear, he must be thoroughly acquainted with the action of these organs in health, in other words, with their physiology. Wherever clinical observation is insufficient or at fault, he can appeal to no better helpmate than to the researches of pathological anatomy, and it may be truly stated that the conviction of this intimate association with the three sciences named is becoming more and more alive in our minds. We no longer leave the investigation of anatomical, physiological, and pathological problems pertaining to our specialties exclusively in the hands of professors of these branches; a large number of very valuable contributions towards the elucidation of such problems has been made of late years by members of our own specialties, and in not an inconsiderable number of instances the coöperation between laryngologists, rhinologists, and otologists with pure anatomists, physiologists, and pathologists has been productive of most valuable scientific results.

It suffices to mention the anatomical work of B. Fraenkel and his school, of Broeckaert, Onodi, Paul Heymann, Elsberg, Carl Seiler, Körner, Jelenffy, Killian, Politzer, Gruber, Urban, Pritchard, Tilley, Logan Turner, Kanthack, Seifert, Siebenmann, Gouguenheim, and Lermoyez; the physiological researches of Schech, Grabower, H. Krause, Katzenstein, Klemperer, Fraenkel, Hooper, Bryson Delavan, Frank Donaldson, jun., Desvernine, Réthi, Hajek, Zwaardemaker, Greville MacDonald; the pathological studies of Heinze, Grünwald, Kuttner, Seifert, Kahn, Heryng, and Butlin, and the joint work of B. Fraenkel and Gad, of Bowditch and Donaldson, of von Mering and Zuntz, of Mikulicz and Michelson, to which I hope I may add the researches undertaken by Victor Horsley and myself — to show that the above statements are not mere assertions, but based upon solid facts. On the other hand we gratefully recognize the most important help that has come of late years to the aid of laryngological knowledge from such distinguished anatomists, physiologists, and pathologists as Luschka, Sappey, Zuckerkandl, Exner, Hermann Munk, Richard Ewald, Risien Russell, Bechterew, and others. And yet these are, I particularly wish to state, a few names only taken at random from one's recollection of those who have enormously improved our knowledge of the anatomy, physiology, and morbid histology of the throat, nose, and ear, within the last twenty years.

Bacteriology. From pathological anatomy in general, there is but one step to the latest development of that science, bacteriology. Here again the close relationship of our specialties to this new science is evident everywhere. We learn from the bacteriological examination of the sputum in cases in which the clinical examination of the nose, pharynx, larynx, or ear leaves it doubtful whether we have to do with tuberculosis the true nature of the process that engages our attention; we differentiate with the help of bacteriological examination between true diphtheria, Vincent's angina, and other forms of septic inflammations of the cavities of the mouth and throat; the employment of antitoxin enables us to deal infinitely more effectively than at any previous state of our knowledge with that scourge of humanity, diphtheria; we ascertain in those terrible although fortunately rare cases, which I have grouped together under the name of "Acute Septic Inflammations of the Throat and Neck," the nature of the particular pathogenic microörganism that is causing the disease in a given case, and although as yet by no means masters of the situation, we succeed in a certain number of these cases, namely, in those in which the streptococcus is producing the septic inflammation in warding off by the employment of antistreptococcus serum the otherwise unavoidable fatal issue. As a matter of fact, an almost unlimited vista of further progress has dawned for our specialties in a number of previously most intractable affections from the rise and progress of bacteriology.

Internal Medicine. On the connection of laryngology, rhinology, and otology with internal medicine it is practically unnecessary to dwell. Whilst there is, needless to say, a number of local diseases of these organs strictly limited to them, in another large and important number the affection for which the aid of the specialist is sought is only part and parcel of a systemic disease, and as I have endeavored to show on another occasion, it would seem high time that not only the public, which has rushed to the conclusion that all affections of the throat, nose, and ear ought to be treated locally, but also some enthusiastic specialists should come to understand that in such cases not so much local as constitutional treatment is indicated. There are numbers of cases of general anemia, of periodical disturbance of the circulation, of general plethora, of nervous irritability, of gout, in which, without any actual changes existing in the throat, nose, or ear, unpleasant sensations are experienced in these parts, which can only be effectually treated by attending to the systemic conditions which underlie these local sensations. On the other hand, actual organic lesions occurring in these parts often enough are of the greatest importance for the diagnosis and proper treatment of grave general diseases. To give but a few examples: paralysis of one vocal cord may for a long time be the only actual sign discoverable, with the means at present at our command, of aneurism of the aorta, or of other mediastinal tumors, of affections in the posterior cavity of the skull, of pleuritic thickening of the apex of the right lung, of cancer of the gullet, and a host of other grave organic affections; certain laryngoscopic appearances may enable us to diagnose the existence of pulmonary tuberculosis at a time when all other signs fail; Killian's bronchoscopy, one of the most valuable modern additions to our diagnostic and therapeutic equipment, permits us to remove foreign bodies from the interior of even smaller bronchial tubes — chronic obstruction of the nose undoubtedly exercises a very unfavorable influence upon the general health, a fact which is most clearly demonstrated by the surprising improvement of well-being which follows removal of adenoid vegetations in much-developed cases — a cerebral abscess is nowadays known to be much more frequently due than was suspected only a few years ago to diseases of the middle ear and mastoid process, and has become infinitely more accessible to treatment than one could venture to hope in previous times. I may further remind you of the frequency with which the throat, nose, and ear are affected in infectious diseases, such as measles, scarlet fever, small-pox, typhoid, and influenza; again, of the manifestations of gout, rheumatism, and syphilis in these parts, and this list could be easily extended. The above examples, however, will suffice, I hope, to show the intimacy of the relations between our specialties and internal medicine.

Surgery. If I just said that it was almost superfluous to insist on the intimacy of our relations with internal medicine, this certainly applies in an even higher degree to their connection with surgery, for indeed they are daily becoming more and more branches of surgery itself. I have on another occasion stated my own conviction that it is in the nature of things, when a part of the human body has been made more accessible to eye and hand by the progress of science, that the treatment of affections of that part should gradually change from the medical to the surgical side. So much has this been the case of late with regard to the development of laryngology, otology, and rhinology, that if there be any danger in its further progress it would certainly not be in the direction of underrating but of over-emphasizing the idea that the existence of an affection of the ear, nose, and throat must be invariably associated with the idea of surgical interference. However, this is a subject on which I have no wish to dwell again on this occasion, and I much rather recognize the brilliant progress made of late years — and I may proudly add mostly by specialists — in the surgical treatment of the early stages of laryngeal cancer by thyrotomy, of affections of the accessory cavities, and of deviations of the septum of the nose in the radical treatment of mastoid disease, and in the removal of foreign bodies from the bronchi and esophagus. All these achievements belong to the veritable triumphs of contemporaneous surgery.

Children's Diseases. The large proportion of children seen in the out-patients' room and at the private consultations of specialists for throat, nose, and ear affections bears eloquent testimony to the close associations between diseases peculiar to childhood and affections of the auditory and upper respiratory tract. Here, of course, in the first place, adenoid vegetations and their far-reaching influence upon general development have to be mentioned, an influence of which it may only be devoutly hoped that it should not be overstated. But there are additionally the infectious diseases of childhood, in the course of which complications on the part of the ears, the throat, and the nose play a large rôle. It is pleasant to note how much more attention is paid to the condition of the upper respiratory tract and the ears of children by Government and public health officers than was the case only a few years ago, and to read of the increased frequency of the examination of school-children with regard to their hearing and breathing powers in different countries of the world. That is certainly the proper way to promote the health of the community.

Ophthalmology. Whilst in this country for a number of years the specialistic treatment of affections of the eye, throat, ear, and nose has frequently been combined on one hand, both in private practice and in hospitals, it is only comparatively recently that attention has been more prominently directed towards the close association of affections of the eyes and nose. The pioneer in this direction has undoubtedly been Dr. Ziem of Danzig. But much has been learned regarding the importance of this connection since he published his first paper about twenty years ago. The reader who has not himself worked on the subject will be surprised to learn from the recent brilliant contribution to this question from the pen of Professor Schmiegelow of Copenhagen how much more has been done in this field since Ziem's first investigations were published and how much more remains to be done.

Dermatology and Syphilitic Diseases. Here again the close connection between manifestations on the external integument and similar ones on the mucous membranes is a well-established fact. The chapter on syphilis of the throat, nose, and ear is one of the most important in our field, and the possibility of syphilis must be always kept in view in the event of our meeting with any obscure affection. On the other hand, eruptions on the mucous membranes of the pharynx, nose, and larynx not only accompany in a number of cases analogous skin affections, but may precede such external manifestations or even remain for a long time limited to the mucous coverings. Thus lupus, herpes, pemphigus, lichen, and a host of other eruptions sometimes occur first in the parts intrusted to our care and may baffle the specialist whose knowledge of skin diseases is limited.

Neurology and Mental Diseases. When discussing the relations of our specialties with internal medicine I have already incidentally mentioned the significance of laryngeal paralysis for the diagnosis of some of the gravest intrathoracic diseases. It is, however, not only in connection with these but with numerous affections of the central nervous system that laryngology is of the greatest importance for neurology. The discovery of a laryngeal paralysis may be for a long time the first sign of the existence of organic central nervous disease, and in no affection is this more clearly shown than in tabes dorsalis. Again, neuroses of the olfactory nerve not rarely accompany important intracranial affections. Thus anosmia may occur in hysteria, basilar meningitis, and locomotor ataxy, and parosmia may be met with in hysteria, epilepsy, hypochondriasis, or may precede mental disturbances of an even graver character. Affections of the inner ear and of the auditory nerve occur in many diseases of the central nervous system. Auditory hallucinations, such as the hearing of voices, may accompany or even usher in different forms of insanity, and symptoms of Menière's disease probably come as often under the observation of the neurologist as of that of the aurist.

I forbear from entering upon a further enumeration of the branches of medicine with which our specialties have points of interest in common. My list is by no means exhausted, and I may as a proof of this remind you of the connection between them and dentistry, the point of contact being the affections of the antrum of Highmore, but in truth it may be said that there is hardly one single branch of medicine which does not occasionally come into touch with laryngological, rhinological, or otological interests.

In conclusion I should have liked to dwell upon the relations of the three specialties to one another, a question on which I hold views of my own. But apart from the need of keeping my own observations within the limits of the time specified, it would be out of place to introduce controversial matters into an address of this kind; and further I have on more than one previous occasion stated my opinions on this most important topic as clearly as I could.

And now, gentlemen, that I am at the end of my task, let me say that nobody could be more painfully conscious than I am how incompletely I have fulfilled it. I had intended to bring before you a picture full of life, and on looking back I have to confess to myself that I have offered you little more than a framework the details of which must be filled by your own knowledge and imagination. I had hoped to give you chapter and verse for every statement I have made, and I see that my paper is little more than a sort of catalogue under the headings of which only indications but no elaborations could be given.

But whilst unreservedly recognizing these shortcomings, I trust I may justly plead that the subject confided to me is one of such magnitude that within the limit of time necessarily imposed upon me it was well-nigh impossible to do full justice to it. Yet incomplete as my exposition has been, I venture to hope that it has illustrated by the demonstration of the intimate connection of laryngology, otology, and rhinology with human activity in so many other branches of Art and Science, the truth of Goethe's immortal dictum:

> Truly the fabric of mental fleece
> Resembles a weaver's masterpiece,
> Where a thousand threads one treadle throws,
> Where fly the shuttles hither and thither,
> Unseen the threads are knit together,
> And an infinite combination grows;

and that it has more than justified the warning words of my great teacher Virchow, which I have quoted at the beginning of this address:

That no specialty can flourish which separates itself completely from the general body of Science; that no specialty can develop usefully and beneficially if it does not ever and ever again drink from the general fount, if it does not remain in relationship with other specialties, so that we all help one another, and thereby preserve for Science, at any rate, even if it should not be necessary for Practice, that unity on which our position rests intrinsically, and, I may well say also, with regard to the outer world.

SHORT PAPER

Professor H. Zwaardemaker, of Utrecht, Holland, contributed an interesting paper on "Die Vestimmung der Gehörschärfe mittelst Flüstersprache."

SECTION L — PEDIATRICS

SECTION L — PEDIATRICS

(*Hall* 7, *September* 21, 3 *p. m.*)

CHAIRMAN: PROFESSOR THOMAS M. ROTCH, Harvard University.
SPEAKERS: PROFESSOR THEODORE ESCHERICH, University of Vienna.
PROFESSOR ABRAHAM JACOBI, Columbia University.
SECRETARY: DR. SAMUEL S. ADAMS, Washington, D. C.

PROFESSOR THOMAS M. ROTCH, of Harvard University, Chairman of the Section of Pediatrics, spoke as follows:

"In opening the Section of Pediatrics I wish to express the great pleasure which I feel in welcoming to St. Louis so many representatives from different parts of the world who have come here this afternoon on account of their interest in the study of children and their diseases. It is remarkable that a more thorough investigation of the early periods of life has for so many years been neglected in all the great medical centres where other branches of medicine have been so thoroughly studied and in which such great advances have been made. It would seem that it should be the very beginning of human life which should be first understood and worked over before it would be deemed possible to understand the later and more developed periods of life and those periods in which retrograde metamorphosis takes place preparatory to and in the midst of old age. It is a fact, however, that for some reason less interest has been taken in these early periods of life than in the later ones and that some twenty or thirty years ago pediatrics was seldom spoken of, much less understood. In the last few years, however, the world has begun to appreciate that if we would have a strong race of adults, both men and women, capable of doing their work in the world in the best way according to their sex, the preparation for such work should be begun in the very earliest days of life.

In accordance with this idea it is now well understood that especial knowledge in regard to feeding infant human beings is essential to their proper development and their vigor. In response to this tendency of modern thought and to the demand which the laity is making for a class of men who feel the great responsibility which is connected with the care of children, especial attention is now given to their study in health and disease. A most remarkable impetus has taken place in the study of pediatrics, new text-books, numerous special journals and medical societies devoted to the subject of pediatrics are becoming more and more prominent and great changes have taken place in the curriculum of most of the large medical schools throughout the world. Following as I have the growth of this important subject for the past twenty years I am convinced that the same time, care, and patient research should be given to the study of pediatrics as to any other important branch of medicine. The student should first acquire a complete knowledge of the anatomy, physiology, and progressive development of the newborn human being in the stages of infancy, during the first year, and the changes from infancy to early childhood in the second year, and the various changes so significant in middle and later childhood. I believe that a thorough knowledge of the infant and child in health is a prerequisite to the proper appreciation of the conditions which occur in that child in sickness and for the possibility of the intelligent treatment of such conditions.

The great rôle which the sensitive, ill-developed, and unstable nervous system plays in its many manifestations both in health and disease shows us unquestionably how only by untiring application, patience, and thought can we hope to produce such great results in the treatment of the young as have already been accomplished in that of adults.

THE FOUNDATIONS AND AIMS OF MODERN PEDIATRICS

BY THEODORE VON ESCHERICH

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PEDIATRICS, as far as it is connected with directions as to the care of the new-born and nurslings, belongs with midwifery to the oldest branches of medicine; but in its scientific development it is among the youngest. Not until the end of the eighteenth century did it separate itself sufficiently from the trammels of obstetrics to allow the first independent book on the diseases of the new-born and children, the well-known work of Rosenstein, to appear. This contains, as do similar works which appeared in the next few years, an unsystematic account of the diseased conditions occurring in or peculiar to children, and among these only those with evident symptoms and concrete changes found especial or detailed consideration. It was not until the French Revolution that the new school of medicine came into existence, and it we must thank for the creation of scientific pediatrics as well as for the birth of modern medicine.

We will seek to sketch in a few words the origin and changes of the leading ideas up to the present time, as this best gives the trend which further development will take in the near future.

Liberation from the ban of natural philosophy and humoral pathology was brought about by the sobering influence of pathologic anatomy, which pointed in no uncertain way to visible changes in individual organs as the origin and seat of diseases. Billard is the most brilliant example of this school, which erected a clinical structure as a commentary to the anatomic changes determined by extremely numerous and carefully performed autopsies.

The lesions themselves he considered in Broussais' sense only as different grades of inflammation, and although to this day his work is still a mine of important and useful facts, it is clear that this clever conception could not by itself fulfill our practical needs, at least not in childhood, where the short duration of diseases generally prevents the occurrence of extreme anatomic changes, and where even to-day, with the help of microscopic and bacteriologic methods, we are often at a loss to bring the autopsy findings into agreement with the clinical course. This lack of agreement is most marked in the domain of the diseases of the gastro-intestinal tract in infancy, and it was on them that the opposition, keenly led by Barrier, established the "Diacrisis doctrine," with which they steered back again into the sea of humoral pathology.

Uninfluenced by these theoretic discussions, however, both parties labored to develop the new science with the newly discovered methods of exact investigation of diseases and the untrod realm of statistics, and thus they created the basis of a special pathology and therapy of childhood, of which the work of Rilliet and Barthez forms a model presentation of the whole subject. With these men the French school of pediatry ceased to occupy the leading position which it had held. The Vienna school became its heir just as in the realm of internal medicine, where under the powerful influence of Rokitansky and Skoda the same favorable conditions for development existed. Here also the clinical study was mostly founded on the basis of pathologic anatomy, as may be learned from the excellent work of Bednar, *Ueber die Krankheiten des Neugeborenen und Saüglings* (*On the Diseases of New-born and Infants*), and the important studies of Ritter of Prague. At the same time clinical symptomatology and casuistry were developed in the newly erected clinic of the St. Anna Kinderspital in Vienna under Mayr and his disciple and successor, Widerhofer, and the clinical types of disease were determined conclusively from the ample material. In a similar manner worked Henoch in Berlin, West in London, and Filatow in Moscow, so that at the end of this period the clinical knowledge and symptomatology of pediatrics were developed as far as it was possible with the simpler methods of investigation.

However important this brilliant clinical development and the sharp definition of its separateness was for the recognition of pediatrics as a distinct science, still following this direction a dead point was soon reached, from which a new route had to be opened up if dullness and routine were not to take the place of scientific investigation. With this, German pediatrics in the narrower sense of the word came into the foreground. At first it had to struggle with great difficulties on account of the lack of separate children's hospitals and of government aid, and in the first half of the century it was almost entirely under French influence. Later the peculiar organization of university policlinics, which were charged with the instruction in pediatrics, brought it about that the care of pediatrics fell to the representatives of internal medicine. I will mention here only the name of Gerhardt, the founder of German pediatrics.

It lay in the nature of this relation that in Germany, in a certain contrast to the French and Austrian schools, the common points of contact with internal medicine and the diseases of later childhood closely related to the same were preferably studied.

Even though the creation of independent chairs of pediatrics in the German universities was improperly delayed by this relation, it had the advantage that the establishment of the rapidly growing natural sciences which was taking place at this period under the influence of German internists came immediately and quickly to the service of the clinic of children's diseases. The clearer knowledge of the disease processes made possible thereby emphasized more and more the identity of most of the diseases occurring in children and in adults, and led them to seek the explanation of their differences in the peculiar characteristics of the youthful organism. Of special importance from this standpoint is the study of artificial feeding carried on with such great energy by German authors (Biedert); this demonstrated in the most convincing manner the unfinished condition of the infantile digestive organs and the consequences arising therefrom. On this basis the modern German school developed, which, by means of the methods developed especially in internal medicine, saw the aim of modern pediatrics in the investigation of those physiologic peculiarities of the childish organism, which cause the differences between its reaction under physiologic and pathologic conditions, and that observed in adults. Recently the term pathologic physiology of childhood has been used for this science. A similar road is being traversed by the rising school of American pediatry; under the leadership of Jacobi it has attached itself closely to the doctrines of the German school.

Thus we see the problems of pediatrics extended from an investigation of diseased processes peculiar to childhood, as conceived by the older pediatrists, to a general consideration of all pathologic conditions occurring during this period of life. If I characterize this as the current ruling at present and consider it the problem of the immediate future for pediatrics, it must also be stated that the solution of the part of this task belonging to physiology or general pathology is not a problem for the pediatrist alone, but can only be taken up successfully if assistance is had from workers in other lines. It is recognized that pediatrics has at all times taken an active and useful part in the building-up of general medicine and in the working-out of questions of special clinical interest, which has been made possible to a great degree by the peculiarity of its material.

Of the greatest importance for the development of modern pediatrics has been the introduction of exact methods of clinical diagnosis, which developed in the middle of last century with the great renaissance of the exact sciences. If this revolution was of great aid in the study of diseases of adults, how much more for those of early infancy, in which subjective statements and so many other diagnostic helps are lacking, and the physician is almost entirely dependent on the information derived from objective phenomena. The introduction into pediatrics of percussion and auscultation, so necessary to the knowledge of lung and heart diseases, took place relatively late and slowly. Not until in the forties were they used systematically, especially by German physicians, to whom we must also be thankful for the only book (Sahli) devoted exclusively to percussion of the organs in childhood.

Of scarcely less importance in diagnosis was the adoption of the thermometer, which, especially in the forms of rectal measurements, can be used so easily in children, even by the laity. This last fact has made it a specially important and reliable instrument. Even though the first thermometric researches were made by Roger, the development of the technic and the working-out of typic fever curves is a merit of the German school, especially that of the University of Leipsic. Together with inspection and palpation, methods which were always used, percussion, auscultation, and thermometry form the trio which is indispensable in the examination of every child, and makes possible the certain diagnosis of many previously unrecognized diseases. The endoscopic methods are used wherever the technical accomplishment in children is possible. By far the most important is the inspection of the throat and mouth, as well as the examination of the ear, all of which are comparatively easy to practice, while the laryngoscopic and opthalmoscopic methods are more rarely used. Electric examination also belongs to the physical methods of examination which are only used under exceptional circumstances, but the importance of which has been increased by the discovery of the frequent increase of electric excitability in early childhood, and radioscopic investigation, which permits a previously unsuspected insight into the conditions of the bony development as well as the changes in the more deeply situated heart and lungs.

Aspiration of pathologic fluids, introduced by Dieulafoy, is an especially useful and valuable method in childhood, and to it lumbar puncture introduced by Quincke has been added. We may say that the manifold varieties of the processes occurring in the meninges have only been made manifest by the latter. Other methods, especially the graphic, are for evident reasons less used in children, although certain authors (Rauchfuss) have succeeded in overcoming the difficulties. On the other hand the histologic methods of investigation are made of great importance by the number and variety of the anemic states, although our knowledge of the pathogenesis of these diseases has not been very much advanced thereby.

In contrast to the physical methods whose technic is generally simple, permitting a relatively rapid development of the realms of knowledge opened up by them, are the chemic methods, which are still undeveloped in spite of the high development of organic chemistry. The subjects of chemic investigation are especially the excreta of the body, the urine and the feces. The study of urine has for a long time, at least in early infancy, been improperly neglected on account of the difficulty in collecting it. Thanks to Kjelberg's suggestion the catheter is now more frequently used for the collection of urine, especially in girls, while in boys we use the Raudnitz urinal. As a result unexpected frequency and variety of albumin, in the study of which Heubner has done especial service. Also the presence of other substances useful in diagnosis; the substances shown by Ehrlich's diazo reaction, acetone, diacetic acid, etc., were found in children of all ages. As regards the morphologic elements, not considering the very great frequency of blood and tube casts, we will only mention the presence of bladder and kidney epithelium, as well as of bacteria (generally colon bacilli), as an expression of infection of the urinary tract occurring especially often in girls. The use of the centrifuge in all these examinations is very advantageous. Another very promising method is the freezing-point determination, introduced into clinical medicine by Koranyi; it has been used repeatedly in pediatrics, in the study of the milk as well as the urine.

The collection of the stools is much easier than of the urine, at least in nurslings; they also offer much more favorable opportunities for diagnosis and analysis than do the stools of adults. While in the latter it is a mass of stinking putrefaction, composed of a third of bacteria, in the nursling, the stool on account of the much shorter intestinal tract is comparable to that obtained from a fistula of the small intestine and shows, like the contents of the small intestine, acid reaction, no putrefaction, and comparatively few bacteria; food constituents if found in it at all are found in relatively slightly altered condition. Another factor which considerably increases the diagnostic importance of the nursling's stool is the similarity or at least very limited variation in the character of the food, whereby the determination of a normal stool in respect to color, amount, and chemic composition is rendered possible. For this reason the chemic analysis of the stools of infants, especially those partaking of breast milk, was undertaken comparatively early (Wegscheider). The composition of the bacterial flora was studied by me, by Booker, and more lately by Tissier, who points with right to the importance of the anaërobes. Thanks to these conditions we are able to determine the pathologic changes in the digestive process of nurslings by chemic and bacteriologic examination of their stools much earlier and more exactly, and even to make the clinical diagnosis in a not inconsiderable number of cases.

The investigation of these excreta gains much in importance because their analysis enables us to gain an insight into the metabolic processes, those mysterious processes, which even though they are not life itself are at least the source of its strength and the most immediate expression of its activity. Although this matter is so very important, for the study of growth and of the dyscrasias occurring so frequently in childhood, it has only been in recent years that we have busied ourselves with the systematic investigation of this subject, urged on by the Breslau school (Czerny). In spite of the careful investigations performed by Camerer and Heubner in the realm of energia only the first steps have been taken toward the clearing-up of these questions, their study is made very hard by the unusual technical difficulties and the vulnerability of the infantile organism.

The science, however, which has had the greatest influence upon the development of pediatrics is that which hardly twenty-five years ago proceeded from the modest workshops of Pasteur and Koch, and has won in this short time so overwhelming an influence on medical thought and research. The reason why bacteriology is of such great importance to pediatrics is that in no other period of life do the infectious diseases take so great a part. Most striking from this standpoint is the earliest infancy, the pathology of which is dominated by the septic diseases produced by the widespread bacteria of suppuration. The nature of these diseases was in most cases first recognized by the demonstration of these easily cultivated disease-breeders; in this field Hutinel and Fischl have rendered the best services. Investigation in the realm of the true epidemic diseases, the acute exanthemas and the infections of mucous membranes, has been less successful, but the example of the diphtheria bacillus, discovered by Löffler, shows how great a furthering of clinical and therapeutic knowledge is to be expected from the discovery of the disease-producers. Also the discovery that not a few infections which were formerly observed only in adults, *e. g.*, tetanus, typhoid, cerebrospinal meningitis, dysentery, etc., occur also in early childhood, was first made possible by the bacteriologic demonstration of the microorganisms concerned.

Bacteriologic diagnosis received an important enrichment by the use of the reaction products of the organism called forth by the disease-process, *e. g.*, the agglutinins of typhoid (Gruber, Widal). This method may serve not only for diagnostic purposes, but also for the discovery of unknown disease-producers, *e. g.*, colon infection and dysentery. Jehle has demonstrated in my clinic the agglutination of pneumococci by the serum of pneumonia patients already in the first days of the disease, and lately it has been made possible to isolate the streptococcus of scarlatinal angina, which is agglutinated by scarlatina immune serum in very high dilution.

Apart from this, we receive through it an unsuspected look into the healing processes and protective mechanisms of nature, which are already present in childhood, and whose further study promises important revelations concerning the peculiarity of these diseases of childhood.

These facts, discovered in the course of the last decades by the use of scientific methods, have considerably extended and clarified the study of pediatrics. In place of the comparatively small number of diseases recognizable by evident characteristics, which form the contents of the older text-books, *modern pediatrics exhibits a scientific structure, including all disturbances of the life processes, arranged according to scientific principles, and in its completeness not reached by any other specialty in medicine.* The causes of diseases as far as they are based on exogenous agencies are the same in children as in adults. It is especially bacteriologic examination, which, being in a position to show disease-producers as such, has aided considerably in showing the identity of diseases which are often so different clinically. Unfortunately, our knowledge is not sufficiently advanced to make an etiologic grouping the sole basis of our classification.

Only a small number of diseases can be considered peculiar to childhood, because they are caused by events which cannot occur in the life of adults. These are the disturbances dependent upon birth and on the change from intra-uterine to extra-uterine life, as well as those concerning growth and development. In a certain way somewhat analogous to the occupation diseases of adults are here to be reckoned the injurious effects of school attendance, as well as the acute infectious diseases which confer lasting immunity. If, in spite of this, as daily experience and medical statistics teach, the diseases of childhood show such great differences in their number and form of manifestation, as well as in their course and termination, this can only be due to the fact that *between the growing organism of the child and that of the completely developed adult great differences exist in the reaction called forth by the disease-process variations, which change constantly in the course of childhood.* The following reflection will show what close relations exist between the stage of development on the one hand and the type and course of disease on the other hand. If we take a bird's-eye view of the whole field we are struck especially by the following peculiarities occurring in the course of diseases in childhood:

1. The overwhelming frequency of fatalities in diseases, especially from functional disturbances, which explains the unsatisfactory autopsy findings in so many cases.

2. The insignificant causes producing the diseases; they are much slighter than those necessary to produce the same diseases in adults. They easily escape detection, and this explains why

all sorts of fantastic representations (influence of milk secretion, eruption of teeth, occurrence of worms), have been taken as explanations.

3. The more rapid course of the disease, terminating sometimes with a fatal ending, sometimes with recovery, but mostly with atypic and uncomplicated course because occurring in a healthy organism. (The diseases which occur in earliest infancy, in which a rapid distribution of the disease-process to other organs is observed as a result of early cessation of their function, form an exception.) Especially to be mentioned is an ability to repair anatomic lesions which are not present to the same degree in later life. (Absorption of corneal scars, Fuchs.)

4. Apart from these general differences, the course of every single disease shows special peculiarities and variations when compared to the course observed in adults; these variations are according to the degree of development and functional activity of the organs concerned, and are the greater the younger the child is.

This last fact already shows that we have to do with processes which are connected with the development of the organism, and so we are again led to the conclusion that *the key to the understanding of the special pathology of the infantile organism is to be found in the study of developmental processes.* In spite of the large number of facts which are known to us, no attempt has been made, barring a but slightly known study by Barrier, to formulate general rules and points of view for the development of the infantile organism, and to make clear its relation to the pathogenesis of the diseases of childhood, as will be attempted in the following pages.

Growth, so far as we understand by this the utilization of foodstuffs for the purpose of new formation and growth of cells (Camerer), demonstrates itself as a function of vegetative life, or more accurately expressed the inherent specific living power of the body cells, the *vital potentiality.* If we, following the idea of R. Hertwig and Exner, see in the conjunction of the male and female egg cells respectively in sexual fecundation, the exciting cause for a new and limited series of asexual cell divisions, we must suppose that the power of growth is a function peculiar to the younger and youngest cell generations. We see, then, in the germinal cell, the bearer of the entire potential energy of life, which expresses itself in at first very rapid, but gradually slowing down, growth in the size of the embryo. Unfortunately, we have no useful measure for the intensity of these life or growth processes. We may soonest consider the increase in length or bulk, as such, as has already been done by the physiologist, Haller. The first is the more suitable, as, it being the greatest of all body measures, progress in its growth is recognized before all others, and negative variations are excluded.

The weight and length curves taken from the work of Quetelet show in so far a corresponding course as their greatest rise occurs in the intra-uterine period. From the fourth to the fifth year a gradual flattening is noted in the curve which, at least in the case of the length curve, passes into the horizontal about the twentieth year. Properly speaking, then, if we would represent the intensity of the vital processes, there should occur a gradual sinking of the curve, so that it would return to the base-line at about one hundred years (as the greatest length of life), supposing that its course remains unaffected by external harmful influences. This curve, reminding one of the parabolic course of a shot hurled aloft, together with the fact that the period of ripeness and bloom of the individual is not reached until the fourth decade, has led many authors (Burdach) to the view that the greatest vital energy, together with the highest functional development and greatest power of execution occurs in the middle of life, at the highest point of this imaginary curve. This idea is certainly wrong, as not only simple consideration but also accurate physiologic study show unequivocally that *the intensity of the metabolic processes calculated for the body measurements present is greater the smaller or younger the organism, and that it continually diminishes from the ovum on through the entire course of life.* I have represented this in a second curve. The straight red, in part dotted line, shows schematically the continually sinking life-energy. The first section of this has added to it a line obtained by the application of the actual increase in length per year corresponding to the expenditure of energy for growth; it rises rapidly to the point corresponding to the beginning of fetal life. Its course corresponds to the change of the potentiality of the embryonic cell into kinetic energy, and shows that at no other time are the energy and power of life as great as in childhood.

In absolute contradiction of this idea, however, is the well-known fact, that no other period of life shows so large a number of sicknesses and deaths as the first years of life; during these years, about a quarter of those born perish. This phenomenon is observed to the same extent in the plant and animal kingdoms, as Lichtenstaedt has already shown in answer to a prize question presented before the Independent Economic Society in St. Petersburg. We have the opportunity every day to see how only a minimal part of the seeds sown broadcast develop, only a few of the fertilized ovums reach full development. The cause of this unnatural fatality, in spite of the excess in vital energy, is *that the organs necessary for the support and protection of the life-processes are at this time so undeveloped* that the slightest injury already suffices to produce an irreparable disturbance of their functions and thus destruction of life. To the extent in which these organs in the course of development grow and become stronger, the mortality falls, diminishing considerably as early as the second and third years, and reaching its lowest point in the period between the sixth and tenth years of life. The occupation of the male, the sexual activity of the female, cause a rise in the mortality from the twentieth year on. In the later age-periods the physiologic sinking and extinction of the life energy finds expression. Haller has expressed this relation in these characteristic words: "Infantes mori possunt, senes vivere non possunt." Infants may die, old people cannot live.

On Table 2 the mortality rate of a certain group of people based on the official German statistics is expressed, along with the curve of the sinking energy of life.

This survey brings me to what I may call the second law of growth. The functional development of each individual organ, measured by the absolute degree of ability for work, takes during childhood a rising course, which, however, is different for each organ, and which as a rule shows a much steeper course than that of the growth curve. Unfortunately we lack the scientific data which would enable us to display graphically the gradual growth of the development and the functional ability of the most important organs of the circulatory, respiratory, digestive tract, etc. In general, however, we may conclude on the basis of anatomic and physiologic data that this occurs comparatively quickly, while other functions, like muscular power, reach their maximum at a much later date. We may consider the overcoming of influences injurious to the organism, in other words, the degree of the power of resistance, as the common result of all these powers, which finds an expression in the statistics of the frequency of diseases and deaths. That the measure so obtained is only relatively useful, and even then only under certain definite suppositions, is seen by the consideration of the first section of intra-uterine life. Although here the organs have the least power of resistance, diseases rarely occur on account of the protected condition of the fetus. But the transition into extra-uterine life already necessitates a wonderful precision of preformed mechanisms. The least failure of these causes the greatest danger to the life of the child, and thus is explained the high mortality peculiar to the act of birth and the period immediately following. This is aided by the conditions of extra-uterine life being felt for a time by the new-born as a direct irritant, whose harmful influence can only be lessened by the most constant and proper care. The more backward the development of the child (premature birth), the less favorable the environment (poverty, illegitimacy, unsuitable nourishment), so much the smaller is the expectation of preserving the life of the child. Under unfavorable social conditions, the mortality rises to 70 % of the births, while in well-to-do families it may sink to 10 %, or even lower. Much more important than these external influences is the rapid development of the organs occurring at this time, especially that of the digestive tract, which, according to Bloch's investigations, reaches its full histologic development from the third to the fourth year of life. This rapid improvement in resisting power, associated with high vital energy, together with the care and protection which guards the child in the parents' house, brings about the period of greatest health, which continues to the end of childhood, and in which disease and death sink to a minimum. The functional development, however, is by no means completed yet with this stage. Rather now begins, after the preservation and protection of life under normal conditions has been assured, the growth of that power and reserve strength which enables the adult to take up the struggle for existence and to care for the continuance of the species under the best possible conditions; the development of strength and activity in the musculature, becoming accustomed to fatigue, to different kinds of nourishment, to climatic influences, and especially the development and training of the mental powers. Into this period falls also the strengthening of the protective influences necessary for the overcoming of infectious diseases, the acquiring of immune substances, etc.

The occurrence of this long so-called puerile period, which is given over mostly to the functional development by relatively slight increase in length and weight, belongs, like the long duration of childhood, among the most eminent peculiarities of development in the human species. There is no doubt that man owes to this slow development and maturing not only the high state of his mental and physical abilities, but also his enormous power of accommodation and functional adaptation which enables him, in contrast to lower forms of life, to exist under the widest extremes of climate, foods, and habits of life, and thereby to make himself really the lord of the world. It would, however, be a fundamental error to believe that this progressive development of functions and organs, which characterizes childhood, occurs to an equal extent in all parts, like the growth of a crystal, which increases in size by addition of equal amounts over the whole surface of the nucleus. The study of embryology, which shows such remarkable changes in the form of the embryo, protects us from this unfortunately widespread opinion which regards the child as the exact image in small size of the adult. The table devised by Langer shows the great differences which on closer observation are seen to exist between the form of the child and that of the adult. But that not only the outward form, but also the internal organs experience during the course of growth a continual change in their relative size, is shown in the table prepared at my suggestion by Oppenheimer; it displays the weight of the organs at the different years of life (compared with the weight of the organs in the new-born). The consideration of these relationships, together with the observations already mentioned, shows that the *growth of the individual organs does not occur simultaneously, but with varying intensity, so to speak by jerks, and that the order is caused by the greater or lesser importance of the developing organs for the preservation or protection of the infantile life.* This I call the third rule of growth.

The life of the child in utero and at the beginning of its extra-uterine existence is so purely vegetative as to make Plato consider seriously the question whether the new-born is actually to be considered as a human being. But just as the intellectual life is bound up with the function and development of the brain, so is the vegetative life with the function and development of the organs serving metabolic ends. The most important of these are the circulatory system, the liver, kidneys, and lymph-glands, which experience an especially early development in intra-uterine life. Beside these, only those organs are well developed in the new-born which are to serve the purposes of assimilation, the lungs and the great digestive tract, while the poorly developed skeleton and the muscles only form a thin and tender covering to these essential organs. After the great increase in the size of the body during the first year of life comes the period of skeletal development which in the fifth or sixth year is joined by that of the building-up of the muscular and mental powers. *Childhood* divides itself thus, as this short sketch shows, into a series of *phases or periods characterized physiologically by the development of definite organ systems.* Their separation is not only justifiable from a scientific, but in a higher degree even from a practical standpoint, for the conditions and necessities of life are so different for each of these periods that the kind of care and treatment is almost exclusively determined by this, that is, by the age of the individual. With the backwardness of development and the slighter variability of life-conditions due to this is connected the fact that the guiding of the life must be the more regular and careful the younger the individual is. Only in later years can individual differences and the influence of social conditions be more marked.

The most useful division of childhood not only for scientific but also for practical purposes has been found in the threefold division accepted by Vierordt :

I. Childhood : Infantia.

(1) New-born period (first week of life). Characterized by the

change from intra- to extra-uterine life and the atrophy of fetal organs; hyperemia and desquamation of the external coverings.

(2) Nursing period (first year of life). Characterized by the necessity for exclusive milk diet on account of the functional weakness of the digestive tract, also a great consumption of nourishment and considerable increase in bodily size (trebling of birth weight) marked growth of the brain ; all other functions remain backward.

(3) Milk-teeth period (second to fifth years of life). Characterized by rapid growth and formation of the skeleton, eruption of milk-teeth, learning to walk and to talk.

II. Childhood : Pueritia. (Sixth year to puberty.) Characterized by special development and exercise of the musculature, by increase of all functional activities, and by slowly progressing growth of the body. Passage of the child from the family life into social life (school). Beginning differentiation of the sexes.

III. Age of puberty (in boys from the sixteenth year, in girls of the Germanic race, from the thirteenth year on). In the latter, beginning menstruation. Awakening of sexual impulses and development of secondary sexual characteristics.

I have limited myself to giving the physiologic characteristics of these periods very briefly. On the contrary, I will try to picture more extensively their close and important relations to pathology. If we conceive of disease as the physiologic reaction and defense of the organism against the disease-producing agency, it is apparent that the physiologic condition present at the time determines the kind and course of the process. As this is true for childhood in general as compared with maturity, so it is also for the different periods of growth, which, depending on the degree of development, show such great physiologic differences. In the first period of life, especially, these are so great that under the influence of local conditions there has developed a further specialization within the limits of pediatrics of such physicians, hospitals, and clinics as are especially concerned with the care and diseases of the nursing period. Even if I do not consider this tendency to separate as justified, still it will serve to demonstrate the great compass and variation of the study of children's diseases.

The relation of the periods of growth to pathology are based, as already stated above, on the fact that the special physiologic peculiarities of each period bring with them a similarity in the course of life, and therefore opportunities for certain diseases such as do not occur at any other time. The undeveloped condition of the organs in general helps along by causing a lessened power of resistance against all disturbances, and further, the organs while growing rapidly are disposed to diseases to an especially high degree. Finally there exists an age disposition for a small number of diseases depending partly on external causes, partly on the condition of the tissues themselves. All these causes unite in individuals of one and the same period of growth, and give rise to the fact that in them a certain group of diseases is observed with especial frequency, which occur much more rarely or not at all in other periods. Thus each of these periods of growth has not only a physiologic, but also a no less marked pathologic physiognomy.

I. *Infantia*

(1) *New-born period.* Malformations, congenital and inherited diseases (lues), tumors, birth injuries (fractures, avulsions, hematomas, brain injury), disturbances in the atrophy of fetal organs (diseases of the navel), icterus neonatorum, irritation and lesions of the tender skin and mucous membranes and favored by this bacterial invasion of the body, which still lacks protective powers, local and general sepsis, gonorrheal infection.

(2) *Nursing period.* Disturbances due to incorrect quantity or intervals of feeding, relative or absolute insufficiency of digestion of food taken, especially in artificial feeding, irritation of the intestinal mucous membrane by bacterial decomposition products, or invasion of the intestinal wall leading to chronic intoxication and atrophy of the mucosa. The rapid growth of the brain is not infrequently accompanied by over-irritability of the nervous system (tetany), eclampsia and hydrocephalus. There is also a susceptibility of the skin and mucous membrane (bronchial diseases, pneumonia) as well as a marked tendency to pyogenic diseases of all sorts; specific infections, however, occur comparatively rarely.

(3) *Milk-teeth period.* Disturbance of ossification processes (beginning already during the first year) with its results (deformities of the thorax and limbs), broncho-pneumonia, etc., from rachitis. At the same time occur other dyscrasias (status lymphaticus, scrofula, anemic states). The creeping of the child on dirty floors and the tendency to put everything into its mouth in conjunction with the lack of instinct for cleanliness produces the so-called dirt infections: Numerous mouth and throat diseases, diphtheria, contagious skin diseases, helminthiasis, pertussis, even tuberculous infection of the upper respiratory or digestive tract and the consequent lymph-gland tuberculosis especially of the bronchial glands. From the latter the form of hilum phthisis peculiar to this age arises. Frequent occurrence of local and miliary tuberculosis. Defects of the intellect show their existence by delay or failure to learn to speak and grave lesions of the brain by appearing idiocy and epilepsy. Especial frequency of acute poliomyelitis.

II. *Pueritia*

Entrance into school brings with it the harmful influences connected with it — scoliosis, myopia, nervous disturbances of all sorts, and manifold contact infections, among which the acute exanthemas with their sequels, nephritis, myocarditis, are by far the most important. The desire for violent exercise explains traumatic diseases, and perhaps also the greater frequency of appendicitis. Tuberculosis, especially of the glands, is rarer and approaches the adult type. On the other hand a new and dangerous infectious disease appears in acute articular rheumatism with endocarditis and chorea.

III. *Puberty*

Furnishes, especially in the female sex, characteristic troubles, chlorosis, hysteria, psychoses, heart diseases. Otherwise the pathologic conditions pass over into those of adult life. (Demonstration of tables.)

This classification of the most common diseases of childhood is familiar to every experienced pediatrist, and by the fact that the number of diseases coming into consideration at each age is relatively limited adds considerably to the facility of diagnosis and exact appreciation. It must also be the basis of every therapeutic consideration as the medical means as well as the care of the healthy child are different for each period of growth. At introduction, however, I wish to say a few words about the treatment of diseases of childhood in general.

Even though the general principles of medical treatment in children must be the same as in adults, still the practical application of the same differs considerably according to the age of the child. For example, it is not sufficient to reduce the dose of the medicament prescribed in a given case for an adult simply according to the body-weight of the child. Rather the physiologic peculiarities of the childish organism, its intolerance for some and tolerance for other drugs, as well as the consideration of the method of dispensing suitable to childhood, necessitate in almost all cases that the choice and method of dispensing in children differ in most all instances from what is usual in adults for the same indications. The physician active in children's practice must therefore make himself familiar by special study with the therapy suitable to each period of growth.

It is similar with the physical methods of treatment. These methods also, which of late are being more and more employed, require careful adaptation to the slighter resisting power, the lack of response, of resistance, which the small patients oppose to their use. On the other hand, the smallness and transportability of the childish body, the comparatively easily overcome resistance, and the lack of anxiety from preconception, afford in many cases a desirable ease of application.

I cannot go into details in the subject of therapy. Only in general I may say that of the flood of medicaments which has in the last few years been thrown on the market by chemic industry, only a few have found a lasting place in pediatrics. The use of medicines is becoming justly more and more limited, and replaced wherever possible by physical and dietetic methods of treatment, which by long and consistent use have given brilliant results.

We may expect a really curative effect only from those measures which stimulate further, or replace the naturally powerful healing processes of the childish organism, as is strikingly done by the diphtheria antitoxin prepared by Behring. Here the pediatrists who generally are forced to travel in the beaten tracks of internal medicine, were in a position to take the leading rôle in the testing and recommending of this precious agent. A second method of treatment also used in diphtheria may here be mentioned, for the introduction of which the pediatrists exclusively are to be thanked. I refer to intubation, recommended by your genial and modest countryman, O'Dwyer, which has made the bloody operation of tracheotomy superfluous in the largest number of cases.

The greatest difference between the therapeutic problems of the pediatrist and those of the internist lies in the overwhelming importance and development of prophylaxis. The word prophylaxis in this sense is to some extent synonymous with care, inasmuch as in the education of the child because of its lacking self-determination, experience, and regulating methods, care must not only satisfy its bodily needs, but also guard it from all threatening dangers. To bring this about, the experience of adults and the general rules of hygiene, however, do not suffice. It requires special individual instruction, which can only be given by a pediatrist cognizant of the laws of child development, and carried out by persons trained in them. Clinical experience and medical statistics show that nothing influences the mortality and liability to disease in childhood as much as a carefully conducted management by experts, and in this way most if not all sicknesses may be kept away, at least in young children. Pediatrists have always known the great importance of protecting care, prophylaxis, even if only the magnificent acquisitions of the last few decades have shown them the proper way. We will attempt to sketch in a few words the most important axioms of prophylaxis for the different periods, and at the same time to touch on some of the questions which are still unsettled.

The prophylaxis in regard to birth injuries belongs to obstetrics. Here I only wish to mention the original idea of Professor Gaertner to overcome the grave asphyxia of the new-born by the introduction of oxygen into the umbilical vein. Apart from this, the task of the pediatrist is to make the surroundings of the new-born as much like the conditions existing in utero as possible, for which purpose an incubator may occasionally be useful. The delicacy of the skin and mucous membranes requires especial care in the cleansing and clothing of the child. It is well known that most of the diseases of the mouth which occur in the first few years are caused, or at least favored by mechanical injuries. Of course, another factor, infection, must assist. The slightest lesion of the coverings, however, and the ordinary pus bacteria which are ubiquitous in man's surroundings suffice already for their occurrence. To their frequency and danger the old foundling asylum statistics and hospital reports, in which 80 % to 100 % of the infants admitted died, bear witness. Through the introduction of asepsis and antisepsis into the care of nurslings, a revolution of these relations and a decrease in the septis diseases which is comparable to the precaution of puerperal fever by Semmelweiss has taken place.

The largest and most difficult task in this period of life, however, is the nourishment. The intestinal canal of the nursing child must in spite of the backwardness of its development, assimilate a sufficient quantity of food for the body-weight to treble itself.

This task is comparatively easily accomplished if the natural nourishment which suits the nursling's needs so wonderfully, mother's milk, is to be had. The difficulty is immeasurably increased, however, if the mother, from lack of milk or for social reasons is unable to nurse her child, a state of affairs which is more and more often met with. As the knowledge of metabolic processes, in spite of the great amount of work spent on it, is not sufficiently advanced to permit the setting-up of experimentally determined values, we are to-day, as in former times, required to keep to the model of mother's milk, and to make the cow's milk which is used in artificial feeding as much like it as possible.

The differences of percentage composition, which at first were considered to be of the greatest importance, we have learned to overcome completely by sufficient dilution and addition of proper amounts of fat and carbohydrates. On the other hand, in course of investigation, the cleft which existed in reference to the quality of the different foodstuffs, has widened. At least, this is true of the most important one of them, the albumin. This shows irremediable differences from the albumin of mother's milk, not only in its elementary composition and chemic reactions, but, as it comes from a different sort of animal, also in its biologic behavior. Wassermann and Hamburger have pointed out the importance of this question in infant feeding.

The thermolabile ferment-like bodies, which are contained in mother's milk, and to the presence of which I have myself drawn attention, also belong to the group of components which differ qualitatively. These substances give the breast-fed child, as they come from the blood of the mother, a part of the antitoxins and metabolic ferments contained therein, while the analogous bodies contained in raw cow's milk are of little or no value to the nursling. Therefore, it does not appear to me justified to give up for this reason the sterilization of cow's milk by heat, an acquisition which I consider one of the greatest advantages in this line, although a general tendency exists to limit the temperature and duration of the heat as much as possible, on account of the chemic changes which it causes. This is the more possible, the more cleanly the method of obtaining the milk has been, and the more carefully it has been handled before sterilization. It appears very questionable, however, whether the recently advocated addition of formalin (Behring), or the passage of electricity (Seifert), will be able to replace sterilization by heat.

An important difference between natural and artificial nourishment exists also in the method of feeding. The child at the breast receives the milk by active suckling, and (presuming feeding by its own mother) in a quantity and composition suited to its needs. The artificially-fed child has at its disposition food in unlimited quantity, and as a rule this is poured into its digestive tract in excessive amount, considering its digestive powers. Another practically important step in artificial feeding lies in strict limitation of the size and number of the feedings, in the determination of the amount of nourishment calculated either by the volumetric method or reckoned in calorics, in a word in the avoidance of the habitual over-feeding of the bottle-baby. In spite of the large amount of work done in this direction in the last decades, we must confess that we are still far from the aim of our efforts, the discovery of a substitute for mother's milk, and that nothing can replace it, especially in children backward in development or weakened by disease. On the other hand, we can say truthfully that we have succeeded in robbing the feeding with cow's milk of a large part of the danger which previously accompanied it, so that if the power to assimilate cow's milk is present at all, artificial feeding can be carried on with confidence as to the result. Of course, its proper carrying-out requires a much greater cost of time, care and pecuniary means than does breast-feeding; so that the improvement in artificial feeding is of slight or no benefit to the poor people, where it is most needed. The same difficulty also exists with regard to care, cleanliness, light and air in their dwellings.

These last factors are of special importance in the period of skeletal development. Unhygienic conditions of the surroundings, insufficient ventilation, crowding together of persons, as occurs especially among poor people and in cold weather, have, as Kassowitz has shown, an undoubted influence on the origin and severity of rachitis. Considering the great frequency and insidious beginning of this disease, it is not unnecessary to mention that the severe forms and deformities of this disease may at the proper time be prevented. In a carefully regulated diet and the use of baths, air and exercise cures, and secondarily in the administration of food preparations and medicines (phosphorus, iron, arsenic), we possess powerful aids against the development of this dyscrasia, which is so frequent at this period. In view of the change of the skeleton from the infantile to the adult type, which occurs at this time, one should also try to influence this process favorably and to prevent for example the development of the dreaded paralytic thorax by suitable means. The dangers of dirt infections are to be avoided by careful avoidance of opportunity for infection, and cleanliness; eventually, also by the use of an inclosed protective pen (Feer). I have reached the opinion that not a few of the cases of tuberculous meningitis, which is so frequent at this age, are to be traced to infection from dust in the dwelling.

In the second period of childhood, which is devoted to functional development, the task of the physician is on the one hand to bring the powers and abilities of the child to harmonious perfection, on the other hand, by an appropriate selection and direction of bodily exercises and by the proper arrangement of hours of work, to prevent exhaustion and harm. From which side the influence of the physician must act depends on the peculiarities of the child and of its guardians, and also on the customs and usages of the country. In the Germanic and Latin countries the general striving toward a better physical development does not begin until this period, while among people under English influence this has started long before.

A new factor comes into the life of the child with the school. The modern method of teaching classes in closed rooms and with a comparatively large number of hours of instruction is, from the hygienic standpoint, to be looked upon as a necessary evil. So much the more we must endeavor to compensate for the unavoidable harm by improving the school arrangements on the one hand, and by sufficient time for rest on the other. From many sides the principal task of the physician in this period is thought to be by rigorous isolation measures to guard the children against the acute exanthemas which threaten them at school. I cannot agree with this point of view under all circumstances and for all the diseases of this group. Even though every appropriate measure, even prophylactic immunization should be recommended for certain diseases like diphtheria and scarlatina, this should only be done as regards the much milder measles and varicella which attack almost every one, in so far as one tries to guard the individual as far as possible from getting the disease at a time or age in which a lessened power of resistance or a tendency to complication exists. After the sixth or seventh year this is as a rule not the case, while on the contrary in adult life measles not infrequently takes a severe course (Biedert).

The immunity acquired by passing through certain infectious diseases is an integral part of that power of resistance which man should acquire in the course of childhood. With this item is also to be classed obligatory vaccination.

Thus every period of childhood brings new and important necessities for the carrying-out of individual prophylaxis, and these might be multiplied without difficulty. The main point is the constant and careful watching over the course of the child's life during the whole but especially during the first period of growth, the care and furthering of normal development according to the sentence "medicus non sit magister sed minister naturae;" therefore in detail the taking care of those backward in development, improvement of the already developed functions, special protection of the rapidly growing organs, prevention of the tendencies to acquired or inherited diseases, protection from injurious agencies, especially infections. Disease with which the medical care generally begins is here to a certain extent a failure of preventive care, an interruption disturbing the normal process of development, In this sense the physician to whom the child is trusted becomes the friend and indispensable adviser of the family in all matters affecting the bringing-up of the child, provided they know how to appreciate the unselfish character of his work. I admit that nowadays this function of the pediatrist is employed only exceptionally and under particularly favorable conditions, and that even in the future only a limited number of families will have it accessible. But why at the close of a century which has shown such unexpected results should we hesitate to place individual prophylaxis, based on raising the power of resistance and avoidance of diseases, as the ideal aim of our efforts?

The picture of modern pediatrics would be incomplete if I were not to mention the efforts and results which have been seen in the realm of the protection of children. This was the more needed, as in many countries, especially the Anglo-Germanic, the care of poor, sick, and deserted children has always been left to private benevolence, while in the Latin countries the orphan asylums cared for the neediest group of these children. Thus were founded the children's hospitals and dispensaries, based on private donations, which to-day are to be found in every large community. These institutions are particularly important, as they form the natural centres for the practical education and scientific work from which the clinical institutes develop.

The assistance of pediatry in the reform of orphan and reformatory asylums, in the question of school physician, in the numberless societies whose purpose is the strengthening and making healthy of growing children (school gardens, vacation camps, seashore homes, etc.), goes without saying. It was the pediatrist who first pointed out the necessity for such institutions and the means of redress.

The latest movement makes the care of nursing infants its aim, the shocking mortality among whom has already been mentioned. In this direction, as in the care of children in general, at least as far as governmental aid is considered, France occupies unopposed the first rank, whom Hungary now follows with praiseworthy zeal. In most other countries there are only private undertakings; homes for cripples, milk dispensaries (so called *grottos de lait*), maternity hospitals, homes for infants. The latter serve also mostly the purposes of educating medically trained nurses. In this respect the institutions existing in the United States, among which I have become best acquainted with St. Margaret's House in Albany directed by Dr. Shaw, are especially worthy types.

All these institutions have been started by pediatrists, in part carried on by them, and sustained by their voluntary and gratuitous assistance. Thus it comes about that every year hundreds of thousands of persons whose financial position would otherwise not permit it enjoy the benefit of specialistic medical advice and treatment, and that the knowledge of a rational care of children, which is so necessary, becomes more and more widespread among the people. The warm interest and the aid which these efforts find among all classes of people show that the usefulness and humanity of these aims are fully appreciated. The great importance of these efforts for the sustaining and strengthening of coming generations is also being more and more recognized by the public authorities.

Thus our young science may, with full justification, claim to have been successful in the great task which has fallen to it in the share of public work.

THE HISTORY OF PEDIATRICS AND ITS RELATION TO OTHER SCIENCES AND ARTS

BY ABRAHAM JACOBI

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The most human of all the gods ever created by the fancy or the religious cravings of mortal men was Phœbus Apollo. It was he that gave its daily light to the wakening world, flattered the senses of the select with music, filled the songs of the bards and the hearts of their hearers with the rhythm and wonders of poetry, that inspired and reveled with the muses of the Parnassus, cheered the world with the artistic creations of the fertile brains and skillful hands of a Zeuxis and Phidias — he, always he, that inflicted and healed warriors' wounds and sent and cured deadly diseases.

In the imagination of a warm-hearted and unsophisticated people it took a god to embrace and bestow all that is most beneficent and sublime — physical, moral, and mental light and warmth; the sun, the arts, poetry, and the most human and humane of all sciences and arts, namely, medicine.

Ancient gods no longer direct or control our thoughts, feelings, and enjoyments, either physical or intellectual. The kinship and correlation of hypotheses and studies, experience and knowledge are in the keeping of the philosophical mind of man, who is both their creator and beneficiary. To demonstrate this rational affinity of all the sciences and arts, some far-seeing men planned this great Congress. The new departure — in the arrangement for it — should be an example to future general and special scientific gatherings. Indeed, some of its features were adopted by the organization committee of the International Medical Congress which was to take place at St. Louis, but was given up on account of the limited time at the disposal of the great enterprise.

Congresses are held for the purpose of comparing and guarding diversified interests. A free political life requires them for the consulting of the needs of all classes. Scientific congresses are convened to gather and collate the varied opinions, experiences, and results of many men, and to create or renew in the young and old the enthusiasm of youth. Their number has increased with the modern differentiation of interests and studies. Specialization in medicine is no longer what it was in old Egypt, namely, the outgrowth of the all-pervading spirits of castes and sub-classifications, but as well the consequence as the source of modern medical progress. It is difficult, however, to say where specialization ends and over-specialization begins, or to what extent specialization in medicine is the result of mental and physical limitation or of the spirit of deepening research; or, on the other hand, of indolence or of greed; or whether, while specialization benefits medical science and art, it lowers the mental horizon of the individual, and either cripples or enhances his usefulness in the service of mankind. For that is what medical science and art are for. José de Letamendi is perhaps correct when he says that a man who knows nothing but medicine does not even know medicine. What shall we expect, then, of one who knows only a small part of medicine and nothing beyond?

Congresses in general have been of two kinds. They were called by specialists for specialists, or they met for the purpose of removing or relieving the dangers of limitation. This is what explains the great success of international and of national gatherings, such as the German, British, American, and others, and what has given the Congress of American Physicians and Surgeons with its triennial Washington meetings its broadening and chastening influence.

Nor are medical meetings the only attempts at linking together what has a tendency to get disconnected. Look at our literature. The rising interest in the history of medicine as exhibited in Europe and lately also among us, and individual contributions, such as Gomperz's great book on Greek thinkers; or even lesser productions, such as Eymin's *Médecins et Philosophes*, 1904; or the important pictorial works of Charcot, Richet, and Holländer, prove the correlation of medicine with history, philosophy, and art.

Our special theme is the history of pediatrics and its relations to other specialties, sciences, and arts. Now Friedrich Ludwig Meissner's *Grundlage der Literatur der Pädiatrik*, Leipzig, 1850, contains on 246 pages about 7000 titles of printed monographs written before 1849 on diseases of children, or some subject connected with pedology. Of these, 2 were published in the fifteenth century, 16 in the sixteenth, 21 in the seventeenth, 75 in the eighteenth. P. Bagellardus *De aegritudinibus puerorum*, 1487, and Bartholomeus Metlinger, *Ein vast nützlich Regiment der jungen Kinder*, Augsburg, 1473, opened the printed pediatric literature of Europe. In the sixteenth century, Sebastianus Austrius, *De puerorum morbis*, Basileae, 1549, and Hieronymus Mercurialis, *De morbis puerorum tractatus*, 1583, are *facile principes;* in the eighteenth, Th. Harris, *De morbis infantum*, Amstelodami, 1715; Loew, *De morbis infantum*, 1719;

M. Andry, *L'orthopédie ou l'art de prévenir et corriger dans les enfants les difformités du corps*, 1741; Nils Rosen de Rosenstein, 1752; E. Armstrong, *An Essay on Diseases most Fatal to Infants*, 1768; and M. Underwood, *Treatise on the Diseases of Children*, 1784; also Hufeland, established pediatrics as a clinical entity; while Edward Jenner, 1798, *An Inquiry into the Causes and Effects of the Variolae Vaccinae*, opened the possibilities of a radical prevention of infectious and contagious diseases, the very subject which, a century later, is engaging the best minds and a host of assiduous workers in the service of plague-stricken mankind.

In the United States pediatrics was taught in medical schools, or was expected to be taught, by the professors of obstetrics and the diseases of women and children. The reorganization of the New York Medical College in East Thirteenth Street facilitated the creation, in 1860, of a special clinic for the diseases of the young. Instead of the united gynecologic and obstetric clinics held by Bedford, Gilman, and G. T. Elliott in their respective medical colleges, there was a single clinic for the diseases of the young exclusively. When the Civil War caused the College to close its doors forever, in 1864, the clinic was transferred to the University Medical College, and in 1870 to the College of Physicians and Surgeons. Meanwhile other medical schools imitated the example thus presented. The teachers were classed amongst the "clinical" professors; only in those schools which are forming part of universities and are no longer proprietary establishments, a few now occupy the honored position of full professors; in a very few the professor of pediatrics is a full member of the "faculty."

In the English Colonies of America the earliest treatise on a medical, in part pediatric subject was a broadside, 12 inches by 17. It was written by the Rev. Thomas Thacher, and bears the date January 21, 1677–8. It was printed and sold by John Foster of Boston. The title is "a brief rule to guide the common people of New England how to order themselves and theirs in the Small-Pocks, or measles." A second edition was printed in 1702.

Before and about the same time in which American pediatrics received its first recognition at the hands of the New York Medical College, European literature furnished a new and brilliant special literature. France which almost exclusively held up the flag of scientific medicine during the first forty years of the eighteenth century, furnished in C. Billard's *Traité des maladies des enfants nouveau-nés*, 1828, and in Rilliet's and Barthez's *Traité clinique et pratique des maladies des enfants*, 1838–43, standard works which were examples of painstaking research and fertile observation. England, which produced in 1801 I. Cheyne's *Essays on the Diseases of Children*, gave birth to Charles West's classical lectures on the diseases of infants and children in 1848, and F. Churchill's treatise in 1850.

The German language furnished a master-work in Bednar's *Die Krankheiten der Neugebornen und Säuglinge,* 1850–53. A. Vogel and C. Gerhardt, both general clinical teachers, gave each a textbook in 1860, Henoch in 1861; and Steffen in 1865–70, published a series of classical essays.

The number of men interested in the study and teaching of pediatrics grew in proportion to the researches and wants of the profession at large. That is why three large and influential cyclopedias, the works of many authors, found a ready market, namely, C. Gerhardt's *Handbuch der Kinder-Krankheiten,* 1877–93; John M. Keating's *Cyclopedia of the Diseases of Children Medical and Surgical,* 1889–90, and I. Grancher's and I. Comby's *Traité des Maladies des Enfants,* in five volumes, the second edition of which is being printed this very year.

The collective and periodic literature of pediatrics began at a comparatively early time. There was a period towards the end of the eighteenth century when the influence of Albrecht von Haller seemed to start a new life for German medical literature before it lost itself again in the intellectual darkness of Schelling's natural philosophy, from which it took all the powers of French enthusiasm and research, and the epoch-making labors of Skoda, Rokitansky, and finally Virchow, to resuscitate it. About that early time of Haller, there appeared in Liegnitz, 1793, a collection of interesting treatises on some important diseases of children (*Sammlung interessanter Abhandlungen über etliche wichtige Kinderkrankheiten*). France followed in 1811 with a collection bearing the title *La Clinique des Hôpitaux des enfants, et revue retrospective médico-chirurgicale et hygiénique. Publiées sous les auspices et par les médecins et chirurgiens des hôpitaux consacrés aux maladies des enfants.* Next in order are five volumes of Franz Joseph von Metzler's *Sammlung auserlesener Abhandlungen über Kinderkrankheiten,* 1833–36 ; twelve fascicles under the title *Analekten über Kinderkrankheiten oder Sammlung ausgewählter Abhandlungen über die Krankheiten des Kindlichen Alters ; la clinique des Hôpitaux des enfants, Redacteur en chef Vanier,* Paris, 1841; and I. Behrend and A. Hildebrandt, *Journal für Kinderkrankheiten,* which appeared regularly from 1843 to 1872. It gave way to the *Jahrbuch für Kinderheilkunde,* which appeared in quick and regular succession from 1858 to the present time. Three series of Austrian journals between 1855 and 1876 consisted of a dozen volumes only. They contain among other important contributions the very valuable essays of Ritter von Rittershayn, who deserved more recognition during his life and more credit after his death, for his honesty, industry, and originality, than he attained.

Special pediatric journals have multiplied since. The United States has two, France three, Germany five, Italy two, Spain one.

As long as they are taken by the profession we should not speak of over-production. I attribute their existence to the general conviction that there is no greater need than of the distribution of knowledge of the prevention and cure of the diseases of the young. The literature of pediatrics seems to prove it. Not 7000, as before 1850, not even 70,000 titles of books, pamphlets, and magazine articles exhaust the number.

Pediatric societies have increased at the same rate. The American Medical Association and the British Medical Association founded each a section twenty-five years ago, the New York Academy of Medicine in 1886. The American Pediatric Society was founded in 1889, the Gesellschaft für Kinderheilkunde connected with the German Gesellschaft der Aerzte und Naturforscher in 1883, the English Society for the Study of Disease in Children, in 1900. There are pediatric societies in Philadelphia, in the State of Ohio, in Paris, Kiew, St. Petersburg, and many places, all of them engaged in earnest work which is exhibited in volumes of their own or in the magazines of the profession. If we add the annual reports of hundreds of public institutions, which are so numerous indeed that a large volume of S. Hügel, *Beschreibung sämmtlicher Kinderheilanstalten in Europa*, was required as early as 1848 to enumerate them; and an enormous number of text-books of masters, and of such as are anxious to become so, and monographs, and essays, and lectures, and notes preliminary and otherwise, which fill the magazines that most of us take or see, and some of us read — we may form an idea to what extent a topic formerly neglected has taken hold of the conscience and the imagination of the medical public.

Before 1769 there was no institution specially provided for sick children. They were admitted now and then to foundling institutions and general hospitals. In that year Dr. G. Armstrong established a dispensary in London which was carried on until he died. A similar institution was founded in Vienna by Dr. Marstalier, in 1784. Goelis took charge of it in 1794, L. Politzer developed it, and it is still in existence. Before the French Republic was strangled, it founded the first and largest child's hospital in Europe, L'Hôpital des Enfants malades, in 1802. The Nicolai Hospital was established in St. Petersburg in 1834 by Dr. Friedburg; the St. Anne's Child's Hospital in Vienna, 1837, by Dr. Ludwig Mauthuer; and the Poor Children's Hospital of Buda Pesth in 1839 by Dr. Schöpf Merei, who afterwards founded and directed the Child's Hospital of Manchester, England.

Since that time the increasing interest in the diseases of children on the part of humanitarians and of physicians and teachers has multiplied children's hospitals. Most of them are small, but they are numerous enough both to exhibit and disseminate the sense of responsibility to the sick and to the necessities of teaching. The United States has been the last country to participate in these endeavors. The mostly proprietary medical schools did not find pediatric teaching to their advantage, and it took the hearts and purses of the public a long time to be opened. The waves of humanitarianism, sometimes directed by a church, and the demands of science have finally overcome previous indolence. There are many general hospitals that gradually opened special children's wards. You find pediatric hospitals in some of the larger cities—New York, Boston, Philadelphia, Albany, St. Louis, and others. It has so happened, however, that real specialties have appealed more to the general sympathy than pediatrics. That is why the number of beds in orthopedic and other special hospitals are mostly favored. Practical teaching has not been extensive. Children's hospitals that should be used for that purpose, and that are directly connected with a medical school, are but few. It has taken the medical faculties even of universities too much time to appreciate the necessity of special and well-regulated bedside teaching. In some instances lay trustees, guided by their medical advisers, have opened their wards before faculties have consented to open their eyes. At the present time, however, there is hardly a great medical school that does not give amphitheatre or bedside instruction, either in a children's ward of a general hospital or in a special children's or babies' hospital. To a certain extent the teaching of pediatrics in a general hospital has its great advantages. It is not a specialty like that of a special sense or a tissue. For the purpose of study it had to be segregated, but it will never be torn asunder from general medicine. Vogel and Gerhardt were both general clinicians.

The comparative anatomy and physiology, hygiene, etiology, and nosology of pediatrics have been discussed before you by one of the most prominent pediatrists of our era. It will be my privilege to explain, as far as time will permit, its relation to general medicine, to embryology and teratology, obstetrics, hygiene, and private and public sanitation, to therapeutics both pharmacal and operative, and to the specialties of otology, ophthalmology, dermatology, and the motor system, to pedagogy, to neurology and psychiatry, forensic medicine and criminology, and to social politics.

Infancy and childhood do not begin with the day of birth. From conception to the termination of fetal life evolution is gradual. The result of the conception depends on parents and ancestors. Nowhere are the laws of *heredity* more perceptible than in the structure and nature of the child. Physical properties, virtues and sins, and tendencies to disease may not stop even with the third or fourth generation. Hamburger and Osler trace an angio-neurosis through six generations, the first case in the series being observed by Benjamin Rush. In many instances still-births, early diseases, atrophy, and undue mortality of the young depend on ante-natal happenings. The condition and diet of the mother influences her offspring. The danger of a contracted pelvis, and the necessity of premature delivery may be obviated by the restriction of the diet, or even by appropriate (thyroid and other) medication of the pregnant woman. Experience and experiment tell the same story. The continued practice of preventing conception causes endometritis. Alcoholism causes chronic placentitis, premature confinement, or still-birth. So does chronic phosphorus and lead poisoning. Fortunately, however, the usual medication resorted to during labor is rarely dangerous, for even morphine or ergot doses given to the parturient woman on proper indications affect the newly-born rarely, and chloroform anesthesia almost never.

Scanty amniotic liquor, by the prevention of free intra-uterine excursions, may cause club-foot; or close contact of the surfaces of the embryo and the membranes give rise to adhesions of the placenta and the head, to filaments and bands whose pressure or traction produces grooving or amputation of limbs, cohesion of toes or fingers, umbilical, meningeal, encephalic, or spinal hernia; not in extra-uterine pregnancy only, where such occurrences are very frequent. Even the majority of harelips and fissured palates have that origin. Arrests of development and fetal inflammation are the headings under which most of the anomalies of the newly-born may be subsumed; congenital diseases of the ear and of the heart may result from either cause or from both. Obstructions of the intestines, the rare closures of the esophagus, the ureter, and the urethra, with hydro-nephrosis and cystic degeneration of the kidneys, are probably more due to excessive cell proliferation in the minute original grooves than to inflammation.

The insufficient closure of normal embryonic fissures or grooves explains many cases of spina bifida, many of encephalocele, most of the split lips and palates, all of porencephalus, bifid uvula and epiglottis, pharyngeal and thyroglossal fistulæ, the communications between the intestinal and uro-genital tracts, and the persistency and patency of the urachus.[1]

Heredity need not show itself in the production of a fully developed disease. It exhibits itself normally either in equality or resemblances, either total or partial, of the body, or some one or

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[1] J. W. Ballantyne, in his manual of ante-natal pathology and hygiene, 1902, has a separate chapter on the relations of ante-natal pathology to other branches of study, to general pathology, to the biological sciences, such as anatomy, embryology, physiology, botany, and zoölogy, and to the medical, including obstetrics, public health, pediatrics, medicine, psychology, dermatology, surgery, orthopedics and medical jurisprudence, finally to gynecology and neo-natal pathology.

more of its external or internal organs. In this way it may affect the nervous, the muscular, the osseous, or other tissues. That is why dystrophies in different forms, obesity, achondroplasia, hyperplasia, or atrophy may be directly inherited, while in other cases the disposition to degeneration only is transmitted.

Hereditary degeneracy is often caused by social influences. The immoral conditions created by our financial system make women select not the strong and hearty and the young husband, but the rich and old, with the result of having less and less vigorous children. Certain professions, the vocations of soldiers and mariners, and subordinate positions of employees in general, enforce complete or approximative celibacy, with the same result. The nations that submit to the alleged necessity of keeping millions of men in standing armies, are threatened with a degenerated offspring, for not only do they keep the strongest men from timely marriages, but they increase prostitution and venereal diseases, with their dire consequences for men, women, and progeny. Wars lead to the same result in increased proportion, for tens and hundreds of thousands of the sound men are slain or crippled, or demoralized. Those who are inferior and unfit for physical exertions remain behind and procreate an inferior race; those who believe with Lord Rosebery that an empire is of but little use without an imperial race will always, in the interests of a wholesome civilization, object to the untutored enthusiasm which denounces the "weakling," and the "craven cowardice" of those who believe in the steady evolution of peace and harmony amongst men, and, in sympathy with the physical and moral health of the present and future generation, will prefer the cleanly and washed sportsmanship of an educated youth to that of the mud-streaked and blood-stained man-hunter.

A great many diseased conditions cannot be thoroughly understood unless they be studied in the evolving being. Tumors are rarely inherited, but many of them are observed in early life. Lymphoma, sarcoma, also lipoma and carcinoma, and csytic degeneration, are observed at birth, or within a short time after, and seem to favor Cohnheim's theory, according to which many owe their origin to the persistence in an abnormal location of embryonic cells. This theory does not exclude the fact that congenital tumors may remain dormant for years or decades and not destroy the young.

So much on some points connected with *embryology* and *teratology.* The connection with *obstetrical practice* is equally intimate. Three per cent of all the mature living fetuses are not born into postnatal life this very day. To reduce the mortality even to that figure, it has taken much increase of knowledge and improvement in the art of obstetrics to such an extent that it has become possible by Cesarean section not only to save the fetus of a living, but also of a dead mother, for the fetus in her may survive the dying woman.

But after all, many a baby would be better off, and the world also, if it had died during labor. There are those, and not a few, who are born asphyxiated on account of interrupted circulation, compression of the impacted head, or meningeal or encephalic hemorrhage, which destroys many that die in the first week of life. Those who are not so taken away may live as the result of protracted asphyxia only to be paralytic, idiotic, or epileptic. Many times in a long life have I urged upon the practitioner to remember that every second added to the duration of asphyxia adds to the dangers either to life or to an impaired human existence. Besides fractures, facial or brachial paralysis, cephalhematoma and hematoma of the sterno-cleido mastoid muscle, gonorrheal ophthalmia, with its dangers to sight and even life, may be daily occurrences in an obstetrician's life. All such cases prove the insufficiency of knowledge without art, or of art without knowledge, and the grave responsibility of the practical obstetrician. To lose a newly-born by death causes at least dire bereavement; to cripple his future is not rarely criminal negligence.

Within a few days after birth the obstetrician or the pediatrist has the opportunity of observing all sorts of microbic infections, from tetanus to hemorrhages or gangrene, and the intense forms of syphilis. Not an uncommon disease of the newly-born and the very young is nephritis. It is the consequence, in many cases, of what appears to be a common jaundice, or of uric acid infarction, which is the natural result of the sudden change of metabolism. The diverticula of the colon, as described by Hirschsprung and Osler, and what nearly 40 years ago I characterized as congenital constipation, which depends on the exaggeration of the normally excessive length of the sigmoid flexure, belong to the same class. Their dangers may be avoided when they are understood. Of the infectious diseases of the embryo and the fetus, it is principally syphilis that should be considered; amongst the acute forms variola and typhoid are relatively rare.

What I have been permitted to say is enough to prove the intimate interdependence and connection between pediatrics and the diseases of the fetus with embryology and teratology, obstetrics, and some parts, at least, of social economics.

After birth there are anomalies and diseases which are encountered in the infant and child only. There are also, common to all ages, though mostly found in children, such as exhibit a symptomatology and course peculiar to them. The first class, besides those which are seen in the newly-born, is made up mostly of developmental diseases, — scrofula, rachitis, chlorosis. The actual or alleged ailments connected with dentition, most forms of stomatitis, Bednar's so-called aphthae, the ulceration of epithelial pearls along the raphe, amygdalitis, pharyngitis, adenoid proliferations, latero- and retro-pharyngeal abscesses belong here. Infectious diseases, such as variola, diphtheria, scarlatina, measles, pertussis, and tuberculosis of the glands, bones, joints, and peritoneum, have been most successfully studied by pediatrists or those clinicians who have paid principal attention to pedology. Meissner prints the titles of more than 200 actual monographs on scarlet fever published in Europe before 1848. Pleurisy and pneumonia of the young have their own symptomatology. Empyema is more frequent and requires much more operative interference. Tracheotomy and intubation are mostly required by the young, both on account of their liability to edema of the larynx and to diphtheria, and of the narrowness of the larynx. Of invagination, 25 % occur under one year, 53 % under 10. Appendicitis, sometimes hereditary and a family disease, would long ago have been recognized as a frequent occurrence in the young if it had not been for the difficulty, mainly encountered in the young, and sometimes impossibility of its diagnosis. That is what we have been taught by Hawkins and by Treves, and lately by McCosh. Operations on glandular abscesses, osteotomies, and other operations on the bones and joints, particularly in tuberculosis, and on malformations such as have been mentioned, require the skillful hand of the operating physician in a great many instances. Omphalocele, exstrophy of the bladder, undescended testicle, spermatic hydrocele, multiple exostoses, imperforate rectum, atresia of the vagina, or an occasional case of stenosed pylorus, belong to that class, some requiring immediate operation, some permitting of delay. It is principally infancy that demands removals of angioma, which are almost all successful, and of hygroma, mostly unsuccessful, mainly when situated on the neck and resulting from obstruction of the thoracic duct sometimes connected with thrombosis of the jugular vein. Childhood requires correction of kyphosis and scoliosis, and operations for adenoids and hypertrophied tonsils, and furnishes the opportunities for lumbar puncture and laparotomy in tubercular peritonitis; also supra-pubic cystotomy, and mastoid operations. That gum-lancing is no operation indicated or permissible in either the young or adult, and not any more so in the former than in the latter, is easily understood by those who acknowledge its necessity only in the presence of a morbid condition of the gums or teeth, and not when the physiological process of dentition exhibits no anomaly. It scarcely ever does. Altogether operating specialists would work and know very much less if a large majority of the cases were not intrusted to them by the pediatrist, who recognizes the principle that those who are best fitted to perform it should be trusted with important medical work. So well is the seriousness and difficulty of operative procedures, as connected with diseases of children, recognized by experts, that 1500 pages of Gerhardt's handbook are dedicated to external pathology and operations, and that special works, besides many monographs by hundreds of authors, have been written by such masters as Guersant, Forster, Bryant, Giraldès, Holmes, St. Germain, Karewski, Lannelongue, Kirmisson, and Broca.

Ear specialists recognize the fact that otology is mostly a specialty of the young. The newly-born exhibit changes in the middle ear which are variously attributed to the presence of epithelial detritus, to the aspiration of foreign material, or to an edema *ex vacuo* occasioned by the separation of formerly adjacent mucous surfaces. Pus is found in the middle ear of 75 % of the still-born or of dead nurslings. It contains meconium, lanugo, and vernix. Aschoff[1] examined 50 still-born, or such as had lived less than two hours; 28 of them had pus in the middle ears (55 %). He also examined 35 infants that had lived longer than two hours; 24 had pus (70 %). Evidently the latter class had been exposed to a microbic invasion. The diagnosis in the living infant is very difficult, mostly impossible, on account of the large size of the Eustachian tube, which after having admitted the infection, allows the pus to escape into the pharynx and the rest of the alimentary canal. Many of the newly-born that die with unexplained fevers perish from the septic material, or its toxins, absorbed in the middle ear or the intestines. Nor are older children exempt. Geppert (*Jahrb. f. Kind.*, XLV, 1897) found a latent otitis media in 75 % of all the inmates of the children's hospitals. Both latent and known otitis is often connected with pneumonia, or with pneumonia and enteritis. In individual cases it may be difficult to decide which of the two or three is the primary, which the secondary affection.

The great vascularity of the middle ear, but still more the accessibility of the funnel-like Eustachian tube in the infant, renders otitis media very frequent. Schwartze's assertion that otitis media furnishes 22 % of all ear cases in general or special practice is surely correct. Besides, difficult hearing is very frequent in the young, a fact of the greatest import to pedagogy. As early as 1886 Bezold found that of 1900 school-children 25 % had only one third, and 11 % of the others only one fifth of normal hearing. The frequent affections of the nose and pharynx in the young explain these facts and exhibit the possibilities of prevention. Finally, the immature con-

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[1] Aschoff, *z. f. Ohrenh.* vol. XXXI.

dition of the mastoid process and of the floor of the external canal and the frequency of primary bone tuberculosis, are best appreciated by the practitioner, general or special, who deals with their abscesses.

Whether deaf-mutism is the result of consanguineous marriage cannot be definitely asserted. It is not often hereditary, quite often it appears to be the result of family alcoholism; it sometimes depends on arrest of development and fetal inflammation, but is more frequently an acquired condition. Not rarely children are affected after they have been able to speak. The majority of cases are caused by cerebral or cerebro-spinal inflammation. According to Biedert, 55 % are of that class, 28 % are caused by infectious diseases (cerebro-spinal meningitis, scarlatina, typhoid fever, diphtheria, also variola and measles), 3.3 % by injuries, and only 2.5 % are original ear affections. Thus many of the congenital cases, and most of the acquired, are preventable. More and more will our deaf-mute institutions avail themselves of this knowledge, and will learn how to teach their children not only how to read and write, but also how to hear.

Not to the same, but to a great extent, pediatrics and *ophthalmology* join hands. Infectious diseases, such as diphtheria, affect the conjunctiva and sometimes the cornea. Syphilis of the cornea, with or without chronic iritis, is the form of parenchymatous or diffuse keratitis. A frequent tumor in the eye of the young is glioma, and frequent symptomatic anomalies are strabismus and nystagmus — both of them the results of a great many and various external or internal causes, with sometimes difficult diagnoses.

The connection of pedology with *dermatology* is more than skin deep; some of the most interesting problems of the latter must be studied on antenatal and postnatal lines. The congenital absence of small or large parts of the surface is probably due to amniotic adhesions; seborrhea and the mild form of lichen, also the furunculosis of infant cachexia and atheroma, to the rapid development, in the second half of intra-uterine life, of the sebaceous follicles; ichthyosis, to the same and to a hypertrophy of the epidermis and the papillæ of the corium, sometimes with dilatation of their blood-vessels and with sclerosis of the connective tissue. Congenital anomalies, such as lipoma, sarcoma, naevus pigmentosus, open all the questions of the embryonal origin of neoplasms; and the eruptions on the infant surface unclose to the specialist the subject of infectious diseases. We recognize in the pemphigus of the palms and soles syphilis; in herpes, gangrene, and in what I have described as chronic neurotic pemphigus, the irritable nervous system; in eczema, constitutional disturbances of the nutrition; in erythema, local irritation or intestinal auto-infection; in isolated or multiple forms ranging between hyperemia and exudation, the effect of local irritation or the acute or chronic influence of drugs. A dermatologist who knows no embryology or pedology, a pediatrist who knows no dermatology, is anything but a competent and trustworthy medical practitioner.

The diseases of the *muscles* interest the pediatrist, the surgical specialist, the orthopedist, and the neurologist, to an equal extent. Many forms of myositis are of infectious origin. Amongst the special forms of muscular atrophy it is the hereditary variety which concerns the first. The spinal neuritic atrophy form the myogenous progressive dystrophy, including the so-called pseudo-hypertrophy, Thomson's congenital myotonia, and atrophy or absence of muscles — mainly the pectoral, but also the trapezius, quadriceps, and others — no matter whether they are primary or myogenous (this probably always when there is a complication with progressive dystrophy), are of special interest. I need not do more than mention torticollis in order to prove that neither the special pediatrist nor the special orthopedist, nor the general surgeon can raise the claim of ownership.

The relations of pediatrics to *forensic medicine* are very close. Nothing is more apt to demonstrate this than the immense literature in every language on infanticide and all the questions of physiology, physics, and chemistry connected with that subject. The monographs and magazine essays of the last two centuries written on the value or the fallacy of the lung test in the dead newly-born would fill a small library. Much attention has been paid by physicians and by forensic authors to lesions and fractures of the newly-born head, and to anomalies of the female pelvis causing them. Apparent death of the newly-born and the causes of sudden death in all periods of life have been studied to such an extent as to render negative results of police investigation and of autopsy reports less numerous from year to year. Most sudden deaths receiving the attention of the authorities occur in the young. There were (Wm. Wynn Westcott, in *British Med. Jour.*, 1903) in England and Wales during ten years 15,009 overlain infants; in 1900, 1774. In Liverpool, out of 960 inquests there were 143 on babies that had died of such suffocation by accident or malice aforethought; in London, in 1900, 615; in 1901, 511; in 1902, 588. In London they had annually 8000 official inquests, one in 14 of which were on overlain infants. The etiology of sudden deaths would be far from complete, indeed the most difficult questions could not be solved except by the facilities furnished by the observations on the young. Foreign bodies in the larynx, beans, shoe-buttons, and playthings generally, even ascarides (Bouchut), bones and pieces of meat aspirated during vomiting, acute edema of the glottis, aspiration of a long uvula, or of the retracted tongue, the rupture of a pharyngeal abscess or of a suppurating lymphoid body into the trachea, a sudden swelling of the thymus in the narrow space between the manubrium and vertebral column, which at best measures only 2.2 cm., even a coryza in the narrow nose of a small infant filled or not with adenoids — are causes of sudden death.

The *nervous system* furnishes many such cases. It is true there is no longer a diffuse interstitial encephalitis, such as Jastrowitz would have it, nor is the hypertrophy of the brain by far so frequent as Hüttenbrenner taught, but there are sudden collapses and deaths by falls on the abdomen, by sudden strangulation of large herniae, and other shocks of the splanchnic nerve. There are sudden and unexplained deaths in unnoticed attacks of convulsions, in the first paralytic stage of laryngismus stridulus, in glottic spasms from whatever cause, in the paralysis — or, according to Escherich, laryngo-spasm — of what since Paltauf has been denominated status lymphaticus, in cerebral anemia, no matter whether it is the result of exhaustion or, as Charles West taught us 60 years ago, from the mere change of position of a pneumonic or otherwise sick baby, when suddenly raised from its bed. Or death may occur suddenly (a very frequent occurrence) in the heart-failure of parenchymatous degeneration of the heart-muscle as it occurs in and after diphtheria, influenza, and other infectious diseases, or in the acute sepsis of appendicitis and other intraperitoneal affections, whether recognized or not. For the absorbing power, even of the normal peritoneum, is enormous. Of a very acute infection ("infectio acutissima") Wernich spoke as early as 1883.

In gastroenteritis, the terminating broncho-pneumonia may destroy life quite suddenly; there is a capillary bronchitis of the very young with no cry, no moan, and no cough, but with sudden death; there are in extreme atrophy fatal emboli into the pulmonary, sometimes renal, more often cerebral arteries. There are the cases of uremic convulsions, sudden, with sudden death, which are often taken to be merely reflected or "providential," because the frequency of acute nephritis in the newly-born and the infant, with its fever and its uremia, in spite of the publications of Martin and Ruge, Virchow, Orth, Epstein, and my own, is not yet fully appreciated. That is so much the more deplorable as the diagnosis of nephritis at any age is readily made by the examination of the urine, which is so easy to obtain in the young. Other suddenly fatal conditions, such as the acute or chronic sepsis I mentioned before, often quite unsuspected, entering through the umbilicus, the intestine, or the middle ear, are quite frequent.

I have been careful not to mention any cause of death that may just as well be and has been studied in the adult: hemorrhages, the many forms of sepsis of later periods of life, poisons, such as carbolic acid and iodoform, intense cold or heat, insolation, etc., for it is my duty to exhibit the relation to forensic medicine of pediatrics only.

Forensic medicine has to guard the interests of all. Nothing in all medicine is more difficult than the discovery of the cause of death. The best knowledge of the advanced practitioner, of the pathologist, of the chemist, of the bacteriologist, of the obstetrician, should be at the service of the people. Every European country understands that and acts on that knowledge. Our own Massachusetts has broken away from the coroner's institution, which was a fit authority for a backwoods municipality, but is so no longer for a cultured people of eighty millions. Now and then, even an expert, or a body of experts do *not* succeed in discovering the cause of death. What shall we say of a system which *now and then does* discover the hidden cause of a sudden death? When the New York State Legislature half a year ago passed a bill abolishing the no longer competent office of coroner, our good cultured mayor, a gentleman and author, vetoed it for the reason that the new law was not perfect. It was not pronounced perfect by anybody, no law is nor ever was. That is why it appears he prefers something that always was and is, and always will be perfect, namely, the absurd incompetency and anachronism of the coroner's office. That is perfect. I have not hesitated to express myself strongly and positively, for I have been called upon to speak to you about the relation of pediatrics to other sciences and arts — politics included, than which there is no more profound practical and indispensable science and art. The greatest historical legislators understood that perfectly well, when they knew how to blend hygiene and religion with their social and political organization.

One of the greatest questions which concerns at the same time the practical statesman, the humanitarian and the pediatrist, is that of the *excessive mortality* of the young. The Paris Academy of Medicine enumerated in its discussions of 1870 the following amongst its causes: Poverty and illness of the parents, the large number of illegitimate births, inability or unwillingness on the part of mothers to nurse their offspring, artificial feeding with improper material, the ignorance of the parents in regard to the proper food and hygiene, exposure, absence of medical aid, careless selection of nurses, lack of supervision of baby-farms, general neglect and infanticide. *If there be* anybody who is not quite certain about the relationship of sciences and arts, he will still be convinced of the correlation and coöperation of ignorance, indolence, viciousness, and death, and shocked by the shortcomings of the human society to which we belong. Most of them should be avoided. Forty per cent of the mortality of infants that die before the end of the first year takes place in the first month. That is mostly preventable. A few years ago the mortality of the infants in the Mott Street barracks of New York City was 325 per thousand. Much of it is attributable to *faulty diet.*[1]

[1] Measures taken for the purpose of obtaining wholesome milk are not quite

Amongst those who believe in the omnipotence of chemical formulae, there prevails the opinion that a baby deprived of mother's milk may just as readily be brought up on cow's milk; that is easily disproved. In Berlin they found that amongst the cows'-milk fed babies under a year the mortality was six times as great as amongst breast-fed infants. Our own great cities gave us similar or slightly smaller proportions until the excessive mortality of the very young was somewhat reduced by the care bestowed on the milk, introduced both into our palaces and tenements. Milk was examined for bacteria, cleanliness, and chemical reaction. It was sterilized, pasteurized, modified, cooled, but no cow's milk was ever under the laws of nature changed into human milk, and with better milk than the city of New York ever had, its infant mortality was greater this summer than it has been in many years.

That hundreds of thousands of the newly-born and small infants perish every year on account of the absence of their natural food is a fact which is known and which should not exist. Why do we kill those babies or allow them to be killed? Why is it that they have no breast-milk? A large number of women work in fields, still more in factories. That is why their infants cannot be nursed, are farmed out, fed artificially, with care, or without it, and die. It is the misrule prevailing in our social conditions which compels them to withhold milk from the infant while they are working for what is called bread for themselves and their families. Many of these women, it is true, would not have been able to nurse their newly-born, for their own physical condition was always incompetent. The same may be said of women in all walks of life. Insufficient food, hard work, care, hereditary debility and disease, tuberculosis, alcoholism of the woman's own father, modified syphilis or nervous diseases in the family — aye, the inability of her own mother to nurse her babies, are ever so many causes why the mother's fountain should run dry. Statistics from large obstetrical institutions (Hegar) prove that only about 50 % of women are capable of nursing their offspring for merely a few weeks. In the presence of such facts what are we to say of the refusal of well-situated and physically competent women to nurse their infants? I do not speak of the "400," I mean the 400,000 who prefer their ease to their duty, their social functions to their maternal obligations, who hire strangers to nurse their babies, or worse yet, who make-believe they believe the claims of the infant-food manufacturers, or are tempted by their own physicians to believe that cow's milk casein and cow's milk fat may be changed

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new. Regulations were given in Venice, 1599, for the sale of milk. Milk and its products of diseased animals were forbidden. The Paris municipality of 1792 enjoined the farmers to give their cows healthy food. Coloring and dilution of milk were strictly forbidden, and in 1792 they knew in France how to punish transgressors.

into woman's casein and fat, that chemistry is physiology, that the live stomach is like a dead laboratory bottle, that the warmth of the human bosom and that of a nursing flask are identical, and that cow's milk is like human milk when it carries the trademark "Certified," or "Modified." Physiological chemistry itself teaches that the phosphorus combinations in woman's milk in the shape of nuclein and lecithin are not contained in cow's milk, and that the large amounts of potassium and sodium salts contained in cow's milk are dead weights rather than nutrients, and particularly the large amount of calcium phosphate occurs in a chemical, not in a physiological combination. But lately, by no means the first time, Schlossmann and Muro (*Münch. med. Woch.*, 1903, no. 14) have again proved that the albuminoids of woman's and cow's milk are essentially different, both in their lactalbumin and the globulin, and Escherich and Marfan, that every milk has its own enzymes.

The quantitative and many of the qualitative differences of cows' and human milk have been known a long time. No addition or abstraction of salts, no addition of cow's fat will ever change one into the other. But it appears that every new doctor and every new author begins his own era. There is for most of modern writers no such thing as the history of medicine or of a specialty, or respect of fathers or brothers. In modern books and essays you meet with footnotes and quotations of the productions of yesterday that look so erudite, but also with the new discoveries of old knowledge which you would recognize if the quotation-marks had not been forgotten by accident. So it has happened that many learn for the twentieth time that the knowledge of the minimum amount of required food is a wholesome thing, that the amount of animal fat in infant food is easily overstepped, that we have discovered that the Dutch had a clever notion when they fed babies on buttermilk with reduced fat; we are even beginning to learn what our old forefathers practiced a hundred years ago, and physiologists taught a third of a century ago — namely, that the newly-born and the very young infant not only tolerate small quantities of cereals but that they improve on it. Indeed, the names of Schiller, Korowin, and Zweifel have been rediscovered. We have also learned — just lately, it appears — what was always known, that morning and night, idleness and work, health and illness, while altering the chemical composition of woman's milk do not necessarily affect its wholesome character. We are beginning to learn that it is impossible to feed a baby on fanatical chemical formulae, for they are not prescribed by Nature, which allows latitude within certain limits. We are even beginning to learn that if that were not so there would be no artificially fed babies alive, and possibly very few participants in the St. Louis Congress of Arts and Science.

The inability or reluctance of women to nurse their own infants is a grave matter. From a physical, moral, and socio-political point of view there is only one calamity still graver, that is to refuse to have children at all. It undermines the health of women, makes family life a commercial institute or a desert, depopulates the child world, reduces native Americans to a small minority, and leaves the creation of the future America in the hands of twentieth century foreigners. The human society of the future will have to see to it that no poverty, no cruel labor law, no accident, no luxurious indolence, must interfere with the nursing of infants. I believe in the perfectibility of the physical and moral conditions of the human race. That is why I trust that society will find means to compel able-bodied women to nurse their own infants. Infants are the future citizens of the Republic. Let the Republic see that no harm accrue from the incompetence or unwillingness to nurse. Antiquity did not know of artificial infant-feeding. The first information of its introduction is dated about 1500. Turks, Arabs, Armenians, and Kurds know of no artificial feeding to-day. It takes modern civilization to expose babies to disease and extinction. I know of no political or social question of greater urgency than that of the prevention of the wholesale murder of our infants caused by the withholding of proper nutriment. May nobody, however, feel that all is accomplished when an infant has finally completed his 12 months. Society and family owe more than life — they owe good health, vital resistance, and security against life-long invalidism.

But even willing mothers may have no milk. We require a stronger, healthier race, and one that physically is not on the down grade. The nursing question is a social and economic problem like so many others, like the child-bearing question, that confront modern civilization.

We are building hospitals for the sick of all classes, and insist upon their being superior to the best private residences; asylums for the insane, neuropathics, and drunkards; nurseries and schools for epileptics, cretins, and idiots; refuges for the dying consumptives; and sanatoria for incipient tuberculosis. We are bent upon curing and upon preventing. Do we not begin at the wrong end? We allow consumptives and epileptics to marry and to propagate their own curse. We have no punishment for the syphilitic and the gonorrheic who ruins a woman's life and impairs the human race. Man, however, should see that his kind must not suffer. One half of us should not be destined to watch, and nurse, and support the other half. Human society and the state have to protect themselves by looking out for a healthy, uncontaminated progeny. Laws are required to accomplish this; such laws as will be hated by the epileptic, the consumptive, the syphilitic, and the vicious. No laws ever suited the degenerates against whom they were passed, and it is unfortunate that while health and virtue are as a rule not contagious, disease and vice are so to a high degree.

Modern therapeutics, both hygienic and medicinal, has gained much by the close observation of what is permitted or indicated or required in early age. Since it has become more humane (remember it is hardly a century since Pinel took the chains off the insane in their dungeons, and not more than half a century since I was taught to carry my venesection lancet in my vest pocket for ready use) and more scientific, so that whatever is outside of strict biologic methods is no longer "a system," but downright quackery — the terrible increase of the latter as a world-plague is deemed by rational practitioners and the sensible public an appalling anachronism. It appears that the states of the Union are most anxious (and have been partially successful) to rid themselves of it, while some at least of the nations of Europe are greater sufferers than we. According to the latest statistics, there is one quack to every physician in Bavaria and Saxony; ten quacks in Berlin, with its emperor and other accomplishments, to every forty-six physicians. Its general population has increased since 1879 by 61 %; the number of physicians, 170, 2 %; that of the quacks, 1600 %.

One of the main indications in infant therapeutics is to fight anemia, which is a constant danger in the diseases of the young, for the amount of blood at that age is only one nineteenth of the whole body-weight, while in the adult it is one thirteenth. The newly-born is particularly exposed to an acute anemia. His blood weighs from 200 to 250 grammes. It is overloaded with hemoglobin which is rapidly eliminated, together with the original excess of iron. This lively metabolism renders the infant very amenable to the influence of bacteria, and the large number of acute, sub-acute, or chronic cases of sepsis is the result. Besides, the principal normal food is milk, which contains but little iron. That is why pediatrics is most apt to inculcate the lessons of appropriate posture, so as not to render the brain suddenly anemic, and of proper feeding and of timely stimulation before collapse tells us we are too late, and the dangers of inconsiderate depletion. The experience accumulated in pediatric practice has taught general medicine to use small doses only of potassic chlorate; large doses of strychnine and alcohol in sepsis, of mercuric bichloride in croupous inflammations, of heart stimulants, such as digitalis, when a speedy effect is wanted, of arsenic in nervous diseases, of potassic iodide in meningitis; it has warned practical men of the dangers of chloroform in status lymphaticus;[1] it has modified hydrother-

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[1] In the meeting of the Society for the Study of Disease in Children, May 27,

apeutic and balneological practice, and the theories of hardening and strengthening according to periods of life, and to the conditions of previous general health.

The appreciation of electricity as a remedy has been enhanced by obstetricians, pediatrists, and general practitioners. It is but lately that we have been told (P. Strassmann, *Samml. Klin. Vortr.*, 1903, no. 353) that a newly-born and an infant up to the third week are perfectly insensible to very strong electrical currents. The incompetency of mere experimental work, not corrected or guided by practice, cannot find a better illustration, for there is no more powerful remedy for asphyxia and atelectasis than the cautious use of the interrupted or of the broken galvanic current.

The domain of preventive therapeutics expands with the increased knowledge of the causes of disease. That is why immunizing, like curative serums, will play a more beneficent part from year to year, and why the healthy condition of the mucous membrane of the nose, mouth, and pharynx, which I have been advising these forty years as a prevention of diphtheria, has assumed importance in the armamentarium of protection against all sorts of infectious diseases.

Amongst the probabilities of our therapeutical future I also count the prevention of congenital malformations, which, as has been shown, are more numerous than is generally known or presumed, and often the result of intra-uterine inflammation. In a recent publication F. von Winckel (*Samml. Klin. Vortr.*, 1904, no. 373) emphasizes the fact that the general practitioner or the pathologic anatomist sees only a small number, that indeed the majority are buried out of sight, or are preserved in the specimen jars of the obstetrician. The known number of malformations compared with that of the normal newly-born varies from one to thirty-six to one to one hundred and two or more. They are met with in relatively large numbers on the head, face, and neck — altogether in 53.2 % of all the 190 cases of malformation observed in Munich during 20 years. A number of them is the result of heredity, of syphilis, or other influences. How many are or may be the result of consanguineous marriages will have to be learned. In all such cases the treatment of the parents or the prohibition of injurious marriages will have to be insisted upon. The number of those recognized as due to amniotic adhesions or bands is growing from year to year. Kümmel could prove that of 178 cases, 29 were certainly of that nature. External malformations have long been

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1904, Mr. Thompson Walker alluded to the collection of ten cases with status lymphaticus in which death had occurred at the commencement of chloroform administration, or during it, or immediately after the operation. In addition to the usual changes, a hyperplasia of the arteries had been notėd, leading to narrowing of the lumen.

ascribed to them; proximal malformations, such as auricular appendices, harelip, anencephalia, cyclopia, flattening of the face, anophthalmia, hereditary polydactylia (Ahlfeldt and Zander, *Virchow's Archiv*, 1891), and lymphangioma of the neck, have been found to be caused by amniotic attachments or filaments. Is it too much to believe that the uterus, whose internal changes, syphilitic or others, are known to be very accessible to local and general medication, should be so influenced by previous treatment that malformations and fetal deaths will become less and less frequent?

The problem of the health and hygiene mainly of the older child refers to more than its food. The *school* question is in the foreground of the study of sanitarians, health departments, physicians, and pedagogues. Its importance is best illustrated by the large convention which was organized in Stuttgart, April, 1904, as an International Congress for School Hygiene. Pediatrists, pedagogues, and statesmen formulated their demands and mapped out future discussions. Rational pediatrics would consider the following questions: Is it reasonable to have the same rule and the same daily sessions for children of eight and perhaps of fifteen years, and for adolescents? Certainly not. The younger the child the shorter should be the session, the longer and more frequent the recesses. There should be no lessons in the afternoon, or only mechanical occupations, such as copying, or light gymnastics. There should be no home lessons.

The problem of overburdening was carefully considered by Lorinser in 1836, and by many since. It deals with the number of subjects taught, the strictness and frequency of official examinations, and should consider the overcrowding of school-rooms. We should try to answer the question whether neuroses are more the result of faulty schooling or of original debility, heredity, underfeeding, lack of sleep, bad domestic conditions, or all these combined. In Berlin schools they have begun to feed the hungry ones regularly with milk and bread. No compulsory education will educate the starving. The child that showed his first symptom of nervousness when a nursling, the child with pavor nocturnus, or that gets up tired in the morning, or suffers from motor hyperesthesia, pointing or amounting to chorea, unless relieved instead of being punished by an uninformed or misanthropic or hysterical teacher, gets old or breaks down before the termination of the school term or of school age. There should be separate classes for the feeble, for those who are mentally strong or weak, or of medium capacity. All of such questions belong to the domain of the child's physician, the physician in general. The office of school physician is relatively new. Whatever we have done in establishing it in

America has been preceded by countries to which we are not in the habit of looking for our models. Bulgaria and Hungary have no schools without physicians. On the other hand, Vienna has none for its 200,000 school-children. It is reported that the aldermen refused to appoint one. One of them objected for the reason that the doctor might be tempted to examine the Vienna lassies too closely. His business would be, and is, to look out for the healthfulness of the school buildings, its lighting, warming, cleanliness, the cleanliness of the children and their health, and that of the teachers. A tubercular teacher is a greater danger to the children than these, who rarely expectorate, to each other. He would take cognizance of the first symptoms of infectious diseases, examine eyes, ears, and teeth, and inquire into chronic constitutional diseases, such as rachitis and scrofula in the youngest pupils. He might undertake anthropometrical measurements and benefit science while aiding his wards. He would be helped in all these endeavors by the teachers, who must learn to pride themselves on the robust health of their pupils, as they now look for the accumulation of knowledge which may be exhibited in public examinations.

They would soon learn, what Christopher demonstrated, that physical development, greater weight, and larger breathing capacity, correspond with increased mental power, joining to this the advice that a physical factor as well as the intellectual one, now entirely relied upon, should be introduced in the grading of pupils. (Charles F. Gardiner and H. W. Hoagland, *Growth and Development of Children in Colorado, Transactions*, American Climatological Association, 1903.)

Our knowledge of the physiology and pathology of the *nervous system* of all ages would be defective without lessons derived from the fetus and infant. Amongst the newly-born we have often to deal with arrests of development, such as microcephalus, or with that form of fetal meningitis or of syphilitic alterations of blood-vessels which may terminate in chronic hydrocephalus. When the insufficient development of reflex action in the newly-born up to the fifth or sixth week has passed, the very slow development of inhibition during the first half-year or more, together with the rapid increase of motor and sensitive irritability, explains the frequency of eclampsia and other forms of convulsions. Many of them require, however, an additional disposition, which is afforded either by the normal rapid development of the brain, or the abnormal hyperemia of rachitis. The last twenty-five years have increased our knowledge considerably in many directions. Congenital, premature, complete, or partial ossification of the cranial sutures lead mechanically to idiocy, or paralysis, or epilepsy; it is a consolation, however, to know that the victims of surgical zeal are getting less in number since operators have consented to fear death on the operating-table and thoughtful surgeons have come to the conclusion to leave bad enough alone. In the very young the fragility of the blood-vessels, the lack of coagulability of the blood, the large size of the carotid and vertebral arteries, the frequency of trauma during labor and after birth, the vulnerability of the ear and scalp, contribute to the frequency of nervous diseases, which before the fifth year amounts to 87 % of all the cases of sickness. Rapid exhaustion leads to intracranial emaciation and thrombosis, the so-called hydroencephaloid of gastro-enteritis. The large size and number of the lymph-vessels of the nasal and pharyngeal cavities facilitate the invasion into the nerve centres of infections which show themselves as tubercular meningitis, cerebro-spinal meningitis, and polio-encephalitis, or more so, poliomyelitis, and as chorea of so-called rheumatic — mostly streptococcic — origin. Nose and throat specialists, as well as anatomists, have contributed to our knowledge on these points — another proof of the intimate dependency of all parts of medicine upon one another. Now all these conditions are not limited to early life, but their numerical preponderance at that time is so great that it is easy to understand that general nosology could not advance without the overwhelming number of well-marked cases amongst children. Amongst them are the very numerous cases of epilepsy. They escape statistical accuracy, for many an epileptic infant or child dies before his condition is observed, or diagnosticated; a great many cases of petit mal, vertigo, dreamlike states and somnambulism, fainting, habit-chorea, truancy, imbecility, incompetency, or occasionally wild attacks of mania, or the perversity of incendiarism, or in older children religious delirium, even hysteric spells, are overlooked or perhaps noticed or suspected by nobody but the family physician; or, in the cases of the million poor, by nobody. They are cared for or neglected at home, and the seizure is taken to be an eclamptic attack due to bowels, worms, colds, and teeth, exactly like three hundred years ago.

Of equal importance in this disease to the pediatrist, the pedagogue, the psychiatrist, the judge, the statesman, no matter whether in office or a thoughtful citizen, is the influence of heredity. The old figures of Echeverria, which have been substantiated by a great many observers, tell the whole story. One hundred and thirty-six epileptics had 553 children. Of these, 309 remained alive; 78 (25 %) were epileptic; how many of the 231 that died had some form of epilepsy or would have exhibited it, nobody can tell. He observed a dozen cases in one family. While in his opinion 29.72 % showed a direct inheritance from epileptic parents, Gowers has a percentage of 35, and Spratling, who has lived among epileptics nearly a dozen years, 66.

Epilepsy is acknowledged to be one of the causes of imbecility, or genuine idiocy. In very many instances it should be considered as the coördinate result of congenital or acquired changes in the skull, the brain, and its meninges, and particularly the cortex. In a single idiot institution, that of Langenhagen, 15% to 18% of the 395–668 inmates were epileptic; in another, Dalldorf, 18.5% to 24.3% of 167–344; in a third, Idstein, 36% of 101 (Binswanger, in Nothnagel, *Syst. Path. u. Ther.*, vol. XII, 1310).

Its main causes are central. External irritations, worms, calculi, genital or nasal reflexes, may be occasional proximate causes. But cauterization of the nares, and still more, circumcision, and clitoridectomy prove more the helplessness or recklessness of the attendant than the possibility of a cure. The individual cases of recovery by the removal of clots, bones, or tumors, are great and comforting results, but if epilepsy and its relations are ever to disappear, it is not the knife of the surgeon but the apparatus of human foresight and justice that will accomplish it. Most of the causes of epilepsy are preventable. To that class belong syphilis and alcoholism in various generations, rachitis, tuberculosis, and scrofula, many cases of encephalo-meningitis, and most cases of otitis. A question is attributed to a royal layman, "If preventable, why are they not prevented?" If there is a proof of what Socrates and Kant said, namely, that statesmanship cannot thrive without the physician, it is contained in the necessities of epilepsy. Prevention, preventives, and hygienic, medicinal, and surgical aids have to be invoked, unfortunately with slim results so far.

The influence of hereditary syphilis on the diseases of the nervous system has been studied these twenty years, both by neurologists and pediatrists. Its results are either direct — that means characteristically syphilitic — or metasyphilitic — that means merely degenerative. Hoffmann cured a case of syphilitic epilepsy in a girl of nine years in 1712. Plenk describes convulsions and other nervous symptoms depending on hereditary syphilis, and Nils Rosen de Rosenstein describes the same in 1781. The literature of the latter part of the eighteenth and of the first half of the nineteenth century is silent on that subject, though the cases of affections of the nervous system depending on hereditary syphilis are very frequent (thirteen per cent of all the cases, according to *Rumpf die Syph. Erk. d. Nervensystems*, 1889). Jullien (*Arch. Gén.*, 1901) reports 206 pregnancies in 43 syphilitic marriages. Of the children, 162 remained alive. Half of them had convulsions or symptoms of meningitis.

According to Nonne (*Die Syph. d. Nervens.*, 1902) hereditary syphilis differs from the acquired form in this — that several parts of the nervous system are affected simultaneously; and that arteritis, meningitis, gummata, and simple sclerosis occur in combination. Simple cerebral meningitis and apoplexies are very rare. Encephalitis is more frequent. Probably spinal diseases are more frequent, according to Gilles de la Tourette, Gasne, Sachs, and others. Tabes dorsalis is not frequent, but may rather depend on an atavistic syphilitic basis; for altogether the nerve syphilis of the second previous generation as a cause of disease in the young is not very rare. (E. Finger, *W. klin. Woch.*, 13, 1900.)

What we call neuroses are not infrequent in infants and children. Neuralgias are not so common as in the adult, but would be more frequently found if sought for. Even adipositas dolorosa has been observed in childhood. Hysteria is by no means rare and its monosymptomatic character, so peculiar to early age, adds to its nosological importance. Its early appearance is of grave import. Its often hereditary origin makes it a serious problem, under-alimentation or ill-nutrition, rachitis and scrofula, frequently connected with and underlying it, may make it dangerous and a fit subject for the study of educators, psychologists, judges, and all those whose direct office it is to study social and socialistic problems. Hysteria is not quite unknown amongst males, though the large majority are females.

Some of the vaso-motor and trophic disturbances are less, others more frequent, in the young than in the adult. Amongst 129 cases of akrosparesthesia there is only one of Frankl Hochwart in a girl of 12 years, and one of Cassirer in a girl of 16. Sclerodermia is met with mostly in mature life, but the cases of Neumann at 13 days, and those of Cruse, Herxheimer, and of Haushalter and Spielmann, who observed two cases in one family, all of them when the infants were only a few weeks old, prove that the same influences which are at work in advanced age, namely, hereditary disposition, neuropathic family influence, low general nutrition, colds, trauma, and so on, may play their rôle in infant life. Nor are infant erythromelalgias numerous. Henoch saw one in a teething infant, Baginsky in a boy of 10, Heimann one in a girl of 13, Graves one in a girl of 16; that means three or four cases below 13 or 16 years of age, out of a number of 65 collected by Cassirer in his monograph. (*Die Vasomotorisch-trophischen Neurosen*, Berlin, 1901.) In half a century I have seen but one that occurred in early age, namely, in a boy of 12, who got well with the loss of two toes. On the other hand, the symmetrical gangrene of Raynaud and acute circumscribed edema of Milton and Quincke, 1882, treated of by Collins in 1892, are by no means relatively rare in infancy and childhood. There are a few cases of the former that occurred in the newly-born. Two I have seen myself. There are those which have been observed at 6 months (Friedel), 9 months (De France), at 15 months (Bjering), at 18 months (Dick). In the year 1889 Morgan collected 93 cases, 13 of which occurred from the second to the fifth, 11 between the fifth and tenth, and 15 between the tenth and twentieth years. Amongst the 168 cases collected by Cassirer, 20 occurred below the fifth, 8 between the fifth and tenth, and 25 between the tenth and twentieth years of life. Like most nervous diseases, these cases had either congenital or acquired causes, amongst which a general neuropathic constitution, and the hereditary influence of alcohol, chlorosis, and anemia are considered prominent. Of acute circumscribed edema, 28 cases are found below nine years of age in Cassirer's collection of 160 cases, one of which at the age of one and a half months is reported by Crozer Griffith, one at three months by Dinckelacker. Again hereditary influence is found powerful. Osler could trace the disease through five generations.

The connection of pediatrics with *psychiatry* is very intimate. Insane children are much more numerous than the statistics of lunatic asylums appear to prove, for there are, for obvious reasons, but few insane children in general institutions. It is only those cases which become absolutely unmanageable at home that are intrusted to or forced upon an asylum. The example of the French, who more than fifty years ago had a division in the Bicêtre for mentally disturbed children, has seldom or not at all been imitated. Thus it happens that though not even a minority of the cases of idiocy become known, its statistics is more readily obtained than that of dementia of early life. Some of its physical causes or accompaniments have been mentioned — asphyxia with its consequences, ossification and asymmetrical shape of the cranium, accidents during infancy and childhood, and neuroses that may be the beginning or proximate causes of graver trouble. Infectious diseases play an important part in the etiology of intellectual disorders. Althaus collected 400 such cases. They were mainly, influenza 113, rheumatism 96, typhoid fever 87, pneumonia 43, variola 41, cholera 19, scarlatina 16, erysipelas 11. In most of the cases there were predisposing elements, such as heredity and previous diseases, or over-exertion of long duration. The overworked brains of school-children were complained of as adjuvant causes of lunacy by Peter Frank as early as 1804. We are as badly off, or worse, a hundred years later.

There is one ailment, however, that appears to hurt children less than it does adolescents or adults, that is masturbation. There are those cases, fortunately few, which depend on cerebral disease, and original degeneracy, but in the large majority of instances masturbation, frequent though it be, has not in the very young the same perils that are attended with it later on when the differentiation of sex has been completed and is recognized. Babies under a year, and children under 8 or 10 will outlive their unfortunate habit, and do not appear to suffer much from its influence. Whatever is said to the contrary is the exaggeration of such as like to revel in horrors. The same exorbitant imagination is exhibited in other statements. What Lombroso and his followers have said of the faulty arrangement of the teeth, prognathic skulls, retracted nose, short and attached lobes of the auricle, as distinct symptoms of mental degeneracy, belongs to that class, and need not always be taken as the positive signs of insane criminality. There is so much poetical exaggeration and word-painting in them that Lombroso and also Krafft-Ebing are the pets of the prurient lay public. In its midst there must be many who are anxious to believe with Lombroso that brown hair and eyes, brachycephalic heads, and a medium size of the body characterizes the insane criminal, if only for the purpose of scanning the hair and eyes and heads of their near friends and their mother-in-law's relatives.

It is certainly not true that, as Lombroso will have it, children are cruel, lazy, lying, thievish, just as little as according to him all savages are like carnivorous animals, and essentially criminal, while others are convinced that by nature they are amiable, like Uncas, and virtuous like Chingacook, and have been rendered savage only by the strenuousness of conquering immigrants. Nor is it true that the idiot brain is merely arrested at a stage similar to the anthropoid, or even saurian development, for it is less arrest of development than the influence of embryonal or fetal disease, beside amniotic anomalies that cause the irregularities of the encephalon.

Amongst the worst causes of idiocy is cretinism, both the endemic and the sporadic. Every cretin is an idiot, not *vice versa*. The endemic could be prevented by state interference which would empty the stricken valleys; the sporadic depends on thyroidism, with or without a shortening of the base of the skull, and is partially curable. The idiotism of cretinism causes a fairly uniform set of symptoms; that which depends on other causes exhibits varieties, though not so many as imbecility, which, too, should not be taken to be the result of a single cause. Osseous and cartilaginous anomalies about the nose are pointed out by William Hill, chronic pharyngitis and nasal polypi by Heller, enlarged tonsils by Kafemann in one third of the cases, some pharyngeal or nasal anomaly in four fifths by Schmid-Monnard. Adenoids are frequently found as complications. Operations to meet all these anomalies have been performed with improvement of the mental condition in some, of the physical in many more, mainly when the anomalies were complications only. But after all we should beware of the belief in miracles and in infallible cures. Mainly the tonsils have been puffed up to be the main causes of many human troubles and their removal a panacea. According to a modern writer it prevents tuberculosis, but the prophet is a little too bold, for he adds that with the exception of himself there are very few able to accomplish it. Defective or diseased brains are frequent in most conditions. The former class allows even imbeciles to excel in some ways. In that class may be found calculating experts, chess-players, or mechanical draughtsmen.

Imbecile persons may be taught sufficiently to prepare for the simple duties of life. There are, however, many transitions between the complete imbecile, the mild imbecile, and the merely slow and dull. That is why the condition is frequently not appreciated. In his school the imbecile child is slightly or considerably behind his class, and the laughing-stock of the rest. As he is intellectually slow, so he is morally perverse or is made to become so. He knows enough to lie and libel, to run away from school, and from truant to become a vagrant. It is true it will not do to declare the imbecile *per se* identical with the typical criminal, but as many of them are illegitimate, or of defective or alcoholic parents, or maltreated at home, or diseased and deformed, they get, by necessity, into conflict with order and the law. Thompson found 218 congenital imbeciles among 943 penitentiary inmates; Knecht, 41 amongst 1214. When the imbecile is once a prisoner his condition is not liable to be noticed on account of the stupefying monotony of his existence.

What is more to be pitied, the fate of the immature or imbecile half-grown child that naturally acts differently from the normal, or the low condition of the state which, instead of procuring separate schools or asylums for the half-witted, has nothing to offer but contumely and prison walls, increasing moral deterioration? There is the stone instead of the bread, of the gospel.

Modern society has commenced, however, to mend old injustices. Every civilized country admits irresponsibility before the law below a certain age, and gradually the mental condition of the criminal is taken into consideration and made the subject of study. But still thousands of children and adolescents are declared criminal before being matured. The establishment of children's courts is one of the things, imperfect though they be, that make us see the promised land from afar. When crime shall be considered an anomaly, either congenital or acquired in childhood, a disease; when society shall cease to insist upon committing a brutality to avenge a brutality; when self-protection shall take the place of revenge, and asylums that of state prisons — then we shall be a human, because humane, society.

Conclusions

Pedology is the science of the young. The young are the future makers and owners of the world. Their physical, intellectual, and moral condition will decide whether the globe shall be more Cossack or more Republican, more criminal or more righteous. For their education and training and capabilities, the physician, mainly the pediatrist, as the representative of medical science and art, should become responsible. Medicine is concerned with the new individual before he is born, while he is being born, and after. Heredity and the health of the pregnant mother are the physician's concern. The regulation of labor laws, factory legislation, and the prohibition of marriages of epileptics, syphilitics, and criminals are some of his preventive measures to secure a promising progeny. To him belongs the watchful care of the production and distribution of foods. He has to guard the school period from sanitary and educational points of view, for heart and muscle and brain are of equal value. It is in infancy and childhood, before the dangerous period of puberty sets in, that the character is formed, altruism inculcated, or criminality fostered. If there be in the commonwealth any man or any class of men with great possibilities and responsibilities it is the physician. It is not enough, however, to work at the individual bedside and in a hospital. In the near or dim future, the pediatrist, the physician, is to sit in and control school boards, health departments, and legislatures. He is the legitimate adviser to the judge and the jury, and a seat for the physician in the councils of the Republic is what the people have a right to demand. Before all that can be accomplished, however, let the individual physician not forget what he owes to the community now. Mainly to the young men amongst us I should say, do not forget your obligations as citizens. When we are told by Lombroso that there is no room in politics for an honest man, I tell you it is time for the physician to participate in politics, never to miss any of his public duties, and thereby make it what sometimes it is reputed not to be in modern life — honorable. A life spent in the service of mankind, be our sphere large or narrow, is well spent. And never stop working. Great results demand great exertions, possibly sacrifices. After all, when everything in science and politics that now is our ideal shall be accomplished while we live or after we shall be gone, we shall still leave to our progeny new problems.

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Total Idiots, 1890	95,609
Total Insane and Feeble-minded, 1890	202,094
Population, 1890	50,155.783

Estimated insane, based on reports from thirty states to the Committee of the National Conference of Charities and Correction in 1896, was 145,000. The Statistics of the United States Census of 1900 are not yet obtainable.

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THE COURT OF CRIMINAL APPEAL

Photogravure from a Painting by Sir Arthur Clay.

Reproduction of the accompanying picture introduces us to the best work produced by one of England's most distinguished painters, who has not only produced a perfect representation of a scene in a crminal court, London, but in doing so has added immeasurable interest to his scene by making his characters actual portraits of famous jurists who have administered the law in the past fifty years. The late Chief Justice Coleridge, apparently delivering an opinion of the Court, is the central figure. The intensity, the gravity, the serious spirit that pervades an English criminal proceeding, has been admirably brought out by the artist, and the scene is impressive as well for the historical accuracy of the ensemble.

DEPARTMENT XVIII — TECHNOLOGY

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(*Hall* 3, *September* 20, 2 *p. m.*)

CHAIRMAN: CHANCELLOR WINFIELD S. CHAPLIN, Washington University, St. Louis.
SPEAKER: PROFESSOR HENRY T. BOVEY, F. R. S., McGill University, Montreal.

THE FUNDAMENTAL CONCEPTIONS WHICH ENTER INTO TECHNOLOGY

BY HENRY TAYLOR BOVEY

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The Fundamental Conceptions which enter into Technology is a large subject and one which, from its very nature, I cannot hope to treat with completeness. In asking me to undertake its exposition, I assume it was understood that, as a technologist myself, I should naturally speak without the terminology of philosophy — shall I say in an untechnical manner? — that is, from the standpoint of a practical man.

The prevailing characteristic of the eighteenth century has been considered to be the philosophic spirit, while that of the present age is admitted to be the scientific spirit; some even call it the age of the application of science. Is it a sign of a coming reaction that I am asked to speak of what might not inappropriately be called the philosophy of science?

Science, which, at the outset, attacked the more striking facts of the external world, now busies itself with the invisible, the intangible, the inaudible. This line of growth must tend in the direction of stimulating the imagination, and of directing the mind to an investigation of the principles on which sciences are based. Thus we find that science, which at first appeared to be leading away from philosophy, is seemingly leading back to it again, and that we, its followers, have been unwittingly tracing out another of the great circles of truth. However this may be, we have now to consider the conceptions which enter into the most practical of all the sciences, and the one which, of all others, was long supposed to be purely experimental and to require no mental foundations of any kind.

A conception is a thing so subtle, so illusory, that it seems capable of receiving the work of many minds and many generations before it can be said to emerge with any — not to speak of absolute — clearness from the background of thought. Our first efforts to give it a shape bear about the same relation to the complete thought as the first rough tracing might do to a finished statue. Take, for example, the conception of the development of the individual, which is so marked a feature of all modern educational theories. How slowly it has taken shape in the thought of the world! How far are we still from acting in accordance with it! How far from realizing that *power* and not knowledge should be the true aim in education!

Towards the better understanding of technology comparatively little has been done, and that for the very natural reason that the practical has constantly turned aside the attention. The Technologue (to use a word not yet adopted into English) has been described as an intermediary between the savant and the mechanic, translating, as it were, the discoveries of the former into the uses of the latter. Although we may see reason later to modify this view, still, in a certain sense, it is quite true, and the truth of it accounts for the fact that the exponents of practical science have hitherto had little time or inclination to travel with any speed towards the realm of the abstract. Yet much good work has been accomplished. Merz has investigated the scientific spirit with a view to discover its effect on the progress of thought in Europe; Reuleaux has spoken of the evolution of science with especial reference to technology; Anderson, in his Forrest Lecture, has chosen as his subject the relation of science to engineering, and a host of others have discussed before learned societies special aspects of technology chiefly relating to the history of its development during the present century. It is little wonder that such splendid achievements as this history chronicles should so have dazzled our eyes that we have not attempted to inquire too closely into their source To-day, however, we shall try to regard these achievements only as the effects of a cause which we seek to find. We shall restrict our admiration of the constructive ability displayed in a Brooklyn Bridge or a Saint-Gothard tunnel; of the inventive genius shown in a Morse system of telegraphy, or a Bell telephone; of the force of insight and determination which overcame the practical difficulties of the steam-engine or saved its vineyards to France. We shall restrict our admiration, I say, and try to discover the controlling ideas which were common to all, and which impelled the directors of these great enterprises along such apparently diverse paths.

We may notice especially three of these ideas. In the first place, these men must have observed that nature works in no arbitrary manner, but by fixed laws; that while the earth remaineth, seedtime and harvest, and cold and heat, and summer and winter, and day and night, shall not cease.

Secondly, they must have perceived that, as Reuleaux points out, if these laws could be brought into the right relation with us, or rather, if we could bring ourselves into the right relation with them — into the line of their working — we might hope to be able to gear our small machines to the vast wheel of nature, and make it do for us what we could never do for ourselves.

A recent writer has asked us to recognize in certain inventions of man *extra-organic sense-organs;* to see a projection of the human eye in the telescope and the microscope, which so marvelously extend our vision that it can resolve the misty light of the far-off nebulae into suns, or discern in a clod of clay a world of wonder; to hear in the telegraph and the telephone the tones of the human voice so intensified as to reach round the world, and in the printed page the silent voices of long past generations; to know the express train and the ocean liner as extensions of our locomotor-mechanism; and to discover in a tool or a lever the human arm grown strong enough to perform seeming miracles.

Thirdly, these master-minds must have realized that in the study of the laws of nature, and in the attempt to put ourselves into touch with them, there would certainly be revealed more and more of what seem to be the infinite possibilities of our environment.

In almost every endeavor to explain the nature of observed phenomena, fresh and important facts emerge which in their turn call for explanation. This is true, for instance, of the investigations in radio-activity now being carried out by Professor Rutherford, in which the deductions are so novel and startling that it would have been impossible beforehand to have made any prediction as to their character. Again, what a vista has already been opened up by the interaction of the sciences! What a great development, for example, has taken place in electro-metallurgy, due entirely to the processes made possible by a combination of physics and chemistry, and based upon Faraday's well-known law of electrolysis!

The first and second of these conceptions, namely, that law is a fixed thing, and that if we and our work could be brought into the right relationship with the laws of nature, they would expend their mighty force in our service, make possible a *process* under the control of man, a process which, while having many intermediate objects, has always the same goal. Thus we may primarily study the steam engine with a view to a knowledge of its mechanism, while our ultimate aim, if we are to work with complete success, must be so to design its several parts that it may lend itself to the power of steam with the least possible resistance.

We may conceive of a law of nature as a fixed thing, a Niagara of force; we want to construct a wheel which shall receive its impact and turn its water into fire. Nothing can change or improve the law; the only thing we can do is to make ourselves familiar with it, which may be done either by watching its operation in nature, or by causing it, as it were, to display itself before us — bringing together the materials whose interaction it is our purpose to investigate. This we call making an experiment, and it has now become the usual method of studying the laws of nature. To this fact, indeed, must be attributed much of the rapid progress of modern science, as we have no need any longer to wait, as did our ancestors, for nature periodically to marshal her forces and cause them to defile before us.

This, in general, is all we can do with our environment. What can we do with ourselves?

In order to study to advantage we must get into line with the laws of the mind, remembering that they are, equally with heat and electricity, the laws of nature. We must make the laws of the mind work for us instead of against us, just as we are seeking to do with the forces external to us.

We find that to bring us into contact with the outer world nature has given us the five senses, and the wonder is with how small a use of them people manage to get through their lives. The reason is, perhaps, that these senses only present facts to us, and facts, although necessary to thought, require, like other raw materials, to be worked up before they give us ordered knowledge.

We also find that the apprehension of a fact by the mind requires the exercise of the power of observation. This presupposes sensibility both of the external organ and of the brain centres, and also a certain amount of will-power which prevents the observation from being a mere photographic reproduction of the external world. The observations we speak of must be of a special character. They should be minute like those of Hunter in his study of a deer's horns; they should be accurate like those which led Adams and Leverrier to the simultaneous discovery of Neptune, and, above all, they should be selective, that is, if we are following up a special point, we should be able to fasten, as it were, on the fact which throws light on the question at issue, remembering that it is not always or even usually the feature most prominent which will put us on the track of the discovery of true connections, but more often some small detail which the ordinary person passes by unheeding. For instance, take the case of Becquerel when examining a definite point suggested by the discovery of the Röntgen rays. At that time it was thought that the phosphorescence produced in a vacuum tube was in some way connected with the excitation of X-rays. Becquerel, therefore, examined bodies which were phosphorescent under ordinary light, to determine if they gave out rays of a similar character. On a certain dull day he happened to leave a photographic plate exposed over uranium, and to his surprise he found that a marked photographic impression was produced. Knowing that the phosphorescent light from the uranium compound persists for only a short time, he was able to draw conclusions which proved to be the commencement of the now great and important investigation into radio-activity.

Observation, as commonly used, seems to mean to see with attention. It therefore involves concentration, or the focusing of the whole force of the mind on one point for an appreciable moment of time. As soon as concentration takes place, a process of analysis begins, and we pass through the perception of likeness and difference to classification and then to generalization, by which we fit observed facts into their proper places in the scheme of nature, gathering up the new with the old into a larger and larger synthesis. Memory now comes into play to retain what we have gained; and a new impulse to gather new facts, as well as, sometimes, a fresh point of view, we gain from the contact of the new with the old and the arousing of the power of deduction.

Further, we must not overlook what is really a fact of the utmost importance — that the cultivation of observation by the sense of touch and the use of the hand as an instrument, together with the possibility of making experiments which must be carried out by the hand, have led to what might be called a discovery, namely, that the training of the hand actually stimulates the brain centres. This has given to manual training its true value.

By this *process*, in the first place, of studying the laws of nature, either as they are presented to us in the natural course of events, or as we may induce them to display themselves before us in experiments; and, secondly, by studying them with all possible reference to the laws of the mind, including those of the interaction of the hand and the brain, we attain to that knowledge of our environment and to that plane of capacity in ourselves which are necessary preliminaries to the bringing of the powers of nature under our control in the interests of humanity.

What is the indispensable step which often intervenes, which, untaken, makes it still necessary that we should call so much of our knowledge by the name of pure science? For how many centuries had sticks been rubbed together to produce fire before Rumford, while superintending the boring of cannon in the Arsenal Works at Munich, hit upon the true explanation of what becomes of work spent in friction? Or, as Lamb humorously puts the case, in discussing the origin of the custom of eating roasted instead of raw meat, "in process of time, says my manuscript, a sage arose, like our own Locke, who made a discovery, that the flesh of swine, or indeed of any other animal, might be cooked (*burnt*, as they called it) without the necessity of consuming a whole house to dress it. Then first began the rude form of a gridiron. Roasting by the string, or spit, came in a century or two later, I forget in whose dynasty. By such slow degrees, concludes the manuscript, do the most useful, and seemingly the most obvious arts, make their way among mankind." The veil which hid the prospect, once dropped, is not our natural exclamation, "Why did we not see that before?" What, then, is the necessary step? Is it not the exercise of just that quality which the scientific man has been blamed, and often with too much reason, for neglecting? — the divine gift of imagination, which

> "bodies forth the forms of things unknown."

In his *Defence of Poetry*, Shelley points out the evil effects "which must ever flow from an unmitigated exercise of the calculating faculty," and says, "whilst the mechanic abridges, and the political economist combines labour, let them beware that their speculations, for want of correspondence with those first principles which belong to the imagination, do not tend . . . to exasperate at once the extremes of luxury and want."

Out of such conceptions as these two, by the process just described, the science which has received the descriptive title of applied science and the general title of technology, has grown up, but almost unconsciously, for, as a matter of fact, it has arisen far more from practical necessity than from thought-out schemes. We can see that it has a twofold nature corresponding to the process referred to.

First, we can learn by specialized study how to understand and apply the principles of mechanics — which is coming to be regarded by some authors as the primary all-embracing science — to the construction of works of utility of every kind. We find this conception distinctly recognized in the founding at Harvard of the Rumford Professorship in 1816. In his will, Count Rumford reserves certain annuities "for the purpose of founding a new institution and professorship, in order to teach by regular courses of academical and public lectures, accompanied with proper experiments, the utility of the physical and mathematical sciences for the improvement of the useful arts, and for the extension of the industry, prosperity, happiness and well-being of society."

Secondly, we can train the mind of the student to work easily along lines of scientific thought; in fact, we can do much to form the scientific mind.

It will now be seen that, so far as we have considered it, technology is really a process of education — a secondary science — a process which has been described by Ellis as an entire system of education by new methods to new uses. He tells us, at the same time, that the first use of the word technology, apparently, was made in connection with the professorship just mentioned, in that Dr. Bigelow, who, for ten years, held it with marked ability and success, published his lectures under the name of the *Elements of Technology*.

We find, however, that technology, as now taught, embraces a third department of a completely different character, and one which has arisen out of the working of the third conception to which I have called attention, namely, that in the attempt to utilize the natural laws, there would certainly be revealed more and more of the infinite possibilities of our environment.

So indeed it has proved. It happens that certain investigations into the chemical and physical properties of matter, into the dynamics of steam, electricity, etc., have been made by the engineer rather than by the physicist and the chemist, because these investigations have been required by the practical work of the engineer, and because they have sometimes to be carried out on a scale inconsistent with the more delicate experiments which are the chief occupation of the physical laboratory. So it has come to pass, as a matter of convenience mainly, that engineering, besides being a profession, has been made directly responsible for certain scientific work, and may in this light be looked upon as containing within itself a pure science.

Numerous examples might be quoted as illustrating this statement from any good engineering laboratory, and I will just refer to one or two which I have taken from our own experience at McGill University. Callendar and Nicolson, with the platinum thermometer and ordinary steam-engine, were able to deduce laws of the utmost importance relating to the cylinder condensation of steam. The experiments of Adams and Nicolson, and subsequently of Adams and Coker, have thrown new light on the flow of rock-masses under high pressures and temperatures, and further developments may be hoped for, as generous provision for the purpose has been made by the Carnegie Institute. By means of specially designed extensometers it has been possible to study, within the limits of elasticity, the lines of stress in beams under transverse loads, and much progress has been made in the solution of many hydraulic problems, notably in the determination of coefficients and the critical velocity.

This department of technology, which is daily assuming more importance, has hitherto been little emphasized, and it naturally brings us to consider the distinction between pure and applied science and also the definition of the place we must assign to technology in the general scheme of knowledge, a definition involving the proper classification of science in the widest sense, a subject which has occupied the attention of many learned minds.

Our very word *science* itself, that is, knowledge so systematized that prediction and verification by measurement, experiment, observation, etc., are possible, is in Germany limited by the name of *exact* science, and is included in a larger idea, *Wissenschaft,* which seems to embrace ordered knowledge of every kind; for example, the accepted principles which govern the search for historical and philosophical truth. The German idea of *Wissenschaft* includes at once the highest aims of the "exact, the historical, and the philosophical lines of thought." "That superior kind of knowledge, dignified by the title of Science, must," says one writer, "have generality as opposed to particularity, system as opposed to random arrangement, verification as opposed to looseness of assumption."

In view of what has gone before, there is no need, I imagine, further to substantiate the claims of technology to a rank amongst the sciences. We have tried to show that its material is scientific, that it is itself in all departments a scientific method of dealing with nature, and, in one department, an actual investigation into nature; but we shall see that its place in a general classification of science is rather a composite one.

Pure science has been defined as "the knowledge of . . . powers, causes, or laws, considered apart or as pure from all applications." It involves a research into facts by which we learn to understand their nature and to recognize their laws, and its description naturally includes a history of the facts or experiments by means of which it has been made manifest. In one sense every one of these experiments is an application of already known laws of science to something of the nature of a machine — a case exactly parallel, in outward seeming, with what is done in the ordinary departments of technology. Yet, with a true instinct, it is not called technology, and why? Because the *aim* is different. Even if the ultimate aim be utility, it is not primarily so. The first and immediate aim is to subserve no practical purpose, but to dig deep into nature's garden and find the roots which, down in the dark, are working out their wonders.

These experiments may be called *applications of pure science,* but we will not give them the name of applied science or technology, which clearly involves the idea of utility. Whether this is necessarily a higher or a lower ideal, we will not at present consider, for we have shown that we have a claim to both ideals; but we will simply admit, nay more we will emphasize the fact, that the technologist, in the ordinary sense, wants to know about the heat of the sun in order that he might drive its chariot with greater success than Phaethon of old. It is not *knowledge* but *power* which is his ultimate aim.

Even in the department of pure science, to which we have referred as the third department of technology, the idea of utility is more prominent than it ordinarily is in the laboratories of pure science, though still in its highest form, and acting rather as an incentive to begin the work than affecting the manner of carrying it out. For instance, the strong desire to eliminate the errors caused by the sensitiveness of metals to variations of temperature has prompted the effort to find a remedy, which has recently resulted in the use of a definite combination of nickel and steel, a material practically insensitive to temperature changes.

The idea of *utility* seems to be the real key to the distinction between pure science and technology.

We find technology variously described as the science of the industrial arts; as the application of scientifically obtained facts and laws in one or more departments to some practical end, which end rules the selection and arrangement of the whole, as, for instance, in the practical sciences of navigation, engineering, and medicine. Again, applied science is defined as a knowledge of facts, events, and phenomena as explained, accounted for, or produced by powers, causes, and laws.

We see that when laws are attached to facts, whether in nature or experiment, for the purpose of explanation merely, we call it pure science, but when laws are attached to facts with an idea of utility in art, manufacture, or in the general service of humanity, we call it applied science or technology. In the first case, the fact is viewed as an instance of the law; in the second, the fact itself is the important thing. Therefore, the distinction between pure and applied science seems to be largely one of purpose; if our purpose is to establish a law we call it pure science, if our purpose is to establish a fact we call it applied science.

We see, therefore, that technology, while in one department a pure science, investigating the laws which govern, for example, the strength of structures both as dependent on material and form, or, in general, any problem arising out of the artificial working-up of natural products, is, in the main, to be called an applied science, and is in fact so described. I can find no essential difference between the use of the two terms "applied science" and "technology," as they are ordinarily employed at present, and scarcely a case in which either of them could not be used. A notable exception is the science of medicine, which is, strictly speaking, an applied science, but which is never described as technology, perhaps foreshadowing a more distinct specialization in the use of the term technology, so that it may indicate only the science of man's makings and not the science of man's doings. The scope of technology, even as thus defined, is, perhaps, its most striking characteristic.

The endless range of knowledge, opened up by an attempt to apply even the known laws of nature to the limitless array of facts, is at once apparent, even if we say nothing of facing the new problems arising in the process. Our material is evidently the whole world, with all the giant forces impelling it on its yearly circuit, lighting, heating, and supporting its myriad forms of life and ruling their motion and their rest.

Where shall we find a guide in this complexity? How shall we choose between necessary and unnecessary knowledge? In theory it seems impossible to draw any line, and one never knows at what moment a new department may become essential; but, in practice, this very possibility has suggested the course which has been followed, namely, the attempt that has been made to gain a knowledge of those laws which *up to the present time* have been adapted to practical needs. As more of these laws are utilized they, too, will be incorporated, and the limitations of the human mind must then be provided for, in a greater degree than is the case at present, by a scheme of options which will allow each individual to use as his *material* mainly the special knowledge that he will require in the department of technology chosen as his particular profession, and which will compel him to know of the other departments only enough to fit this into its right place in the general scheme.

Such a system of options is, fortunately, feasible by reason of the fact that the mental powers, trained to work scientifically in a given direction, can afterwards be turned to other objects. At least this is the case when the *method* of working is given the first importance, as then only is it possible to form the scientific mind.

If we examine the best modern schools of technology we find that the curriculum contains departments founded on the conceptions with which we have been dealing. We notice,

First, a study of selected laws of nature (*i. e.*, those which have already been applied to practical purposes);

(*a*) as seen in nature;

(*b*) as seen in examples and descriptions of the means by which they have been utilized. This corresponds to learning by experiment, and includes especially the study of all types of machinery, implements, and instruments.

Secondly, a distinct aim to train the mind of the student in accordance with the laws of the mind.

This is not usually done theoretically, *i. e.*, by any inquiry into the laws of the mind, but practically, *i. e.*, by causing the student to learn some particular form of industrial art in a scientific manner.

Thirdly, a distinct desire to encourage,

(*a*) research into the nature of the practical facts essential to any art, with a view to finding out reasons for the same in the *known* laws of nature, thereby giving workmen the opportunity to work intelligently;

(*b*) original research into the problems arising out of industrial processes, with a view to finding out unknown laws of nature, and especially those which must be investigated on a large scale.

We may observe that this classification includes in the *third* division a kind of research, (*a*), which, though not exactly pure science, as it does not seek for unknown laws but only for known laws which will fit a particular case, yet partakes of the same nature as far as the action of the mind is concerned. It is practically useful and necessary as a part of technology, because it supplies to the workers in any art the fundamental reasons which justify the employment of a certain procedure (whether such procedure has been developed by practical experiment or whether it has been developed as a result of theoretical research). This search for causes will naturally increase in importance with the growth of knowledge as to the scientific carrying out of any art, or, in other words, as trades and arts tend to become more scientific.

In practice it is found that foremen, educated in a knowledge of fundamental laws as well as in scientific processes, are far more valuable, and that the workmen also will be all the better, for whatever knowledge of this kind can be given them. Numbers of firms and corporations are now acting on this principle, some even refusing to accept a messenger-boy unless he has passed through a high school.

Further, this training, which enables a worker to recognize essential principles, has the great advantage of showing to the worker in what direction it is possible to make advances and improvements and — no less important a matter — in what direction progress is impossible. The history of invention will emphasize the truth of this statement. How much time and brains, for instance, have been wasted in devising mechanism which involves the fallacy of perpetual motion!

We notice also that, in the second department, the classification includes instruction in the scientific process of carrying out any art required by a student for his future work. In any true university this practically useful plan is made to subserve the end of mental development in the student. This department naturally takes up a great deal of space in an institution, as there may be almost as many options as there are students. Partly for this reason, partly because it is the easiest end at which to begin a technical school, and partly because it appeals most strongly to the non-university man, as being apparently a short cut to success, it is not infrequently *all* that is understood by technology, and is *all* that is directly included in its definition as the *science of the industrial arts.* This scientific instruction in the industrial arts may be said to have been the beginning of technology, and where it has been over-emphasized, it has given apparent justification to the idea (of which there is still a survival) that the subject is not necessarily scientific in any wide sense, and that the practical training of workers is more important than the theoretical.

Technology may be called the child of science on the one hand, and of industrial progress on the other; therefore we must not be surprised to find a very curious blending of the spirit of both in an institute of technology.

We can do exactly the same thing at different times with a different, even with an opposite motive, but though the same thing is produced externally, the result on the mind of the student is, in each case, the result of the inner motive. What happens depends, as it were, on the point upon which the stress is laid. Wherever the spirit of science prevails, we are on the lookout for phenomena which may lead us to a better understanding of a known law, or to a knowledge of some hitherto unknown law of nature. Wherever the spirit merely of industrial progress prevails, we are on the lookout for some adaptations of our machines or processes which may add to the chances of commercial advantage. In the former case, while we learn the best, because the scientific, method of carrying out an art, we put at the same time the real emphasis on producing the scientific man. In the latter case you produce merely an intelligent handicraftsman, whose very highest aim is to improve his art — by no means an ignoble end, but one which might easily be ennobled, and one which may and often does defeat its own purpose — for the true scientific spirit is also a spirit of prophecy, and if you do not succeed in producing it, those things which might have been to you a new revelation will lie by your side unperceived. Merz likens Bacon to "one who inspects a large and newly discovered land, laying plans for the development of its resources and the gathering of its riches."

In the fact of scientific foresight is found a strong practical argument for curbing the impatience to acquire the training requisite for success in a practical profession — the readiness to sacrifice a more remote to a more immediate end. This impatience is still so great as to cause a serious danger that our technical schools may be tempted to give a purely professional training, or that professionalism may become overwhelmingly strong in them, and threatens to introduce, into even our common schools, a far too soon begun specialization.

That this danger exists is one reason why it is true, and probably always will be, that the scientific spirit is relatively more often produced in the students of pure science than in the students of applied science, but note that this is only relatively true. Other things must be considered. Where you can get one man to devote himself to pure science, you can find a thousand to fill the ranks of practical workers, so that you greatly multiply the actual chances of discovering the why and the wherefore of things, and, at the same time, you secure the enthusiasm derived from numbers. Also besides the mere increase of chances arising from larger numbers, and the immediate effect of numbers, we can claim for the workers in applied science, under the *best* conditions,as remarkable a development of the scientific spirit as has ever been recorded in the annals of pure science. Take, for example, the great French chemist and naturalist, Pasteur, who "has been able," as Ray Lankester justly says, "not simply to pursue a rigid path of investigation dictated by the logical or natural connection of the phenomena investigated, but deliberately to select for inquiry matters of the most profound importance to the community, and to bring his inquiries to a successful practical issue in a large number of instances. . . . The discoveries made by this remarkable man would have rendered him, had he patented their application and disposed of them according to commercial principles, the richest man in the world. They represent a gain of some millions sterling annually to the community."

Moreover, we must remember that what we have called professionalism, though limited to a sphere which appeals to our individual interest, is, after all, in part of its nature, very closely akin to the scientific spirit — inasmuch as it seeks for truth, and is often imbued with the spirit which would spend itself in the effort to achieve honest work, in the joy of overcoming, in the patient performance of duty, or in the search for what will bring honor to the profession. Therefore, in contrasting the spirit of professionalism with the scientific spirit, it is rather the element in professionalism that we may call commercialism which we wish to avoid — the way of estimating values by money value and of measuring our interests by dollars and cents.

Further, we cannot afford to condemn even commercialism in a wholesale manner, as is often done. We are led to look for the element of real value which must be there, when we find, for instance, the last India budget pointing with satisfaction to the great increase in bank deposits in spite of plague and famine, and when we find, in general, that we are always able, to a certain extent, to measure any nation's progress by its increase in riches.

Let us notice, however, that the purely scientific man contributes greatly to the world's wealth, but seldom to his own, and has to be supported by a world which knows the value of his work and makes an appreciative *entourage*. Notice, also, that the study of commercial methods is distinctly good as opposed to waste, being quite necessary to the study of economics, which is the application of philosophical and scientific principles to the conduct of life — a kind of final aim of the general application of science to life. To know how to live and conquer our environment financially, in a manner easy enough to leave some margin for intellectual advancement, seems to be a necessary condition of living on a high plane. True, one can have plain living and high thinking, but when it comes to sordid living, when the food is perhaps too little to feed the brain, or even when every scrap of energy is used up in providing for material wants, then indeed the wings of the imagination are clipped and the eagle becomes a barnyard fowl.

If, then, this commercialism has so much that is good and necessary, why should we look upon it as a danger? Because, like fire, it is a good servant, but a bad master; because, in this world, we must look upward, or with level eyes, or downward. We feel instinctively that true scientific thought is an *aspiration*, that a wise economy or management, a taking far-seeing advantage of circumstances, or any honorable making of money, especially for unselfish purposes, is practical common sense, and is helpful in, as it were, buying time in which we may rise to higher things. On the other hand, we feel no less that if we turn the making of money into a goal in itself, the road to it is beset with the pitfalls of greed, selfishness, and dishonor, and that the looking at it thus, or as the chief standard by which to measure values, is quite unworthy of our higher nature. "What lovely puppies!" exclaimed the child. "A hundred dollars' worth of dogs," remarked the lad, who was trying to reach too quickly the time when the glory of dawn melts into the light of common day.

On these grounds we feel that any teaching that allows commercialism to become too important a factor is fraught with danger. That we speak of it not as an evil, but as a danger, suggests a reason why it is not shunned with more care. It is only a risk, and I am afraid that, over-confident in the steadiness of our heads, we seldom mind skirting moral precipices, but in a scientific institution, at least, we ought steadily to build up the invisible moral ideal.

Risk is a conception distinctly opposed to any science seeking after absolute knowledge, and should be as far as possible discouraged, whatever legitimacy there may be in it being replaced by a keener foresight. If we deal with risks at all, it should be in a scientific way, calculating their amount and providing for them, and we should certainly practice what we preach, estimating with care the danger of commercialism, and deciding whether it would not be better to avoid it, lest we be confronted with the necessity of providing a counterpoise for which a technical institute offers no adequate material.

It may be said that this is a side issue, and not a fundamental conception, but our assumptions are always greater than our conscious knowledge, and, in one sense, there are no side issues. No truly scientific man can be blind to the position of his immediate object in the general scheme of things, and the more broad-minded he is the more careful will he be that, as he moves along, he is not stirring up forces for evil; more, he will be *positive* in his effort, and will try to see that it is tending to produce a man whose work shall be worthy of his own nature.

All moral issues, which have been often used in support of the idea of the new technical education, are, in the same sense, side issues. A technical school is not, and cannot be, primarily a school of morals; but even men, sufficiently careless about their own standard of life, are glad enough to encourage and cultivate in others that stability of conduct which is the best bulwark of a democratic state. If we consider the manner in which any moral effect may be looked for, as a result of technical training, we shall see that the process must be something of the following nature. The inner eye, which sees truth, is necessarily aided by the immediate detection of errors in form, or in the nice adjustment of outward things, and the consequent emphasis which is laid upon the value of accuracy. We cannot take the first step towards a virtue until we see it clearly, and, therefore, whatever magnifies it makes that step more possible. Again, we may reflect that the enforced yet pleasant exercise of a virtue may do much to make it agreeable, and may diminish any natural opposition to it which may happen to exist. Further, still, we may go, and assert that the will itself may be, and is, cultivated in the overcoming of obstacles, and, therefore, may be made the more powerful instrument of an awakened and a holy purpose — for deep down beyond all this, we come to the place where we are forced to admit that we have reached the limit of human effort, to the place where the wise will lift up "hands of faith." No science can teach a *love* of truth which shall be strong enough to conquer life. Yet, within its limits, in common with all true scientific teaching, and perhaps in a larger measure proportionate to its appeal to a larger *clientèle*, technology may lay claim to produce moral strength, truth, and manliness.

Nor is this all by any means. Technology has been exalted as the spring of civilization, and it is, and not only or merely because the promoters of utility increase the ease of life, "make space and give time," and so broaden our mental horizon, but also because in the contest with the earthly and the sensual it is no small matter to be reinforced by the widespread existence of intellectual tastes, and because the patient waiting on nature, often so necessary in scientific work, tends to produce self-restraint. To self-restraint and true temperance we must look to save our civilization from passing into rottenness, as has been the fate of many another, which, dahlia-like, has blossomed only to turn into a sodden mass, because, perhaps, it has not recognized the truth that it is of no use at all to *refine* the vices of the state, that the plow, which uproots the evil weeds without mercy, must prepare the way for the waving grain and the fruitful harvest of a true civilization. We might go on — we might call attention to the self-sacrifice which often leads the man of pure science and surely, not seldom, the true technologist, to count his life well lost in the service of truth. Nor in this busy practical age must we forget that, if we choose, we can make each obstacle overcome, not a step from which, like a child in play, we can leap back to our former position, but a point of vantage from which we can scale,

> "By slow degrees, by more and more,
> The cloudy summits of our time."

There is one subject on which I should like to say a word, one that is generally used as a *contrast* to technology, namely, "fine art," or the science of beauty, the beautiful being regarded as the antithesis of the useful. I cannot feel content so to express the relation between the two.

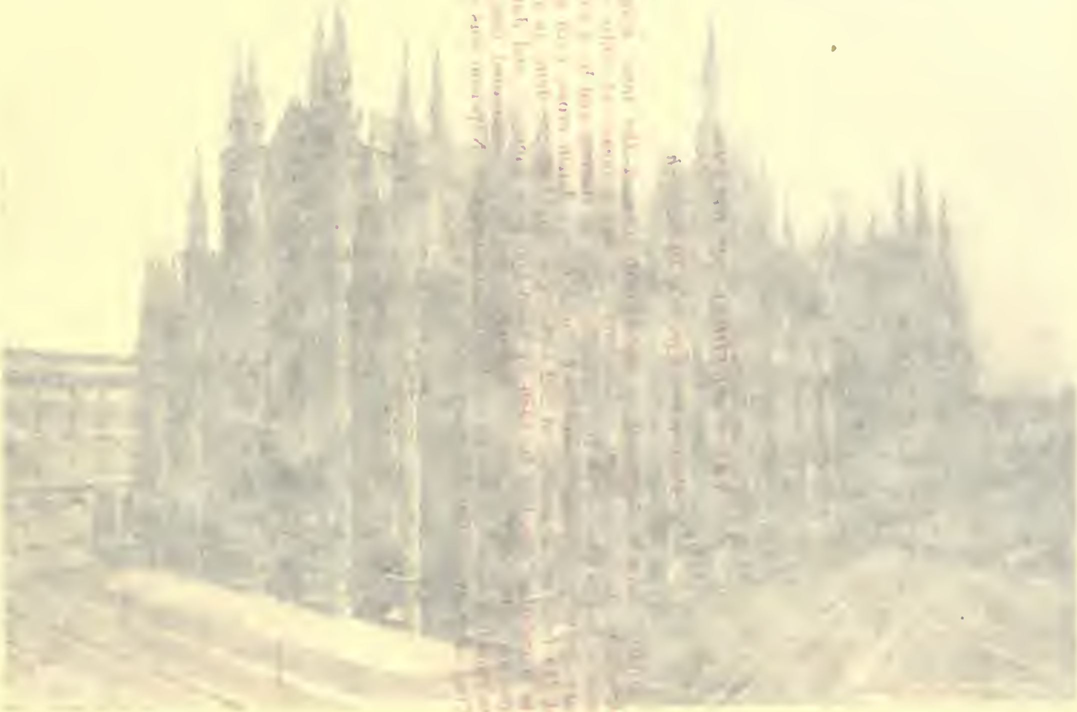
Have we not already noticed that the inspiration of genius, no less in science than in art, requires the imagination as its instrument, and can only express itself in terms of its language? Also, has not one of the greatest writers on the science of the beautiful called our attention to the fact that beauty without strength and truth is a sham? No, there can be here no true antithesis. The power of seeing the abstract must be much the same mental power, to whatever subject it is applied, and whether it discovers ideal truth or ideal beauty, it matters little; the great thing is to feel the Soul of things at all, and not to be only capable of seeing with a surface realism which thinks nothing worth discussing unless it can be handled.

In practice, however, we still find a difficulty. In the early stages of technological education, drawing is recognized to be the foundation of the industrial as well as of the fine arts, but later, an apparently inevitable specialization differentiates between the two, and, except in the one department of architecture, beauty and the science of beauty have been largely ignored by the new education.

Is it really necessary to be ugly in order to be useful? Can we not lift and store our grain without disfiguring our most beautiful views? Must we strip our great forest of trees and make them into bare poles from which to swing our electric wires? Should it be possible to describe any human habitations as packing-boxes pierced with holes? Is it *really* a useful purpose which would take for any common end the glorious redwood forests, planted before the Christian era, "for the service of man" indeed, but for what service — to build him a house — to kindle him a fire — or to waken his soul to a knowledge of its own value?

Here, then, is not a danger to be guarded against, but a want to be supplied. We need the imagination in the highest departments of technology, but there is at present no distinct training for it, and there should be, if only to help a man to realize the unity of his own mental being and the mighty unity of Nature, which could give us a type of the fixity of law in the rainbow, of all colors the most beautiful and ephemeral, of all forms the strongest, throwing across the clouds, still black with threatening, its perfect arch, —

> " A glorious thing that dauntless, deathless,
> Sprang across them and stood steady."



THE CATHEDRAL OF MILAN

Photogravure from a Photograph

Milan's famous Cathedral is undoubtedly one of the most magnificent structures in ecclesiastical architecture. It has a facade of white Carrara marble, and is adorned by 106 pinnacles and 4500 statues, and by a variety of carvings of unsurpassed beauty. In form it is a Latin cross, with a length of 485 feet, and a breadth of 252 feet. The height of the dome is 355 feet. Its foundation was laid in 1386 by Gian Galeazzo Vinconti, and during its creation many of the greatest European architects contributed designs for its embellishment. It was in the Milan Cathedral that Napoleon was crowned King of Italy in 1805.

SECTION A — CIVIL ENGINEERING

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(*Hall* 10, *September* 21, 10 *a. m.*)

CHAIRMAN: PROFESSOR WILLIAM H. BURR, Columbia University.
SPEAKERS: DR. J. A. L. WADDELL, Consulting Engineer, Kansas City.
MR. LEWIS M. HAUPT, Consulting Engineer, Philadelphia.

THE RELATIONS OF CIVIL ENGINEERING TO OTHER BRANCHES OF SCIENCE

BY JOHN ALEXANDER LOW WADDELL

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THE topic set for this address is "The Relations of Civil Engineering to Other Branches of Science." In its broad sense civil engineering includes all branches of engineering except, perhaps, the military. This is its scope as recognized by two of the highest authorities, viz., the American Society of Civil Engineers and the Institution of Civil Engineers of Great Britain; for these two societies of *civil* engineers admit to their ranks members of all branches of engineering. It is evident, though, from a perusal of the Programme of this Congress that the Organizing Committee intended to use the term in a restricted sense, because it has arranged for addresses on mechanical, electrical, and mining engineering. But what are the proper restrictions of the term is, up to the present time, a matter of individual opinion, no authority having as yet attempted definitely to divide engineering work among the various branches of the profession. To do so would, indeed, be a most difficult undertaking; for not only do all large constructions involve several branches of engineering, but also the profession is constantly being more minutely divided and subdivided. For instance, there are recognized to-day by the general public, if not formally by the profession, the specialties of architectural, bridge, chemical, electrical, harbor, highway, hydraulic, landscape, marine, mechanical, metallurgical, mining, municipal, railroad, and sanitary engineering, and possibly other divisions; and the end is not yet, for the tendency of modern times in all walks of life is to specialize.

Between Tredgold's broad definition of civil engineering, which includes substantially all the applied sciences that relate to construction, and the absurdly narrow definition which certain engineers have lately been endeavoring to establish during the course of a somewhat animated discussion, and which would confine civil engineering to dealing with stationary structures only, there must be some method of limitation that will recognize the modern tendency toward specialization without reducing the honored profession of civil engineering to a mere subdivision of applied mechanical science.

Without questioning in any way the correctness of the Tredgold definition, civil engineering will be assumed, for the purposes of this address, to include the design and construction of bridges; extensive and difficult foundations; tunneling; retaining-walls, sea-walls, and other heavy masonry; viaducts; wharves; piers; docks; river improvement; harbors and waterways; water-supply; sewerage; filtration; treatment of refuse; highway construction; canals; irrigation works; dams; geodetic work; surveying; railways (both steam and electric); gas-works; manufacturing plants; the general design and construction of plants for the production of power (steam, electric, hydraulic, and gaseous); the general design and construction of cranes, cable-ways, breakers, and other mining structures; the heavier structural features of office buildings and other large buildings that carry heavy loads; the general problems of transportation, quarrying, and the handling of heavy materials; and all designing and construction of a similar nature.

In contradistinction, mechanical engineering should include the design and construction of steam engines, machine tools, locomotives, hoisting- and conveying-machinery, cranes of the usual types, rolling-mill machinery, blast-furnace machinery, and, in fact, all machinery which is designed for purely manufacturing purposes.

Electrical engineering should include all essentially electrical work, such as the designing, construction, and operation of telephone and telegraph lines; electric-light plants; dynamos; motors; switchboards; wiring; electric devices of all kinds; transmission lines; cables (both marine and land); and storage batteries.

Mining engineering should include all underground mining work; means for handling the products of mines; roasting, smelting, milling, stamping, and concentrating of ores; drainage and ventilation of mines; disposal of mine refuse; and similar problems.

It is impracticable to draw hard-and-fast lines between the various branches of engineering, because, as before indicated, nearly all large constructions involve several specialties; consequently no specialist can confine his attention to a single line of work to the exclusion of all other lines. For instance, the bridge engineer encounters mechanical and electrical engineering problems in designing movable bridges; railroading in approaches to bridges; river improvement in the protection of piers and abutments; highway construction in the pavement of wagon bridges; architecture in the machinery houses of swing spans; hydraulic engineering in guarding bridges against fire; and chemistry and metallurgy in testing materials. The railroad engineer encounters architecture and structural engineering in depots, roundhouses, and other buildings; hydraulic problems in pumping-plants and bank protection; mechanical engineering in interlocking plants; and electrical engineering in repair-shop machinery. The mining engineer invades the field of mechanical and electrical engineering in his hoisting, ventilating, and transporting machinery; deals with civil engineering in his surveys; and encounters chemistry and metallurgy in testing ores. Similarly it might be shown that all branches of engineering overlap each other and are interdependent.

It was the general opinion among scientists not many years ago that engineering was neither a science nor a profession, but merely a trade or business; and even to-day there are a few learned men who hold to this notion — some of them, *mirabile dictu,* being engineers; but that such a view is entirely erroneous is now commonly conceded. He is an ill-informed man who to-day will deny that civil engineering has become one of the learned professions. Its advances in the last quarter of a century have been truly gigantic and unprecedented in the annals of professional development. It certainly can justly lay claim to being the veritable profession of progress; for the larger portion of the immense material advancement of the world during the last century is due primarily and preëminently to its engineers.

It must be confessed that half a century ago engineering was little better than a trade, but by degrees it advanced into an art, and to-day, in its higher branches at least, it is certainly a science and one of the principal sciences.

The sciences may be divided into two main groups, viz., "Pure Sciences" and "Applied Sciences."

The "Pure Sciences" include:

(1) Those sciences which deal with numbers and the three dimensions in space, the line, the surface, and the volume, or in other words "Mathematics."

(2) Those sciences which deal with inorganic matter, its origin,

structure, metamorphoses, and properties; such as geology, petrology, chemistry, physics, mineralogy, geography, and astronomy.

(3) Those sciences which deal with the laws, structure, and life of organic matter; such as botany, zoölogy, entomology, anatomy, physiology, and anthropology.

(4) The social sciences; such as political economy, sociology, philosophy, history, psychology, politics, jurisprudence, education, and religion.

"Applied Sciences" include:

(1) Those which relate to the growth and health of organic matter; such as medicine, surgery, dentistry, hygiene, agriculture, floriculture, and horticulture.

(2) Those which deal with the transformation of forces and inorganic matter, viz., the various lines of engineering,—civil, mechanical, electrical, mining, marine, chemical, metallurgical, architectural, etc.

(3) Those which relate to economics; such as industrial organizations and manufactures, transportation, commerce, exchange, and insurance.

Some writers make no distinction between the terms "Political Economy" and "Economics," but in this address they are divided, the former relating to broad subjects of national importance, and the latter to minor matters and to some of the details of larger ones. For instance, currency, the national debt, banking, customs, taxation, and the subsidizing of industries pertain to "Political Economy," while economy of materials in designing and of cost of labor in construction, supplanting of hand-power by machinery, systemization of work of all kinds, adjustment of grades and curvature of railroads to traffic, and time- and labor-saving devices come under the head of "Economics."

The distinctions between the pure and the applied sciences are at times extremely difficult to draw, for one science often merges almost imperceptibly into one or more of the others.

The groups of pure sciences that have been enumerated may be termed:

The Mathematical Sciences,
The Physical Sciences,
The Physiological Sciences, and
The Social Sciences;

while the groups of applied sciences may be called:

The Organic Sciences,
The Constructive Sciences, and
The Economic Sciences.

In what follows the preceding nomenclature will be adopted.

The terming of engineering the "Constructive Science" is a happy conception, for engineering is truly and almost exclusively the science of construction. The functions of the engineer in all cases either are directly constructive or tend toward construction.

The engineer has ever had a due appreciation of all the sciences, imagination to see practical possibilities for the results of their findings, and the common-sense power of applying them to his own use.

Pure science (barring perhaps political economy) is not concerned with financial matters, and its devotees often look down with lofty disdain upon everything of a utilitarian nature, but engineering is certainly the science most directly concerned with the expenditure of money. The engineer is the practical man of the family of scientists. While he is sufficiently well informed to be able to go up into the clouds occasionally with his brethren, he is always judicious and comes to earth again. In all his thoughts, words, and acts he is primarily utilitarian. It is true that he bows down to the goddess of mathematics, but he always worships from afar. It is not to be denied that mathematics is the mainstay of engineering; nevertheless the true engineer pursues the subject only so far as it is of practical value, while the mathematician seeks new laws and further development of the science in the abstract. The engineer does not trouble himself to consider space of four dimensions, because there are too many things for him to do in the three-dimension space in which he lives. Non-Euclidian geometry is barred from his mind for a fuller understanding of the geometry which is of use to ordinary mankind. The mathematician demonstrates that the triangle is the sole polygonal figure which cannot be distorted, while the engineer, recognizing the correctness of the principle, adopts it as the fundamental, elementary form for his trusses. The mathematician endeavors to stretch his imagination so as to grasp the infinite, but the engineer limits his field of action to finite, tangible matters.

The geologist, purely studious, points out what he has deduced about the construction of the earth; but the engineer makes the mine pay.

The chemist discovers certain facts about the effects of different elements in alloys; but the engineer works out and specifies a new material for his structures. Again, the chemist learns something about the action of clay combined with carbonate of lime when water is added, and from this discovery the engineer determines a way to produce hydraulic cement.

The physicist evolves the theory of the expansive power of steam, and the engineer uses this knowledge in the development of the steam engine. Again, the physicist determines by both theory and experiment the laws governing the pressures exerted by liquids, and the engineer applies these laws to the construction of dams and ships.

The botanist with his microscope studies the form and construction of woods, while the engineer by experimentation devises means to preserve his timber.

The biologist points to bare facts that he has discovered, but the engineer grasps them and utilizes them for the purification of water-supplies.

In short, the aim of pure science is discovery, but the purpose of engineering is usefulness.

The delvers in the mysterious laboratories, the mathematical gymnasts, the scholars poring over musty tomes of knowledge, are not understood by the work-a-day world, nor do they understand it. But between stands the engineer with keen and sympathetic appreciation of the value of the work of the one and a ready understanding of the needs and requirements of the other; and by his power of adaptability he grasps the problems presented, takes from the investigators their abstract results, and transforms them into practical usefulness for the world.

The work of the engineer usually does not permit him to make very extensive researches or important scientific discoveries; nor is it often essential to-day for him to do so, as there are numerous investigators in all lines whose object is to deduce abstract scientific facts; nevertheless there comes a time occasionally in the career of every successful engineer when it is necessary for him to make investigations more or less abstract, although ultimately utilitarian; consequently it behooves engineers to keep in touch with the methods of scientific investigation, in order that they may either perform desired experiments themselves, or instruct trained investigators how to perform them.

The engineer must be more or less a genius who invents and devises ways and means of applying all available resources to the uses of mankind. His motto is "utility," and his every thought and act must be to employ to the best advantage the materials and conditions at hand. To be able to accomplish this object he must be thoroughly familiar with all useful materials and their physical properties as determined by the investigations of the pure scientists.

Many well-known principles of science have lain unused for ages awaiting the practical application for which they were just suited. The power of steam was known long before the practical mind of Watt utilized it in the steam engine.

The engineer is probably an evolution of the artisan rather than of the early scientist. His work is becoming more scientific because of his relations and associations with the scientific world. These relations of the engineer to the sciences are of comparatively recent origin, and this fact accounts for the rapid development in the engineering and industrial world of the past half-century. The results of this association have been advantageous to both the engineer and the pure scientist. The demands of the engineers for new discoveries have acted as an incentive for greater effort on the part of the investigators. In many instances the engineer is years in advance of the pure scientist in these demands; but, on the other hand, there are, no doubt, many valuable scientific facts now available which will yet work wonders when the engineer perceives their practical utility.

The engineer develops much more fully the faculty of discernment than does the abstract scientist, he is less visionary and more practical, less exacting and more commercial.

It is essential to progress that large stores of scientific knowledge in the abstract be accumulated and recorded in advance by the pure scientists, so that as the engineer encounters the necessity for their use he can employ them to the best advantage. The engineer must be familiar with these stores of useful knowledge in order to know what is available. This forms the scientific side of the engineer's work. While he must know what has been done by investigators, it is not absolutely necessary that he know how to make all such researches for himself; although, as before stated, there are times in an engineer's practice when such knowledge will not come amiss.

As engineers are specializing more and more, each particular specialty becomes more closely allied with the sciences that most affect it; consequently, to insure the very best and most economic results in his work the engineer must keep in close touch with all of the scientific discoveries in his line.

The early engineers, owing to lack of scientific knowledge, took much greater chances in their constructions than is necessary for up-to-date, modern engineers. There is now no occasion for an engineer to make any hazardous experiments in his structures, because by careful study of scientific records he can render his results certain.

In future the relations between engineers and the pure scientists will be even closer than they are to-day, for as the problems confronted by the engineer become more complex and comprehensive the necessity for accurate knowledge will increase.

The technical training now given engineers involves a great deal of the purely scientific; and it is evident that this training should be so complete as to give them a comprehensive knowledge of all the leading sciences that affiliate with engineering. There is no other profession that requires such a thorough knowledge of nature and her laws.

Of all the various divisions and subdivisions of the sciences hereinbefore enumerated and of those tabulated in the Organizing Committee's "Programme," the following only are associated at all closely with civil engineering:

Mathematics.
Geology.
Petrology.
Chemistry.
Physics.
Mineralogy.
Geography.
Astronomy.
Biology.
Botany.
Political Economy.
Jurisprudence.
Education.
Economics.

Attention is called to the fact that this list contains a number of divisions from the four main groups of pure sciences, viz., the mathematical, physical, physiological, and social, and but one division (economics) from the three groups of applied sciences, viz., the organic, constructive, and economic. The reasons why so little attention is to be given to the relation between civil engineering and the applied sciences are, first, in respect to organic science, there is scarcely any relation worth mentioning between this science and civil engineering, and, second, because the interrelations between civil engineering and other divisions of constructive science have already been treated in this address.

Of all the pure sciences there is none so intimately connected with civil engineering as mathematics. It is not, as most laymen suppose, the whole essence of engineering, but it is the engineer's principal tool. Because technical students are drilled so thoroughly in mathematics and because so much stress is laid upon the study of calculus, it is commonly thought that the higher mathematics are employed constantly in an engineer's practice; but as a matter of fact, the only branches of mathematics that a constructing engineer employs regularly are arithmetic, geometry, algebra, and trigonometry. In some lines of work logarithms are used often, and occasionally in establishing a formula the calculus is employed; but the engineer in active practice soon pretty nearly forgets what analytical geometry and calculus mean. As for applied mechanics, which, as the term is generally understood, is a branch of mathematics (although it involves also physics and other sciences), the engineer once in a while has to take down his old text-books to look up some principle that he has encountered in his reading but has forgotten. Strictly speaking, though, engineers in their daily tasks utilize applied mechanics, almost without recognition; for stresses, moments, energy, moments of inertia, impact, momentum, radii of gyration, etc., are all conceptions of applied mechanics; and these are terms that the engineer employs constantly.

There are some branches of the higher mathematics of which as yet engineers have made no practical use, and prominent among these is quaternions. When it first appeared the conciseness of its reasoning and its numerous short-cuts to results gave promise of practical usefulness to engineers, but thus far the promise has not been fulfilled.

Notwithstanding the fact that the higher mathematics are of so little use to the practicing engineer, this is no reason why their study should be omitted from or even slighted in the technical schools; because when an engineer has need in his work for the higher mathematics he needs them badly; besides, the mental training that their study involves is almost a necessity for an engineer's professional success.

Geology (with its allied branch, or more strictly speaking subdivision, petrology) and civil engineering are closely allied. Civil engineers are by no means so well versed in this important science as they should be. This, perhaps, is due to the fact that the instruction given on geology in technical schools is mainly from books, hence most graduates find difficulty in naming properly the ordinary stones that they encounter, and are unable to prognosticate with reasonable assurance concerning what a proposed cutting contains.

Geology is important to the civil engineer in tunneling, railroading, foundations, mining, water-supply, and many other lines of work; consequently, he needs to receive at his technical school a thorough course in the subject given both by text-books and by field instruction.

A knowledge of petrology will enable the engineer to determine readily whether building-stone contains iron which will injure its appearance on exposure, or feldspar which will disintegrate rapidly under the action of the weather or of acids from manufacturing establishments.

Next to mathematics, physics is undoubtedly the science most essential to civil engineering. The physicist discovers and formulates the laws of nature, the engineer employs them in "directing the sources of power in nature for the use and convenience of man." The forces of gravitation, adhesion, and cohesion; the pressure, compressibility, and expansibility of fluids and gases; the laws of motion, curvilinear, rectilinear, accelerated, and retarded; momentum; work; energy; the transformation of energy; thermodynamics; electricity; the laws of wave-motion; the reflection, refraction, and transmission of light; and the mass of other data furnished by the physicist form a large portion of the first principles of civil engineering.

The function of applied mechanics is to establish the fundamental laws of physics in terms suitable for service, and to demonstrate their applicability to engineering construction.

Chemistry is a science that enters into closer relations with civil engineering than does any other science except mathematics and physics, and as the manufacture of the materials of engineering approaches perfection the importance of chemistry to engineers increases. Within a comparatively short period the chemist has made it possible by analyzing and selecting the constitutents to control the quality of cast-iron, cast-steel, rolled-steel, bronze, brass, nickel-steel, and other alloys. The engineer requires certain physical characteristics in his materials, and obtains them by limiting the chemical constituents in accord with data previously furnished by the chemist. The proper manufacture of cement requires the combined skill and knowledge of the chemist and the mechanical engineer.

In water-supply the chemist is called in to determine the character and amounts of the impurities in the water furnished or contemplated for use. The recent discovery that the introduction of about one part of sulphate of copper in a million parts of water will effectively dispose of the algæ, which have long given trouble, is a notable instance of the increasing interdependence of these two branches of science, as is also the fact that the addition to water of a small amount of alum will precipitate the earthy matter held in suspension without leaving in it any appreciable trace of the reagent.

In the purification of water and sewage, in the selection of materials which will resist the action of acids and the elements, and in the manufacture of alloys to meet various requirements, a thorough knowledge of chemistry is essential.

A knowledge of mineralogy is requisite for a clear understanding of the nature of many materials of construction, but is otherwise of only general interest to civil engineers.

Geography in its broad sense is related to civil engineering in some of its lines, for instance, geodesy and surveying, but generally speaking there is not much connection between these two branches of science.

Astronomy is perhaps more nearly related to civil engineering than is geography, although it is so related in exactly the same lines, for the railroad engineer on a long survey must occasionally check the correctness of his alignment by observations of Polaris, and the coast surveyor locates point sby observations of the heavenly bodies.

Biology is allied to civil engineering mainly through bacteriology as applied to potable water, the treatment of sewage to prevent contamination of streams, and the sanitation of the camps of surveying and construction parties. The treatment of sewage has been given much more thorough study abroad than in this country, but the importance of its bearing upon life in the large cities of America is becoming better understood; consequently the progressive sanitary engineer should possess a thorough knowledge of bacteriology. In important cases, such as an epidemic of typhoid fever, the specialist in bacteriology would undoubtedly be called in; but a large portion of the work of preventing or eradicating bacterial diseases will fall to the lot of the sanitary engineer.

Botany comes in touch with civil engineering mainly, if not solely, in the study of the various woods used in construction, although it is a fact that a very intimate knowledge of this pure science might enable a railroad engineer or surveyor to determine approximately the characters of soils from plants and trees growing upon them. A knowledge of botany is of no great value to the civil engineer, and much time is often wasted on its study in technical schools.

Political economy is a science that at first thought one would be likely to say is not at all allied to civil engineering; but if he did so, he would be mistaken, because political economy certainly includes the science of business and finance, and civil engineering is most assuredly a business as well as a profession; besides, the leading engineers usually are either financiers themselves or advisers to financiers. Great enterprises are often evolved, studied, financed, and executed by engineers. How important it is then that they understand the principles of political economy, especially in its relation to engineering enterprises. It is only of late years that technical students have received much instruction in this branch of social science, and the ordinary technical school curriculum to-day certainly leaves much to be desired in respect to instruction in political economy.

Jurisprudence and civil engineering are closely allied, in that engineers of all lines must understand the laws of business and the restrictions that are likely to be placed upon their constructions by municipal, county, state, and federal laws. While most engineering schools carry in their lists of studies the "Laws of Business," very few of them devote anything like sufficient attention to this important branch of science.

Are the sciences of civil engineering and education in any way allied? Ay, that they are! and far more than most people think, for there is no profession that requires as much education as does civil engineering. Not only must the would-be engineer study the various pure and applied sciences and learn a great mass of technical facts; but he must also have in advance of all this instruction a broad, general education — the broader the better, provided that no time be wasted on useless studies, such as the dead languages.

The science of education is so important a subject for civil engineers that all members of the profession in North America, more especially those of high rank, ought to take the deepest interest in the development of engineering education, primarily by joining the special society organized for its promotion, and afterwards by devoting some of their working time to aid this society in accomplishing its most praiseworthy objects.

The science of economics and that of civil engineering are, or ought to be, in the closest possible touch; for true economy in design and construction is one of the most important features of modern engineering. Every high-class engineer must be a true economist in all the professional work that he does, for unless one be such, it is impossible to-day for him to rise above mediocrity.

True economy in engineering consists in always designing and building structures, machines, and other constructions so that, while they will perform satisfactorily in every way all the functions for which they are required, the sum of their first cost and the equivalent capitalized cost for their maintenance, operation, and repairs shall be a minimum. The ordinary notion that the structure or machine which is least in first cost must be the most economical is a fallacy. In fact, in many cases, just the opposite is true, the structure or machine involving the largest first cost being often the cheapest.

Economics as a science should be taught thoroughly to the student in the technical school, then economy in all his early work should be drilled into him by his superiors during his novitiate in the profession, so that when he reaches the stage where he designs and builds independently, his constructions will invariably be models of true economy.

It has been stated that the relations between civil engineering and many of the pure sciences are very intimate, that the various branches of engineering, although becoming constantly more and more specialized, are so interdependent and so closely connected that they cannot be separated in important constructions, that the more data the pure scientists furnish the engineers the better it is for both parties, and that a broad, general knowledge of many of the sciences, both pure and applied, is essential to great success in the engineering profession.

Such being the case, the question arises as to what can be done to foster a still closer affiliation between engineering and the other sciences, and how engineers of all branches and the pure scientists can best be brought into more intimate relations, in order to advance the development of the pure sciences, and thus benefit the entire world by increasing the knowledge and efficiency of its engineers.

One of the most effective means is to encourage the creation of such congresses as the one that is now being held, and to organize them and arrange their various meetings so as to secure the greatest possible beneficial results.

Another is for such societies as the American Association for the Advancement of Science and the Society for the Promotion of Engineering Education to take into their membership engineers of good standing, and induce them to share the labors and responsibilities of the other members.

Conversely, the various technical societies should associate with them by admission to some dignified grade (other, perhaps, than that of full member) pure scientists of high rank and specialists in other branches of constructive science, and should do their best to interest such gentlemen in the societies' objects and development.

A self-evident and most effective method of accomplishing the desired result is to improve the courses of study in the technical schools in every possible way; for instance, by bringing prominent scientists and engineers to lecture to the students and to tell them just how scientific and professional work of importance is being done throughout the world, by stimulating their ambition to rise in their chosen professions, by teaching them to love their work instead of looking upon it as a necessary evil, and by offering prizes and distinctions for the evidence of superior and effective mental effort on the part of both students and practicing engineers.

There has lately been advanced an idea which, if followed out, would aid the development of engineering more effectually than any other possible method, and incidentally it would bring into close contact scientists in all branches related directly or indirectly to engineering. It is the establishment of a great post-graduate school of engineering in which should be taught in every branch of the profession the most advanced subjects of all existing knowledge that is of real, practical value, the instructors being chosen mainly from the leading engineers in each specialty, regardless of the cost of their services. Such specialists would, of course, be expected to give to this teaching only a few weeks per annum, and a corps of regular professors and instructors, who would devote their entire time and energies to the interests of the school, would be required. These professors and instructors should be the best that the country possesses, and the inducements of salary and facilities for investigation that are provided should be such that no technical instructor could afford to refuse an offer of a professorship in this school.

Every modern apparatus needed for either instruction or original investigation should be furnished; and arrangements should be made for providing means to carry out all important technical investigations.

It should be the duty of the regular faculty to make a special study of engineering literature for the benefit of the profession; to prepare annual indices thereof; to put into book form the gist of all technical writings in the *Transactions* of the various engineering societies and in the technical press that are worthy of being preserved and recorded in this way, so that students and engineers shall be able to search in books for all the data they need instead of in the back files of periodicals; to translate or assist in the translation of all engineering books in foreign languages, which, in the opinion of competent experts, would prove useful to engineers or to the students of the school; and to edit and publish a periodical for the recording of the results of all investigations of value made under the auspices of the institution.

In respect to what might be accomplished by such a post-graduate school of engineering the following quotation is made from the pamphlet containing the address in which the project was advanced:[1]

"The advantages to be gained by attendance at such a post-graduate school as the one advocated are almost beyond expression. A degree from such a school would always insure rapid success for its recipient. Possibly for two or three years after taking it a young engineer would have less earning capacity than his classmates of equal ability from the lower technical school, who had gone directly into actual practice. However, in five years he certainly would have surpassed them, and in less than ten years he would be a recognized authority, while the majority of the others would be forming the rank and file of the profession, with none of them approaching at all closely in reputation the more highly educated engineer.

"But if the advantages of the proposed school to the individual are so great, how much greater would be its advantages to the engineering profession and to the entire nation. After a few years of its existence there would be scattered throughout the country a number of engineers more highly trained in the arts and sciences than any technical men who have ever lived; and it certainly

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[1] Higher Education for Civil Engineers: an Address to the Engineering Society of the University of Nebraska, April 8, 1904, by J. A. L. Waddell, D.Sc., LL.D.

would not take long to make apparent the impress of their individuality and knowledge upon the development of civil engineering in all its branches, with a resulting betterment to all kinds of constructions and the evolution of many new and important types.

"When one considers that the true progress of the entire civilized world is due almost entirely to the work of its engineers, the importance of providing the engineering profession with the highest possible education in both theoretical and practical lines cannot be exaggerated.

"What greater or more worthy use for his accumulated wealth could an American multi-millionaire conceive than the endowment and establishment of a post-graduate school of civil engineering."

Another extremely practical and effective means for affiliating civil engineering and the other sciences is for engineers and professors of both pure science and technics to establish the custom of associating themselves for the purpose of solving problems that occur in the engineers' practice. Funds should be made available by millionaires and the richer institutions of learning for the prosecution of such investigations.

Another possible (but in the past not always a successful) method is the appointment by technical societies of special committees to investigate important questions. The main trouble experienced by such committees has been the lack of funds for carrying out the necessary investigations, and the fact that in nearly every case the members of the committees were unpaid except by the possible honor and glory resulting from a satisfactory conclusion of their work.

Finally, an ideal but still practicable means is the evolution of a high standard of professional ethics, applicable to all branches of engineering, and governing the relations of engineers to each other, to their fellow workers in the allied sciences, and to mankind in general.

As an example of what may be accomplished by an alliance of engineering and the pure sciences, the construction of the proposed Panama Canal might be mentioned. Some years ago the French attempted to build this waterway and failed, largely on account of the deadly fevers which attacked the workmen. It is said that at times the annual death-rate on the work ran as high as six hundred per thousand. Since the efforts of the French on the project practically ceased, the sciences of medicine and biology have discovered how to combat with good chances for success the fatal malarial and yellow fevers, as was instanced by the success of the Americans in dealing with these scourges in the city of Havana after the conclusion of the Spanish-American war.

The success of the American engineers in consummating the great enterprise of excavating a navigable channel between the Atlantic and Pacific oceans (and concerning their ultimate success there is almost no reasonable doubt) will depend largely upon the assistance they receive from medical science and its allied sciences, such as hygiene, bacteriology, and chemistry.

Geological science will also play an important part in the design and building of many portions of this great work, for a comprehensive and correct knowledge of the geology of the Isthmus will prevent the making of many costly mistakes, similar to those that resulted from the last attempt to connect the two oceans.

Again, the handling of this vast enterprise will involve from start to finish and to an eminent degree the science of economics. That this science will be utilized to the utmost throughout the entire work is assured by the character and professional reputation of both the Chief Engineer and the members of the Commission.

Notwithstanding, though, the great precautions and high hopes for a speedy and fortunate conclusion of the enterprise with which all concerned are starting out, many unanticipated difficulties are very certain to be encountered, and many valuable lives are likely to be expended on the Isthmus before the first steamer passes through the completed canal. Engineering work in tropical countries always costs much more and takes much longer to accomplish than is at first anticipated; and disease, in spite of all precautions, is very certain to demand and receive its toll from those who rashly and fearlessly face it on construction works in the *tierra caliente.* But with American engineers in charge, and with the finances of the American Government behind the project, success is practically assured in advance.

What the future of civil engineering is to be, who can say? If it continues to advance as of late by almost geometrical progression, the mind of man can hardly conceive what it will become in fifty years more. Every valuable scientific discovery is certainly going to be grasped quickly by the engineers and put to practical use by them for the benefit of mankind, and it is only by their close association with the pure scientists that the greatest possible development of the world can be attained.

THE PRESENT PROBLEMS OF TECHNOLOGY

BY LEWIS MUHLENBERG HAUPT

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STANDING in the shadow of the century which this greatest of expositions signalizes, it is fitting that one should consider its fruition, as typified in these exhibits, and also indulge in a forecast of the magnificent possibilities which they portend.

Amongst the varied subjects assigned for the consideration of this distinguished international Congress, that of "Present Problems" would seem, from its title, to be restricted to the existing status of civil engineering; yet it is so intimately related to both history and prophecy as to involve a brief reference to its past evolution and its future potentialities.

This is the more evident when it is considered that the present is but an infinitesimal link between the two infinities, past and future; the former, being the storehouse of models, tools, and experiences; the latter, the great laboratory of psychological possibilities, rendered attainable only through the application of present activities.

Whenever the curve of progress[1] in any art or science may be traced from sufficiently exact data, its present status becomes at once known and its prospective possibilities may be predicted within reasonable limits of certainty, under similar conditions.

It is by such graphical records of quantitative events that the composite results of history are most clearly projected forward into the domain of accurate predictions. The grandest problem of the present is to portray definitely that curve of progress which will point the way most surely for succeeding generations.

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[1] See *Scientific Research*, by Dr. R. H. Thurston, *Science*, vol. XVI, 1902.

To this end it is important that all of the elements which determine its *locus* should be duly weighed and coördinated, since the resultant law and prediction must depend upon the accuracy of, and the interpretation placed upon, the available data used in the compilation.

Some of the physical elements are reasonably well understood with reference to the laws governing their action, such as universal and terrestrial gravitation; the relations of thermic and dynamic, chemical and electric energies; the conservation of force, or the mutations of matter and the like; but who can fathom the basic principles underlying all physical activities and trace the origin of all energies as revealed in the life of organic bodies?

In the language of our lamented and distinguished physicist, Dr. R. H. Thurston:

"All life and movement, whether of man, animal, vegetable, seasons, suns and planets, arts, commerce, civilization, intellectual, moral or physical worlds, depend upon transformations of preëxisting energy. . . . We have learned to compute the velocity, refraction and reflection of light, but we still know little of its exact character as motion of molecules.

"We know the related form, heat-energy, in its sensible effects; but we are still unable to differentiate the one from the other. . . We can produce and utilize electricity in many ways, but we do not even know what it is or how its transformations from other energies are effected. We work with these three forms of power, but we do not know what is the nature of the substance through which they act to produce their beautiful, marvelous, world-impelling effects." He adds in substance:

The chemist, by analysis, can determine the composition of compounds, but he has only recently discovered that his theoretical basic atom can be atomized. The physicist finds in the spectroscopic lines a strange language of which he lacks the key. He can isolate the phosphorus of steel, but cannot produce that of the glow-worm or the firefly. The analyst can separate organic matter into its elements, but he cannot by synthesis reconstruct the storage batteries of brain and spine nor the subtle alchemy of the bee, which converts the nectar of the rose into its sublimated honey, nor the vegetable verdure of the field into the life-giving, lacteal pabulum of the mammal for the sustenance of its offspring.

The astronomer has unraveled the laws of the motions of the celestial bodies, but he is unable to determine their duration, origin, or destiny. His little span of life is all too brief to enable him to reveal the secrets of their Maker.

The geologist probes the bowels of the earth, from its loftiest to its lowliest depths, but fails to ascertain its age or longevity or to state whether it shall endure for a million years or perish in a season.

The biologist has yet to learn the mysteries of life in plant and animal and has not even unraveled the secret of sex in generation. He studies the mechanism of the fish, but cannot explain the process of separating the oxygen from the medium in which it moves; so likewise he may understand the structure and mechanism of the bird, but fails to learn the mysterious power whereby it soars aloft, and, perceiving its prey from afar, captures it.

The anatomist may know to an ounce the power developed in an animal per pound of muscle, but he cannot say how that power is originated, transferred, or exerted by the transmitting thread of the working muscles. Our authority concludes:

"The engineer has learned how to convert the potential energy of perhaps a myriad ages into steam and to apply it to the dynamics of the factory or locomotive, but in doing so he wastes from four fifths to nine tenths of it. He transforms the elastic force into an electric current, but frequently loses as much as he applies at the tool's edge. He diverts the energy of the waterfall into an electric-light current with its concomitant heat-rays, while the glow-worm shames the man, producing light without heat and heat without light.

"He crowds his fellow man into mills and factories, but he has not yet solved the social problem of giving to each an individual life, work, and wage, with comfort, health, and happiness in just proportion."

Thus the man of science finds that the acquisition of learning, gain in knowledge, and increasing appreciation of the wonders of creation, only serve to impress upon him the greatest responsibilities, possibilities and opportunities as well as the mightier mysteries of its Maker, stimulating him to nobler aspirations, more earnest labor and higher aims and giving him a larger faith and a stronger sense of the infinitude of duty and opportunity.

In short, no more sublime arraignment of the impotency of man to solve the ever present problems of his existence and necessities, in the most economic manner, can be found than that recorded in the closing chapters of the Book of Job, wherein the Lord charges him with "darkening counsel by words without knowledge" and proceeds to catechize him as to the origin of the world and its phenomena, in a manner so profoundly majestic that most of the queries remain unanswered even unto this day.

These same interrogatories therefore constitute a catalogue of present problems in all departments of science, and their solution can best be approached only by a closer communion with the omniscient Source of all Wisdom.

Most of the great inventions and discoveries which have ennobled and advanced civilization have come from inspiration and deep research, prompted by the exigencies of time and place, yet but few efforts have been wholly successful, for, as the poets have said:

> "God hath appointed wisdom the reward of study!
> 'T is a well of living waters,
> Whose inexhaustible bounties all might drink,
> But few dig deep enough."

Yet let no one fear that the field of research in any of the mental or physical sciences will ever become exhausted, for the Source is infinite.

If all the wisdom of all the sages of mankind, in all ages from the foundation of the world, were summed into a series and integrated between the limits of zero and infinity, they could not compass the unfathomable resources of the Almighty. "Can man by searching find out God?"

To solve the problems confronting the present generation, it is fundamental that the laws and properties governing mind and matter be more fully understood and better applied.

Much energy is wasted and many failures follow from the crude and inexperienced methods adopted, which too often violate the laws of nature and leave but a wreck to tell the story; for "few dig deep enough."

Some of these laws are so occult that man has not yet wholly unraveled their mysteries. Has not the wisest of kings admitted: "There be three things which are too wonderful for me, yea, four which I know not: The way of an eagle in the air; the way of a serpent upon a rock; the way of a ship in the midst of the sea; and the way of a man with a maid."

And do not these four things involve all the elements of the technological problem embodied in the transportation question of to-day? aëronautics, dynamics, navigation, and psychology, — transportation in the three media of air, water, and land, as well as such mental conceptions of their conditions and requirements as shall render them all equally available; which state man has not yet attained unto. There is therefore a large sphere still open in this field for future research.

It will be the main purpose of the writer, therefore, to outline the elements which must be focused upon this particular phase of economic transportation, having in view the attainment of the best results.

This attainment is conditioned upon something more than the fundamental conception of the ideal or its mere graphical expression in the formal technology of the shop or the patent office. Its practical fulfillment necessitates a large accumulation of means, men, and materials, and their intelligent coördination in certain prearranged sequences, at definite times and under favorable environments. Moreover, it is essential that all of these factors should work together harmoniously under a single controlling head, impelled by an earnest, zealous, generous, and humane desire to secure the best effects. But it, unfortunately, too frequently happens that vested interests, jealousy, ignorance, cupidity, conservatism, strikes, and physical obstacles conspire to delay or defeat the best-laid plans.

It becomes the part of wisdom, therefore, to consider both sides of the equation before embarking on any extensive innovation, in the nature of works affecting large interests, however beneficially.

The successive stages which mark the progress of great enterprises may be conveniently formulated into a *General Law of their Development*, of which the first step is *educational.*

It is opposed by

(1) *Ignorance*, on the part of the public as to its possibilities;

(2) *Indifference*, as to its economics, after they have been stated;

(3) *Incredulity* as to its feasibility, or utility before demonstration.

The second step enters the forensic arena where efforts to secure authority from legislative bodies are met by

(4) *Argument* which, failing to convince, leads to

(5) *Bribery*, instigated by vested rights or cupidity, and

(6) *Patronage*, withdrawn as a punishment to the offenders, or granted as a reward for opposition. But should the project outlive these allied enemies and enter the third phase of active construction, the opponents then have recourse to

(7) *Violence*, by use of physical obstacles or force to obstruct the works;

(8) *Persecution*, leading to an impugnment of the motives, character, and credit of the parties at interest;

(9) *Murder*, either by premature death from excessive futile, unrequited efforts or by actual assassination or war, to remove the guiding spirits of great movements and thus debar their consummation.

These psychological phases being outlived and the physical forces being overcome, the way to success is at length assured. The former elements are not so often taken into the account as the latter, yet they are frequently the most subtle, uncompromising, and intangible. Underneath many of the great achievements of the world, in the arts of peace, there lies buried a romance of heroic endurance, self-abnegation, and masterful resource, intensely realistic, which would put the pages of fiction to shame, were they made public. Truly, "Peace hath her victories no less renowned than war."

Whilst the above reflections may appear to be merely "glittering generalities" they are in fact fundamental requirements in the successful execution of great projects, since, however thoroughly an inventor may have convinced himself of the great practical economy of his theory, he cannot point to his demonstration as a basis for public confidence and the underwriting of his conceptions, until he has established his precedent; and, on the other hand, it is impracticable to establish his claims by actual works, until he has secured his capital and authority. Especially is this true of great improvements involving governmental jurisdiction, where the personnel and responsibility for appropriations are constantly shifting, and trained experts are not permanently available in the conduct of the works. Although this is a problem of government, it is intimately related to the questions at issue, viz., the work of the civil engineer in providing the way for the safe, rapid, and economical distribution of the products of the earth for the benefit of mankind. Works of this class, requiring the opening of lines of least resistance between distant centres, are impracticable without the exercise of the rights of eminent domain, accompanied by the accumulation of large amounts of capital and the control of labor whereby the physical resistances to traffic may be reduced to a minimum.

Of the three elements, earth, water, and air, the first offers the greatest resistance because of its density and the irregularity of its surface. It has therefore been the crucial problem of all ages so to modify it that "every valley shall be exalted and every mountain and hill shall be made low, and the crooked shall be made straight and the rough places plain," that a highway might be there, over which the peaceful revolutions of the wheels of commerce might cement the nations of the earth and distribute its products. But whilst history testifies to the excellence in alignment, grades, and durability of some of the ancient roads, it fails to record any evidences of such magnificent avenues of trade as have been developed within the space of a single life in the railways constructed during the past century.

These were unknown and impossible prior to 1825, since the state of the mechanic arts did not furnish materials in sufficient quantity and quality to permit of such constructions. The demand, however, created the supply, the storehouses of the earth yielded an abundance of the raw materials, the railways and waterways assembled them at convenient centres of industry, the metallurgist and chemist refined and reduced them to improve their quality and durability; the mechanical and electrical engineers developed new machinery for increasing the output at reduced cost, and thus supplied the markets with structural materials for roads, bridges, and buildings far beyond any possible conception of even fifty years ago. Then, steel rails were unknown and the durability of the wrought-iron rails, which had supplanted those of cast-iron, was limited in some instances to a few months only, but at this critical period the invention of the Bessemer pneumatic process, followed by Gilchrist, Siemens-Marten, and others, supplied an urgent necessity as to quality; the various inventions of George and John Fritz, Alexander Holley, William R. Jones, Nasmyth, Nobel, Krupp, and many others met the demands for quantity, while the development of commercial channels and establishment of improved plants at strategic points has reduced the cost and increased the output to such an extent that there is no retardation as yet visible in the curve of progress so far as the quantity is concerned. The last fiscal year (1902) shows an increment of 9626 miles of railroad in the country which exceeds that of any year since 1890, so that the demand for construction material continues to be one of the problems of the present.

Especially is this the case with wooden cross-ties having a life of only from seven to ten years. They require frequent renewals at the expense of our hard-wood forests, with incidental injury to the entire country from denudation, causing rapid erosion of uplands, floods, and barren wastes. Therefore the recently established policy of irrigation and reforestation has come none too soon to check the evils of the wholesale slaughter of our forests.

The increasing paucity of timber and the greater strength, durability, and economy of the metals have led to their rapid substitution for the vegetable fibers, in most of the engineering structures, but the tendency is now returning strongly to the use of stone, brick, or concrete wherever they are practicable and available, as the best material for bridges and buildings. Where they cannot be secured, artificial concretes and cements are frequently used either singly or in combination with the metals in the form of meshings for imparting tenacity. Although much progress has been made in this class of material, it yet remains to discover the secret of the ancient compounds as instanced in the remarkably durable water-tanks of the Arabs, built at Aden about 600 years B. C., and still in a perfect state of preservation.

Notwithstanding the extended researches made upon the properties of material for structural purposes, much still remains to be discovered. One of the latest investigations made as to the use of pure sand, encased in light sheet-metal tubing, merely to prevent it from flowing, reveals some astonishing results in transmitting pressure in the form of beams subjected to cross-strains, or in the form of columns carrying heavy loads. These investigations, conducted by Prof. A. V. Sims, may result in important economic changes in engineering structures in the near future, when reduced to a practical basis. They cannot be elaborated in this paper.

But the selection and preparation of suitable materials for structures are details which rather belong to the domain of the chemist and physicist than to the engineer whose province it is to design, assemble, and direct work, whereby he may more generally apply the resources of nature to the wants of man.

Fuel

For this purpose, power is a fundamental factor, and for many years it was readily derived from the forests, so generously dispersed over the earth; but the rapid increase in the demand for all classes of motors as well as for domestic and structural purposes has threatened an early exhaustion of this supply. For locomotives, it soon became impracticable, while for the modern steamship it would be absolutely impossible. With the discovery of coal and its stored energy, the world was revolutionized. The first quarry for anthracite was opened at Summit Hill, Pennsylvania, in 1792, but the cost of hauling to the market was such as to prohibit its use. Thus was stimulated the construction of the Lehigh, Schuylkill, and Union canals and the Switchback Railroad early in the last century, the progenitors of our extensive system of public works, which has been developed by private capital and enterprise with occasional aid from local and general governments until the railroads of the country now exceed 215,000 miles, representing a capital of over 14,000,000,000 dollars and carrying over 1,200,000,000 tons of freight per annum, at an average cost of 7.6 mills per ton-mile.

The rapid increase in the demand for anthracite coal from the Schuylkill and Lehigh regions resulted in a maximum yield, for some years, of 65,000,000 tons per annum; but the discovery and working of large deposits of soft coal in West Virginia and many other localities, as well as the greater cost of mining, has reduced the output of hard coal to about 59,000,000 tons, with resulting increase of price, while the bituminous mines are now furnishing 260,000,000 tons. This, with the opening of the free-working iron ores of Lake Superior and the exceptionally cheap transportation on the Great Lakes, has concentrated the mammoth iron and steel plants near their borders and given to the world a new stimulus in structural materials. Coke, natural gas, and petroleum have also aided in the general movement for cheaper power, and the generation of artificial gas, as the most effective form of energy, has proceeded, *pari passu*, with the demand for greater economies. Attention is now being concentrated upon the utilization of the dynamic agencies of the earth, found in her water-courses, atmosphere, and electricity, to great advantage for the generation and transmission of power through long distances and under high tension, with corresponding gain in efficiency. Yet these fields are still in an embryotic state. The possibilities of the radio-active group is at present beyond the power of man to predict. The accomplishment of alleged impossibilities is becoming a commonplace event.

The great economy and convenience of fuel in a gaseous form would seem to be manifest from the mere statement of the relative calorific powers of wood, 6480° F.; coke, 13,550° F.; bituminous coal, 13,692°; anthracite, 14,200°; ordinary illuminating gas, 23,000°, and natural gas 35,000°, which makes it nearly six times greater than that of wood and threefold that of coal, yet a modern publication recently announced the superior "economy of coal as compared with oil and natural gas for fuel."

In 1881 the late Sir Frederick Bramwell predicted that by the year 1931 the steam engine would be of interest only as a relic and would be supplanted by gas motors. Subsequent facts sustain in some measure the prediction, for to-day they have reached units of 1750 h. p. and are extensively used in many industries.

The fear that the introduction of electric plants would exterminate gas for lighting and power has not been realized, since it is found more economical in many cases to make the gas-plant supplementary to the electric and thus increase the scope and efficiency of both. But the application of electricity as a motor, whether developed from water or steam, is merely a phase in the evolution of power, which will ultimately yield in large part to the superior advantages of pneumatic transmission from the natural sources now available in the great waterfalls of the world, when they are more fully appreciated and properly harnessed.

Although much attention has been devoted to the application of the tidal energy to manufacturing purposes, but little practical use has thus far been made of it. This enormous storehouse is yet awaiting the touch of a master hand to utilize it advantageously.

Aside from the source and character of the power which may ultimately be employed, there is also great room for further economies in the handling of the enormous tonnage already required to meet present demands. Here the problem has been and still is to increase the ratio of live to dead load and to reduce the resistances by betterments in alignment, grade, distance, and terminal facilities even at large increase of capital. Still the delays in handling and drilling trains, composed of relatively small units and containing miscellaneous freights, in complicated yards, and the use of cars for many days for storage, necessitates great expense for which no adequate solution has been provided, although some relief may be obtained by the earliest possible transfer to waterways at the nearest practicable point, thus substituting the short for the long haul, in some cases. In others, where bulky freight, like ore, coal, or grain is handled, great improvements have been introduced so that the entire contents of each car may be dumped through chutes into the hold of the vessel in one operation. The capacity of the car has also been increased so that instead of the paying load being less than the weight of its carrier, it is now about three times greater. Probably the greatest advance in economic transportation ever effected was that which has revolutionized the movement of petroleum from the oil-wells of Pennsylvania to tidewater. This product was formerly handled by the trunk-line railroads in specially constructed tank-cars, required to return empty, thus reducing the live load to about 25 per cent of the total for the round trip and costing forty cents per barrel for the freight. To control the market and limit the output a combination was effected amongst the common carriers, which made it impossible for independent producers to market their oil.

In this extremity, *carte blanche* was given to an experienced engineer,[1] in 1878, to secure a continuous right-of-way, in fee, across the states of Pennsylvania and Maryland and to construct a pipe-line to the seaboard, without the exercise of the right of eminent domain and in the face of a most determined and well-organized opposition. By tact, energy, and strategy, this was successfully accomplished in a remarkably short time, and by the use of the principle of the hydraulic gradient and the mutually automatic regulation of the pumping-plants, of which only four were required, the cost of this movement was reduced ninety per cent and the cordon was broken, to the great relief of both producer and consumer. After which demonstration, general pipe-line laws were adopted and other lines constructed so that the tank-car is now almost a relic of the past. Thus the oppression of a trust has operated to effect an economy which has reacted upon it for its own greater emoluments as well as for the public benefit.

The engorgement which has resulted in railroad centres from the concentration of freight at certain seasons may be partially relieved by so improving the feeders and outlets of all the avenues of transportation as to distribute the movement more uniformly over a longer period by the improvement of the *common roads* to make them available at all seasons, with the expenditure of less power and also of the internal *waterways* of the country, that they may be utilized to relieve the traffic by distributing raw materials which will not bear a long rail-haul. Moreover, the bars which obstruct all harbor inlets along alluvial coasts constitute a serious obstacle to the general distribution of commerce by requiring ves-

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[1] General Herman Haupt.

sels to clear light, wait for favorable conditions of wind and tide, or store their freight for lack of sufficient draught. It is even now true that the most economical vessel cannot be built because of the existing limitations of channels and ports, not yet removed, and which, notwithstanding the great improvements in hydraulic dredging-plants, cannot be permanently relieved by these mechanical devices.

The great fertile plains and deltas at the mouths of sedimentary rivers are but the natural depositories for the detritus fed to them by their hydraulic conveyors whose source is in the highlands, which streams carry hundreds of millions of yards of earthy matter to the sea, where it must ultimately rest.

The problem here is, then, so to dispose of this deposit by natural agencies as to prevent its obstructing the channels of commerce. This can be accomplished by utilizing the potential energy of the stream itself by means of a concave resisting medium, placed across the bar in such position as to develop a reaction and scour, which changes the form of the channel and transports the sediment laterally to the counterscarp thus created, and from which the waves and littoral currents remove it.

This method has been demonstrated by actual experience and is found to effect great economies in cost of construction and maintenance, since the trace of the work is less than half as long as that required by the preëxisting methods, and there is no corresponding bar advance, but an automatic adjustment of the channel and dump to the requirements of that particular stream and locality.

This is a physical problem which has impressed itself with more and more emphasis, because of the rapid strides made in commerce and manufactures and the greatly increased demands for larger tonnage and correspondingly deeper channels. The mere cutting of a ditch across an ocean bar in the face of the ever active forces which created it is not a satisfactory nor an economic solution of this question. It is estimated that the automatic reaction breakwater would have saved over fifty millions of dollars in the past decade in this country alone, had it not been for the conservatism which was unable to concede its advantages prior to an actual demonstration, and which has debarred its general introduction.

This incident is cited, without detail of the resistances it has overcome, merely to illustrate the truths of the general principles enumerated, as to the elements opposed to progress, in the introduction to this paper.

Returning now to the general theme as to the future of economic transportation, it will be found necessary to devote large appropriations from the treasuries of states and nations to the betterment of the public highways, for the general welfare and as feeders to the extensive systems of railroads, that they may utilize their rolling-stock and power to best advantage. In this work the railway companies can well afford to expend large sums for road-metaling in coöperation with local interests, as some are now doing, instead of building railroads for their exclusive use and control, to be maintained at great cost. The highway, thus improved, will become available for all classes of vehicles (and at all seasons), from the freight-wagon to the automobile, and will play a most important part in the commercial, social, and industrial well-being of the country. The introduction of the trolley has also served to elevate the general condition of mankind by the facilities it has afforded for the circulation of mind and matter at a very reasonable cost; while the various devices for transmitting knowledge by electric agencies, with or without metallic conduits, has given a great impetus to the interchange of knowledge and the promotion of all classes of improvements. Yet each innovation has had to establish its *raison d'être* by a long contest and only the fittest have survived. The war of extermination waged by certain transportation monopolies against competition has in general established the principle that the greater the distribution and mobilization of the population, the greater the resulting benefits to the common carrier.

Thus the improvement of waterways has invariably increased the profits of the railways from the resulting greater tonnage even though carried at reduced rates; the building of trolleys, so long bitterly opposed, is now recognized as a public benefaction; the improvement of the highways, so strenuously resisted by the rural districts, is now hailed with delight as adding immensely to the value of the farm and at the same time reducing the cost of its products to the consumer.

This apparent paradox results from the saving in the waste formerly incurred in overcoming needless resistances, which has gone to increase the margin available for transportation for the benefit of producer, consumer, and carrier alike.

The Isthmian Canal question, the solution of which has been the desire of nations for four centuries, is still an ever-present problem. Though a route has been selected and the right-of-way secured, the canal is not *un fait accompli*. Were it so, the cost of transportation, by water, between the North Atlantic and North Pacific ports would be reduced to about one third of the existing rates, with far greater safety and with a corresponding increase in the potentiality of the fleets. Even under existing conditions, with the necessity of circumnavigating South America, the railroads cannot compete with the Cape Horn route for the reason that the average charge for the overland movement, at 7.6 mills per ton-mile, would make the cost of transportation about $21, which is more than the market value of the great bulk of the tonnage.

It is therefore a physical impossibility, at present rates, to carry this traffic by rail at a reasonable profit, whereas it could readily be moved by the water-route at a charge of less than $5 per ton, thus stimulating manufactures and building up a higher class of freight for local distribution with a shorter haul, for the general benefit not only of the railways but of all parties at interest. Under existing conditions the total overland tonnage of all the transcontinental lines probably does not exceed 2,000,000 tons per annum.

It is estimated that an Isthmian route would save to the commerce of the world not less than $200,000,000 annually, or an amount equal to our foreign freight bill, so that there can be no question as to its justification and imperative necessity at any cost.

Another pressing desideratum in the development of international commerce is the enlargement of the internal waterways of our own country, which have not kept pace with the traffic requirements.

The state of New York has at length awakened to the necessity of meeting the competition of her energetic neighbors and is about to respond generously to the demand for a larger waterway from the Great Lakes to tidewater, hoping by a limited twelve-foot draft to compete successfully with one of much greater capacity traversing a shorter route. The fallacy of this proposition would seem to be self-evident, but the general government makes no appropriation for this great enterprise.

The Chicago Sanitary District has by its own contributions accomplished the triple benefits of improving its water-supply, disposing of its sewage in a harmless manner, and creating an ample navigable channel across the "Sag" between Lake Michigan and the Illinois River (a model of which may be seen in the Liberal Arts Building).

It now remains to enlarge and improve the remainder of that route all the way to the Gulf of Mexico and to open the mouth of the great Mississippi River, to permit the rapid escape of the flood waters, and to improve its navigation; but the means to this end cannot be treated in the limits of this paper. Suffice it to say that it is still a present problem, as is admitted by the last report of the Mississippi River Commission in these words: "Experiments are continually being made looking to the best use of the available material and the development of appliances and methods which may be economically and effectively employed when Congress shall provide for such systematic improvement."

This quotation serves to emphasize one of the most serious obstacles to the development of the commercial interests of the country, namely, the meagre appropriations made only biennially by Congress for works of this class. Attention is also directed to the absence of all competition in the preparation of the designs and plans and to the rigid requirements of the specifications, which have the effect of deterring many responsible companies from underwriting government contracts, thus increasing the cost of these important improvements with no guaranty as to the results to be secured.

The effect of the absence of cheap water transportation from the interior to the seaboard is impressively exhibited by the fall in the average farm-price of the staple cereals as the distance from the seaboard increases. The export price being the standard, the cost of the overland haul must be deducted to determine the farm-value. It is found from the statistics of the Department of Agriculture, during the past decade, that if the average price of wheat on the Atlantic seaboard is 79 cents per bushel, it will be 78 cents for New York State; 72 for Pennsylvania; 69 for Ohio; 65½ for Indiana; 64 for Illinois; 60.8 for Missouri; 58 for Iowa; 53 for Kansas; 50.9 for Nebraska, which is the lowest area reached.

The ability to ship via Kansas City and St. Louis down the Mississippi River contributes to raise the value of farm-products in Kansas as compared with Nebraska to such an extent that Nebraska would have saved nearly $15,000,000 in one year could her crops have been sold at Kansas prices (in 1901).[1]

The same general principles prevail in other states, to raise the value of agricultural products and consequently of real estate, as the waterways are more accessible and capacious; yet the demands for their enlargement, improvement, and emancipation from tolls are far in excess of the ability of the Government to provide for them either financially or administratively. The total estimate for works required at the present time exceeds the entire cost for construction and maintenance of rivers and harbors, since the foundation of the Republic.

Yet private parties and localities are prohibited by law from relieving their own exigencies, by their own methods, at their own expense and risk, without charge upon commerce, thus compelling them to submit to the non-competitive tariffs, which restrain trade and drive it to other more favored locations, or to go into liquidation.

There would seem to be great necessity for further remedial legislation in line with the recent resolutions of the National Board of Trade, authorizing the letting of contracts for this class of work

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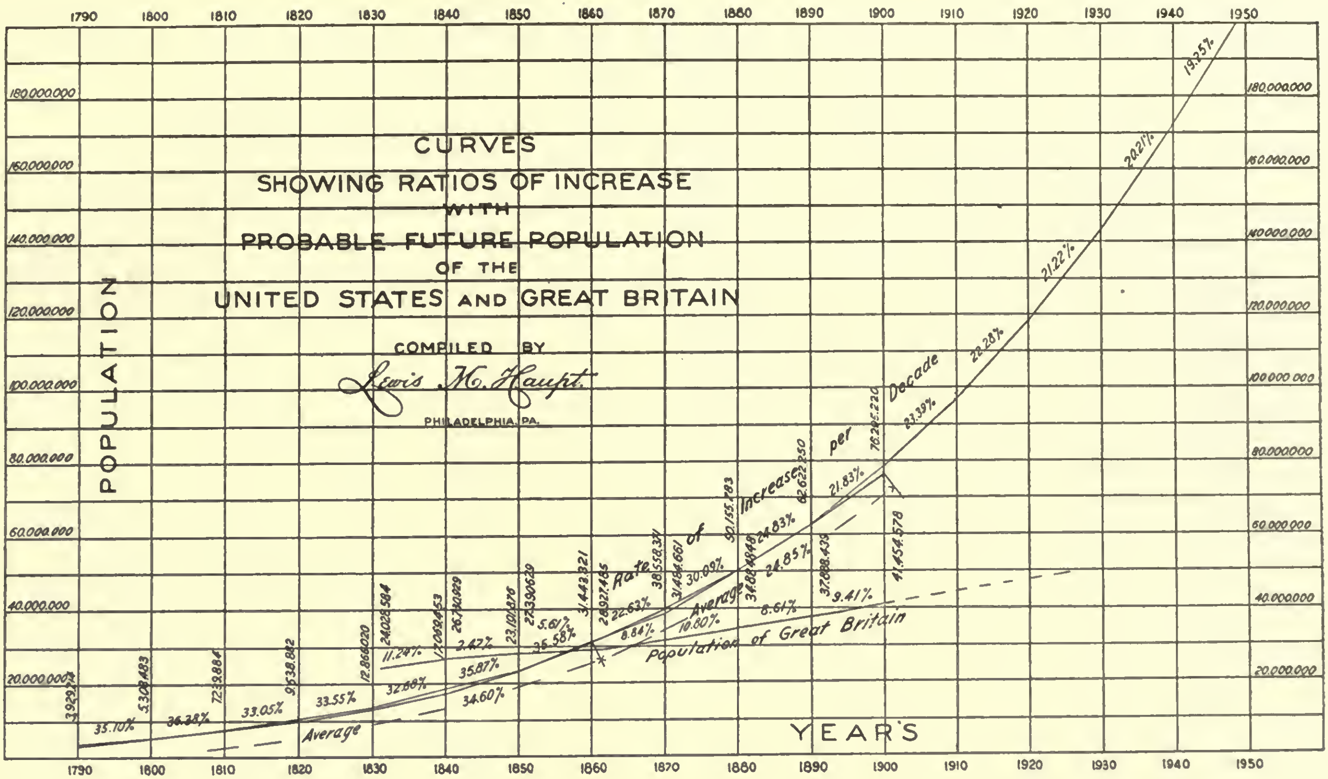
[1] See *The Forum*, January, 1903: *Waterways, An Economic Necessity.*



CURVES
SHOWING RATIOS OF INCREASE
WITH
PROBABLE FUTURE POPULATION
OF THE
UNITED STATES AND GREAT BRITAIN

COMPILED BY
Lewis M. Haupt.
PHILADELPHIA, PA.

upon the basis of payments for results secured, by whatever method.

These details of transportation, and their related factors of legislation, finance, and policy, have been elaborated to some extent, since they affect the well-being of the people of all nations. It is as true to-day as in the time of MacCauley, that the civilization of a country is determined by the conditions of its highways, and yet, as has been shown, the provision made for this purpose in this country, at least for common roads and waterways, is wholly inadequate to meet even present demands. We have no executive department of highways, and that for waterways is but an adjunct to the military arm of the government, presumably inaugurated for the movement of naval vessels in the event of war and not to promote the arts of peace and commerce, such as exist in other great nations of the world. The general demand for national aid for our public roads should meet with a prompt and generous response from the general government as well as from all sections of the country in a local coöperation, to place the highways of the nation, state, county, or township in the best possible condition, and for this purpose all legitimate local influences should be concentrated upon the citizens who are selected to represent their constituents in the honorable service of legislation, to secure their active efforts in its behalf.

The momentous importance of immediately providing for the more general and cheaper distribution of the products of the earth is apparently not fully realized, and certain it is that the increased supply of transportation has not kept pace with the demand. The operating expenses of some of the best managed trunk-line railroads, last year, were increased 25 per cent because of their overtaxed facilities.

It does not appear to be generally known that the population of the United States is increasing at a more rapid ratio than that of any other portion of the globe and that by the year 1935 the enumeration of the last census will have become doubled, while the tonnage movement is expanding at a much more rapid rate, in consequence of the greater output of mines, mills, and manufactories, as well as from the increased acreage under cultivation.

As this is a fundamental element affecting all industries, it is respectfully submitted to this distinguished Congress in a carefully compiled graphical diagram, showing the increments of growth during the past century, as actually recorded, subject to all the vicissitudes of wars, famines, plagues, immigration, births, deaths, and conditions of servitude which affect vital statistics, and to these data the curve of population has been closely applied and its law of evolution determined. It is thus found that the increment per decade has decreased by a constant which reduces any ratio one twenty-first less than that of its predecessor.

By projecting this curve forward, subject to this law of decreasing percentages, a very close approximation may be obtained for the future, which will serve as a reliable basis for the solution of the many social, industrial, commercial, and financial problems, based on population.

Thus there results for the present half-century, the following tabular statement:

PROBABLE INCREASE IN POPULATION OF THE UNITED STATES DURING THE PRESENT SEMI-CENTENNIAL

Date.	*Rate of Increase.*	*Population.*	*Numerical Increment*
1900		76,295,220	
1910	23.39	94,249,201	17,952,298
1920	22.28	115,266,772	21,017,571
1930	21.22	139,703,327	24,436,555
1940	20.21	167,923,399	28,220,072
1950	19.25	200,248,653	32,325,254

Hence it appears that within the lifetime of many of our contemporaries the population of this great republic may reasonably be expected to increase 2.6 times, or 260 %, which is at the average rate of 52 % each decade, thus showing the effect of compounding of the curve due to the decennial increment.

Urban Population

But it is not merely the rapid growth in numbers for which adequate provision should be made. The distribution of the population is quite as important a problem. With the centralization in great communities the engorgement has become not only inconvenient, but at times oppressive and even dangerous. Ferries, trolleys, elevateds and subways, bridges, and tunnels are all taxed to their utmost limits, and the headway of trains is reduced to the danger-point, yet the facilities are wholly inadequate for the morning and evening service between dormitory and shop.

Moreover the daily tonnage of food required to be furnished to man and beast, and the waste required to be removed from the great manufacturing centres, is enormous, thus greatly increasing the risks to life and health. This excessive concentration also leads up to the overcrowded tenements, sweat-shops, and brothels, with their unwholesome environments and immoral diversions; for all of which the most tangible remedy is dispersion.

The density of the population should be held within safe limits by strict sanitary legislation, centres of industries should be established in rural districts, thus requiring shorter hauls for dairy and agricultural supplies and creating local markets for many products. The utilization of waterfalls for the generation and transmission of power to long distances will aid in this effort to distribute the laboring classes to their manifest advantage.

So great is the traffic on the municipal lines that the patronage in many cities exceeds 300 times the total population, per annum, which at times greatly surpasses the capacity of all the cars in the service. There is apparently no relief in sight, excepting the addition of a double deck to the elevated railroads or the introduction of a series of continuously moving sidewalks having different relative velocities, which latter method has been frequently proposed but appears to have many disadvantages, especially in the requirements for space, cost, and freedom from danger and noise.

So long, therefore, as movement is confined to the surface, elevated. or underground roads, the difficulties of handling the traffic must increase in a very rapid ratio unless the population can be confined to smaller local centres or be removed from the surface altogether. This desideratum has given rise to many efforts to construct some practical device for *aërial navigation*, and thus it happens that there is still a medium into which man's ambition would lead him, like Icarus, to soar, were it possible to find some antidote for gravity.

Much progress has, however, been made in the construction of dirigible balloons and special forms of captive kites, which give promise of becoming of commercial value as means of communication and for collecting data, in this rarer medium. It is therefore a part of the laudable purpose of the management of this Exposition to encourage this effort by the awarding of large premiums for the most successful practical efforts. The problem is most alluring because of the manifest advantages to result from its fruition. Instead of having to improve waterways, or to build railways and highways at enormous cost for construction and maintenance, the way would be free to all. There would be no bridges, tunnels, tollgates, sand-bars, reefs, or other obstacles to the ready interchange of commerce. No custom-houses, forts, or frontiers. Commercial and military barriers would be obliterated and wars would soon become a memory. Were the inhabitants of the earth able to "move like an army of locusts with banners," seeking the garden-spots of the globe, what would become of the Chinese Exclusion Act or the laws restricting pauper immigration? Then would it appear that "the earth is the Lord's and the fulness thereof, the world and they that dwell therein;" for man could seek his own environments much better, and more readily secure the opportunity to earn his bread by the sweat of his face, denied to so many under existing social conditions.

With the inspiring precedent set by Mother Earth herself, floating through an imponderable ether, and held in her courses by the mutual attraction of celestial bodies, and with the wonderful mechanisms of the myriads of beasts and birds constantly mocking the climax of God's creatures, it is not surprising that man should set himself sedulously to the task of surmounting the circumambient clouds and seek to convey himself through a ponderable atmosphere, by flight.

In the mean time the world awaits his efforts with hope and expectation that unknown resources and energies may soon add wings to time and solve the long-desired paradox of aërial navigation.

In conclusion, from this general review of the technological field in civil engineering it will be seen that while much has been revealed and applied in the utilization of the forces and resources of this wonderful planet, there is still much to be discovered. The pregnant past has showered upon this generation coal, oil, and gas; steam, compressed air, and water-power; dynamite and melonite; the turnpike and railway; the palace-car and ocean greyhound; the bicycle and automobile; the telegraph and telephone; and the wizard electricians are now prophesying, like Puck, that they will put a girdle round the earth in forty minutes and will furnish millions of electrical horse-power from a central plant, to any part of the world without metallic conduits.

Quid nunc? Is this only a dream? Who knows? Yet the wheels of progress are ever revolving in an ascending gradient, surmounting obstacles, spanning chasms, uniting continents, eliminating distance, abridging time, and lifting humanity upon the higher planes of consecrated labor to the lofty summits of a Christian civilization.

But to be more specific as to the work before us, it may be said that there is still great need of further improvement in the utilization and transmission of power of all kinds, both by movable and stationary engines; in the application of natural forces to remove and prevent the formation of alluvial bars in commercial channels; in the improvement and extension of better highways for the transportation of materials; in the betterment and standardization of the rolling-stock used in the conveyance of freight and passengers; in the more general introduction of pneumatic plants for the distribution of the mails and for local deliveries in great cities, to reduce the congestion from the delivery-wagons; in the construction of subways for the installation of public-service conduits, sewers, water-supply, lighting, power, drainage, and interurban traffic; in the original provision, in the planning of cities, for all classes of municipal service, prior to the establishment of new strategic, commercial, and populous centres; in the timely equipment of existing towns, in anticipation of the rapid expansion of the population, due to the compounding increment of growth; in additional terminal facilities at points of trans-shipment, to avoid delays and demurrage in port; in the utilization of tidal energy; in continued efforts to attain practical results in aëronautics; and in many other special branches of technology too numerous to mention.

That these desiderata may be attained, it is fundamental that the religious, social, financial, and legislative conditions be made to harmonize by broad and wise laws and statecraft, giving ample opportunities for the utilization of the best-known methods and resources which the country affords, for it is found that law is sometimes a serious obstacle to progress in not keeping pace with nor anticipating the demands of science.

It is not wise to limit our scope to present problems nor confine attention to the fleeting moments. There is a duty which this generation owes to posterity, and it must be met, that history may accord to us the credit of having "builded better than we knew," by laying broad foundations that its pathway be not incumbered by our errors of judgment nor by a narrow cupidity which makes provision only for the passing hour.

Then will the people of our day and generation be true to their heritage, realize their responsibilities, and transmit to the future a basis for still greater aspirations and attainments in the arts of peace and the science of government, that wars may cease and good will prevail amongst the sons of men, for "righteousness exalteth a nation" and "wisdom is justified of her children."

SHORT PAPER

Lieutenant-Colonel Thomas W. Symonds, Corps of Engineers, United States Army, presented a short paper to this Section on "The New Barge Canals of New York."

SECTION B — MECHANICAL ENGINEERING

SECTION B — MECHANICAL ENGINEERING

(*Hall* 10, *September* 23, 3 *p. m.*)

CHAIRMAN: PROFESSOR JAMES E. DENTON, Stevens Institute of Technology.
SPEAKER: PROFESSOR ALBERT W. SMITH, Cornell University.
SECRETARY: MR. GEORGE DINKEL, JR., Jersey City, N. J.

THE RELATIONS OF MECHANICAL ENGINEERING TO OTHER BRANCHES OF ENGINEERING

BY ALBERT WILLIAM SMITH

[**Albert William Smith,** Director of Sibley College, Cornell University. **b.** August 30, 1856. B.M.E. Cornell, 1878; M.M.E. Cornell, 1886; Post-graduate, Cornell University, 1886–87. Assistant Professor of Mechanical Engineering, Sibley College, Cornell University, 1887–91; Professor of Machine Design, University of Wisconsin, 1891–92; Professor of Mechanical Engineering, Leland Stanford Junior University, California, 1892–1904. Member of American Society of Mechanical Engineers. **Author** of *Materials of Machines; Elementary Machine Design.*]

THE problem of educating young men to take up the world's work in engineering is a continually changing one. Engineering continually increases in scope and complexity and keeps demanding better trained and wiser men for the solution of its problems. What are the technical schools to do to meet this demand?

Engineering is not an exact science; the sum of knowledge on which it rests is too meagre for exactness. Many of the factors of an engineering problem are susceptible of exact determination from known facts and mathematical deductions; others can be approximately estimated; while others still are elusive and prone to hide themselves, often successfully. Many a man has based an engineering work involving the expenditure of large sums of money upon an analysis in which one factor has eluded the "round-up." Then when money was spent, when the idea was in cold metal, this little cold-blooded factor came out, pointed a condemning finger at the man and said: "This won't do, you forgot me!"

I wish to make a slightly adapted quotation: "The mathematician in solving a problem takes into account all the factors that appear; the engineer must consider all the factors there are." The work of the engineer must not fail, or destruction of human life and property results, and he is criminally responsible. He must consider all the factors there are!

As the sum of knowledge grows it becomes quite complete in certain divisions of engineering work. Then factors of safety are reduced, standards are designed, and the work may be done by any one who can learn a routine and can follow it repeatedly with accuracy. But the real engineer has nothing further to do with it, unless new applications are demanded.

But most engineering work reaches into unexplored or partially explored fields, and in such cases the last appeal is to the judgment of some man. In other words the real engineer is a man of trained judgment. It is impossible to teach any general method for the solution of engineering problems. No two are alike; the modifying factors are so many that the possible number of combinations is indefinitely great and the same combination seldoms recurs. A man's judgment must be trained so that he can take any combination and reach a good solution; not necessarily the best solution, for there may be many good solutions differing only slightly in results.

Judgment for its training must draw from many sources. There must be the understanding of the mathematical basis of all engineering; a knowledge of inorganic nature's laws and of the qualities of engineering materials and of constructive principles; and all this the schools ought to supply. But there must also be the experience which comes from being "up against the real thing" with no authority at hand to appeal to — when there is just the man and the problem and the necessity for a result. This is the kind of experience which tries men's souls and makes engineers — or failures. It cannot be supplied by the schools.

There has always been a gap between the technical schools and the practice of engineering. Thirty years ago when practice was simpler and the schools cruder, this gap was wide. In those days engineering firms and manufacturers did not seek to employ technical graduates; they said: "We have tried them and they always try to shift a belt on the wrong side of a pulley; we prefer to train up our own men." That this gap has narrowed somewhat is shown by the fact that men in authority in three prominent engineering and manufacturing firms came to Cornell last June to meet members of the graduating class with a view to engaging young men for their work, and this same thing happens at other schools. But still there is the gap; the graduate must still unlearn some things that have been improperly taught, and must learn other things that have not been taught at all. There must of course always be a period of readjustment because the conditions in practice and in the schools can never — from the nature of the case — be the same.

To meet the demand therefore the schools must cease to teach wrong things, and must teach right things.

The development of engineering, with the accompanying development of the engineering schools, has been a very interesting process. Out of the "chalk age" has come the orderly present practice. In the chalk age a man would go into his shop with an idea in his head and a piece of chalk in his hand; he would clear off a place on the work-bench and call up his best man. He would sketch and explain and when asked about dimensions would take out his two-foot rule and slide his thumb along it till he reached the right place and chalk it down. Then the best man would look in the scrap-heap for available parts; would interview the pattern-maker and the blacksmith; and later there would be a machine. This machine would be tested; parts that failed would be replaced by stronger ones, motion ratios would be adjusted, and finally the machine would perform its function, all honor to the fine men who did this work. But this process of machine evolution was tedious and expensive, and the chalk man often wished he could figure out dimensions because he saw profit in getting things right the first time. It was in response to many such wishes that the technical schools appeared. But they did not spring full-armed into being. Like other earthly things they have developed by orderly growth. The law of survival of the fittest operated as in organic evolution; unfit things have fallen away and have been replaced by fitter ones, while much that was good has survived. From the first it was clear that an engineer should understand the laws of inorganic nature and the relations of numbers, and hence physics and chemistry and mathematics were included in the early courses. But the use of shops for the training of engineers does not seem to have been grasped, for students in most cases were simply taught handicraft. One exception was the shop in which Professor Sweet taught not only skill with tools but also principles of construction, together with the highest ideals in machine design. But Professor Sweet is such a man as comes but once in a generation or two.

Many of the technical courses were grafted on the existing college courses and an attempt was made to combine a liberal and a technical training. It does not need to be stated that these schools were inadequate even in the simpler state of engineering; and yet — out of these schools came many of the men who have helped to bring engineering to its present advanced state. But that was because they had power to bring what they had learned into action, to supplement it by wisdom gained in practice; in other words, to train their judgment till they became real engineers.

In contrast to this is the present state of the technical schools. Engineering has developed steadily and the schools have tried to meet its demands; not with perfect success, but still successfully.

One of the difficulties about technical schools is that the teacher by the very fact of teaching is put out of touch with his profession; and the profession advances so rapidly that in a few years he is side-tracked. He teaches engineering as he knows it; but that is not as it is.

Some teachers who are fortunately placed combine consulting work with teaching, and if a nice balance can be maintained this must give good results. There is always, however, a temptation to give too much attention to the consulting work with its strenuous demands and to slight the teaching.

It would seem that the ideal way is to spend alternating periods of a few years in teaching and practical work. This has been done in several cases on personal initiative with good results; and in at least one institution it now has the approval of trustees, president, and faculty.

If a man had just spent three years in advanced practice in engineering what would he find to criticise in any one of the many good modern American technical schools?

Let us consider this briefly in detail.

Mathematics. The devotee of pure mathematics delights in abstract processes. We have all heard of the toast offered at a banquet which concluded a congress of mathematicians: "Here's to Higher Mathematics, may she never be degraded to any human use." This was only half-meant.

I know a man who says that a mathematical question loses all interest for him as soon as it proves to have a practical application. His feeling is right; the work of his kind has been of infinite service to humanity, but he is not of the stuff of which engineers are made.

The mathematical subjects in technical schools have always been taught to engineers by mathematicians and they have very naturally presented and emphasized the things that had greatest interest for them. These are not usually the things of most use to the engineer. In some cases, no doubt, such teachers have resented suggestions as to their teaching; but in most cases I believe they receive suggestions gladly and are anxious to do all in their power to make their service most efficient. I believe we are to blame who have allowed suggestions to be lacking. He who has spent any considerable time in modern mechanical engineering work knows that for most of the figuring only a knowledge of the elements of the mathematical subjects given in the technical courses is needed. But it must be a *working knowledge.* Occasionally a problem arises requiring more advanced knowledge for its solution. Why not then apply to what Mr. A. P. Trotter in a recent paper calls a "tame mathematician" for a solution which can be applied by the engineer. If a man can be an expert mathematician and an able engineer also, it is a fine thing; but most men cannot because of the time-limit to life.

It would seem that the trouble with the teaching of mathematics for engineers is that it goes too far and not deep enough. It is a working knowledge of elements that the engineer needs. Why not drill him till he can use the elements as he uses arithmetical processes, and leave the advanced work to the pure mathematician?

Shops. The object of a shop-course in a trade-school is to teach handicraft to one whose life-work is to be in the shop. The object of a shop-course in an engineering school is to give an understanding of principles of machine construction to one who needs such understanding to be a successful engineer. Obviously the method should be different in the two cases. In the first case it is of great importance for the student to chip and file an exercise-piece so that it exactly fulfills the specifications; in the second case it is of very little importance.

A student cannot learn four trades working six or nine hours a week for nine months during each of three years; but he can learn in that time — if properly taught — much of machine construction which will help to make him a better engineer.

In the machine-shop all exercises that are for the training of the hand alone should be dropped and the student should learn the operation of every machine tool; he should be led to put each to its maximum safe output, so that he may grasp something of the meaning of economic production. He should be taught the methods of producing duplicate parts in large numbers at low cost. He should learn something of the shop organization and arrangement for minimum cost for handling; he should learn something of shop lighting and sanitation and its bearing on the cost of product; he should learn something of the methods of reward by which workmen are led to increase the shop output and their own incomes; he should learn about accurate and simple cost accounting and its economic results.

In the pattern-shop the making of ornamental vases and inlaid boxes should be excluded and the student should learn the best methods of pattern-making, and to distinguish between the allowable expense of a pattern made for one casting and a pattern made for many castings; he should be shown all the short cuts that save labor in the pattern-shop and the foundry.

In the foundry art-casting should cease and the student should learn the methods of green-sand, loam, and sweep-work, either by the actual execution or by explanation with models; he should do snap-flask work and should see moulding-machines operated; he should learn economic methods of handling raw material and the product in large foundries; he should know how to make charge mixtures for different results and should study cupola and air-furnace operation for best product.

In the smith-shop artistic forging should be excluded and the student should learn not only simple forging, tool-dressing, and heat-treatment of steel; but he should also be introduced in the production of duplicate parts by drop-presses, and in the methods used for the production and annealing of large forgings.

This is not too high a standard for the shops of an engineering school; its realization will increase the value of the schools to practice and hence it will come. Obviously it involves great changes in existing methods. Shop-talks and class-room work must supplement actual work because so many principles are involved, and the actual work must be greatly modified. Already many of the schools have made a start in this direction.

Drawing and Design. In drawing all art-work should be excluded, and the student should learn to make neat and clear-dimensioned sketches and accurate, well-executed working drawings with good plain lettering.

In machine design the theory has long been well taught; but the modifications of design in response to the demands of practical every-day considerations have usually been neglected.

Experimental Work. The prime function of the undergraduate mechanical laboratory is to teach men to test the efficiency of machines, the secondary function is to afford opportunity for research. Many will object to this order because research is undoubtedly the higher work. For a post-graduate laboratory the order would be reversed; but for an undergraduate the thing of first importance is to learn methods of testing. If in addition to that he is able to catch something of the investigator's spirit it is fortunate; but in most cases it will be but little; there is n't time. Moreover, the investigator and the engineer belong to different classes.

The engineer is he who conceives and materializes ideas that help humanity harness nature for its use. The investigator is he who extends the field of knowledge. This is not an absolute division, for many engineers find out lacking facts for their own use, and many investigators apply the facts they have determined; but in general the classification holds.

Once in a while there comes a student with the investigator's spirit; he is born to add to human knowledge. He is to be cherished and encouraged; if he shows a tendency toward engineering work, the brakes should be applied. The world has many engineers and few investigators, and the few cannot be spared.

The mechanical laboratory, although a comparatively recent addition to the technical courses, is very efficient in most of the schools. This is probably partly due to the fact that the induce-ment for teachers to keep in touch with practice is greater through consulting work than in the other departments. The criticism of the man just out of practice upon the mechanical laboratory would probably be that things are arranged too conveniently. A machine or a series of machines is made ready for operation, and the student makes certain observations from which he deduces results. In some cases he is not even allowed the responsibility of operation. In practical testing it is the getting ready that needs the engineer's best ingenuity and judgment and effort.

Steam Engineering. The tendency in this work has been too much to go far into theoretical thermo-dynamics. This is usually "over the heads" of the average undergraduates. What the engineer needs is a working knowledge. The thermo-dynamic theory which suffices for this is not difficult, but it needs to be thoroughly understood. Again it is better to go deeper and not so far. Also the economic part of power development should be emphasized. It is not so much producing a maximum result per pound of steam as producing a maximum result per dollar cost.

These are criticisms in detail. What would be the criticism of the course as a whole — of the spirit of the place? In general it would probably be that the school needs to "get in line" with practice. The student coming out should not need to turn even through a small angle but should go straight on. Some details may illustrate:

Engineering work is done because it is paid for, and no solution is right which ignores the money factor. In the operation of any mechanical engineering installation, there is cost of labor; cost of supplies, including energy; cost due to depreciation; cost due to interest on first cost; cost of repairs; cost of probable delays; cost of taxation and insurance.

There may be many combinations of machines and apparatus that would give the required result, and each combination might vary all cost items. The engineer must determine the combination that would give the least sum of costs. It is believed that the schools are apt to consider economy of elements rather than of aggregates, and to neglect variations due to local conditions. This is not in line with practice.

Another thing that is not sufficiently emphasized is the judging of results by their reasonableness. I quote from a recent address to the graduating class of Stevens Institute by Mr. Walter C. Kerr: "This again is a thing which each man does for himself in his own best way, and its essence consists in asking one's self whether the thing is reasonable. It is a great check upon error. It applies equally to nearly everything of which engineering is composed. It is the power of the human mind, after performing in more or less systematic and conventional ways, to stand off and look at results and ask one's self whether they are reasonable. One man will figure that certain material weighs two hundred tons, and believe it. Another will say that there is something wrong in that, for it all came in two cars."

The engineer in practice has to check results in this way because errors are costly in money and reputation; but in the school where ideas are not materialized the result of errors is less serious. The consequence is that it is customary to assume that a result is right because it has been figured. To use another illustration: One man may get a result by using seven-place logarithms and may say that it must be right because of the seven places. But another may check it through with a slide-rule and show a large error in the second figure of the result. After working out in detail, the whole problem should be looked at broadly for reasonableness. The schools should lead the student in this direction to line up with practice.

These are probable criticisms of a man fresh from practice. Every practicing engineer will, I think, recognize their reasonableness.

Who then are the men to work out the changes? The men with teaching capacity fresh from practice; and so again we come to see the desirability of alternating teaching and practical work.

Another difficulty is the present time-limit of the technical course. With engineering development has come the demand that the engineer should have broader training. The course was made to cover four years at first, and that served for the early days; but now for years we have — so to speak — been blowing steam into a closed vessel from a high-pressure source; the result is too high pressure. Students are worked too hard and as a result cannot do the best work of which they are capable. It takes time for ideas to soak into the human brain. The solution is to increase the course to five years. The objection usually made is that students cannot afford the time and expense. But is this true? I know a man who spent ten years after entering college before he began the practice of medicine; four years in college, four years in the medical school, and two years in hospital work. This may be an extreme case, but this is the kind of a physician I would like to call in case of serious illness. Suppose the student leaves the technical school at the age of twenty-four. He may reasonably look forward to thirty-six or more years in the practice of his profession. If an additional year's study can increase the efficiency of each one of these years, is it not worth while? The increase in efficiency is not due alone to the additional year's work. The stress is reduced, and the development is more normal. Moreover, the danger of mental overstrain is reduced. The five-year course also would give opportunity for the introduction of outside work that would increase the engineer's power: elementary economics and transportation problems; elementary law and contracts; with a great deal more English composition and theme-writing.

The student will say that his father will not give him five years at the university. How about his brothers and friends who study law or medicine? We have only to get used to the idea. I believe the five-year course will come within the next five years.

In this same connection is another point. An engineer's success is increasingly dependent on his ability to meet men of refinement and culture on their own plane. Obviously there is no time in a technical course for culture studies. For fifteen or more years there has been a tendency for a few men who have completed an arts course to take two or more years in engineering. This is a tendency to be encouraged, for it makes for increased power and efficiency in engineering. We ought to get into the habit of thinking of the technical school as a professional school to be entered only on the completion of the broader general course.

There is another criticism which has come to me many times from men in different grades of practice. The technical schools are organized so that a young man who has passed regularly through the public-school system finds entrance easy; while maturer men whose schooling has been irregular, but who have had several years of practical work in lines connected with engineering, find entrance difficult. Yet the latter class are apt to have greater capacity for becoming engineers. It seems certainly necessary to require that all candidates shall have the mathematical preparation. It is impossible to build without a foundation. But any earnest man with engineering capacity can get this preparation. It is other subjects that give trouble. If a man has spent several years in a shop or drafting-room, or at some other work directly connected with engineering, he certainly has increased his understanding of what engineering training should be; he has usually very much greater earnestness for study than the young man from the high school. In other words his work has been effective preparation for a technical course. There should not be any difficulty in giving value to such work toward entrance.

This problem may be solved as follows: Make the mathematical and English requirements rigid. Let the other requirements stand as at present, but add to them shop-work, drawing, and such other subjects as may be judged to give equivalent training. Let a certain number of these subjects be required with free election. This plan is now in successful operation at Stanford University.

Some desirable men (I have known many of this class) might still be unable to enter. If they can offer the required mathematics, they may be admitted as special students. This would bar them from taking degrees, and this might seem a hardship if degrees are really of any value. This difficulty has been overcome at Stanford University by allowing a man who has entered as a special student to graduate by making a total of one hundred and fifty hours; that is by taking an extra year's work. This is of course simply making a man with defective entrance training take a five years' course for a degree.

After the technical school has done its full duty by a young man his education is only begun; he must spend years in contact with practice before he can attain that ripeness of judgment which will enable him to say of engineering schemes, this is right and that is wrong; before he can reach his full power as an engineer.

SHORT PAPERS

Mr. H. L. Gantt, of Providence, Rhode Island, contributed a paper to this Section on the "Application of Scientific Methods to the Economic Utilization of Labor."

Professor James E. Denton, of Stevens Institute of Technology, Hoboken, New Jersey, read a paper on "The Best Economy of the Piston Steam Engine at the Advent of the Steam Turbine."

SECTION C — ELECTRICAL ENGINEERING

SECTION C—ELECTRICAL ENGINEERING

(*Hall* 10, *September* 22, 3 *p. m.*)

SPEAKERS: PROFESSOR ARTHUR E. KENNELLY, Harvard University.
PROFESSOR MICHAEL I. PUPIN, Columbia University.
SECRETARY: MR. CARL HERING, Philadelphia, Pa.

THE RELATIONS OF ELECTRICAL ENGINEERING TO OTHER BRANCHES OF ENGINEERING

BY ARTHUR EDWIN KENNELLY

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ENGINEERING is coeval with civilization. Its crude beginnings must have evolved with the first banding of men together for a common purpose. In a very broad sense of the term, engineering comprises all material construction and operation executed by a community through the efforts of a specially selected few. The degree to which engineering is carried in a community is a measure and criterion of the degree of its material civilization. *Ex pede Herculem.* The pyramids of Ghizeh and the Cloaca Maxima at Rome clearly reveal by inference the status of their respective communities at the dates of those constructions.

In the same broad sense, engineering lays every art and science under contribution. But whereas the branches of engineering dealing with architecture, mechanics, mining, ship-building, road-making, and hydraulics go back to prehistoric times, steam engineering and electrical engineering are of comparatively recent date, steam engineering being about two hundred years old and electrical engineering about seventy. These youngest branches of engineering have completely changed the aspects of the parent tree. Without them modern civilization could not exist.

Each new industrial application of electricity has opened a new field for electrical engineering. The electric land telegraph first opened commercially in 1835. The electric submarine telegraph commenced in 1850. Since 1870 the electric dynamo and motor, the electric telephone, the electric arc and incandescent light, the electric furnace, the electric railway, and the electric wireless telegraph have all come into existence. These industrial applications have jointly created an applied science and an art with a large and rapidly growing literature, language, and technology. In the United States alone it is estimated that these industries have a total investment of three billions of dollars and employ 400,000 workers.

The most significant difference between electrical engineering and all other engineering lies in the fact that electrical engineering deals with the application and control of wave-movements propagated through the universal ether with the speed of light; whereas all other engineering deals with the mutual relations between material substances. In other words, electrical engineering is the controlled operation of the immaterial upon the material. All other engineering is the controlled operation of the material upon the material.

A projectile may be fired from a cannon over a thirty-kilometer range at an initial velocity of about one kilometer per second. A locomotive may be driven over a smooth level track at a speed of fifty or sixty meters per second; but an electric impulse will travel over a wire at a speed of 300,000 kilometers per second. Both the projectile and the locomotive must displace the air through which they move, producing violent frictional disturbance of the medium. The electric impulse moves through the air without friction or appreciable disturbance. Hence the wonderful adaptability of electricity to play the part once assigned to the winged Mercury among the gods on Mount Olympus, and by its enormous speed to annihilate distances.

In nearly all industrial electrical applications, energy is transmitted over wires, and it is the transmissibility of electrical energy which gives its principal value. The energy is transmitted from convenient sources, or points of generation, to sinks or consumption points, where the energy is abstracted and converted. In some cases it is directly converted by electric motors into mechanical work. In other cases, it is converted into heat, as in electric furnaces for heating, or in electric lamps for lighting. In yet other cases it is converted into mechanical energy, not for doing work, but for communicating intelligence, as in the telegraphic receiving-instrument. But in all these cases the electric energy is carried to the point of consumption and delivery through the ether, guided by the wire or wires. The interior of the wire is the only place where the transmitted energy does not flow, for whatever energy enters the wire is wasted therein as heat, and fails to reach its destination.

Prior to the introduction of the steam engine, men worked in two ways; first, as intelligent beings exercising skill and judgment; second, as muscular machines, or peripatetic sources of brute force, like beasts of burden, with vestiges of intelligence. This segregation of a large section of the people into competition with animals tended to brutalize all men, both the muscular machines and the more intelligent beings over them. Coal and the steam engine gave a great lift to humanity by removing the competition of human muscle with brute muscle. The applications of electricity have so far aided the uplifting process, by the improved distribution of power, that not only are men emancipated in civilized communities from draught-service or mere animal-haulage; but even horse-haulage in large cities has commenced to be uneconomical.

From an economical standpoint, electrical engineering coöperates with other branches of engineering in distributing either special utilities exclusively, or general utilities with particular advantages. Distributions of the former class are intelligence and power. Distributions of the latter class are light and heat. That is to say, the telegraph and telephone maintain a monopoly of the rapid transmission of ideas. The electric motor has almost a monopoly of the distant transmission of power. But electric light is in competition with other forms of illuminant, and maintains its present position by virtue of convenience, cleanliness, or other special qualities.

The sociological advantages derived from the electric telegraph and telephone are enormous. If, as has been claimed, the invention of the logarithm-table has virtually doubled the lives of astronomers, the invention of these electric implements has virtually doubled the lives of business-men. Moreover, our modern systems of government would be impracticable in the absence of these instrumentalities. It is stated that in the year 1815, prior to the electric telegraph, the news of the battle of New Orleans was not received in the national capital, Washington, for three weeks. On the other hand, in 1898, the news of the battle of Manila was reported in Washington a few hours after it occurred, by actual time; or, some hours before it occurred, by local Washington time.

As regards the electrical distribution of power, the convenience with which insulated wires may be carried and distributed to motors in and among buildings has profoundly affected the construction and operation of modern factories, where the long overhead rows of constantly running countershafting, with large numbers of endless belts thence descending to machine tools, has been replaced to a considerable extent by a clear headway for cranes, and an electric motor on each machine tool or near to each group of tools. The complete control of tool-speed which this system provides and the cessation of all waste of power in running friction when a tool is out of use, are great advantages in favor of electric factory driving.

The contrast between the transmission of power by electricity and that by rope-haulage is very remarkable. A steel cable in a rope-drive can transmit say 300 kilowatts (about 400 horse-power) to a distance of a few kilometers by its bodily movement at the rate of a few meters per second. On the other hand, a quiescent electric cable of copper, suspended on the insulators of a pole line, can transmit 3000 kilowatts to a distance of a few hundred kilometers, with about the same efficiency. In the case of the mechanical transmission, the wear and tear and depreciation of the steel cable is considerable. In the case of the electric transmission, the wear and tear of the conductor has never yet been detected. The depreciation is practically limited to that of the poles, insulators, and mechanical supports. So far as is yet known, an electric conductor does not wear out electrically by the exercise of its functions.

At the present time, the longest commercial electric power transmission is in California, from de Sabla water-power house, in the foot-hills of the Sierra Nevada, to Sausalito, opposite San Francisco, a distance of 232 miles (373 kilometers); while 7500 kilowatts (10,000 horse-power) is regularly transmitted from Electra, another water-power house in the Sierras, to San Francisco, a distance of 147 miles (236 kilometers). It would seem as if it were only a question of time when every important waterfall shall be harnessed to turbines and dynamos for the transmission of solar energy to the nearest mart.

Up to the present time, the coal-supplies of the world have kept us amply furnished with power at low rates. With coal averaging say $2.25 per metric ton in the Eastern United States, the cost of a kilowatt-hour at the steam-engine shaft during the working hours of the year is from 1.75 cents in small plants to 1.33 cents in larger plants, with good management and economy. It is estimated that the world's total output of coal is approximately two millions of metric tons daily. At the present rapidly increasing rate of consumption, the cost of coal delivery tends slowly to increase. Unless, therefore, discoveries are made of new available sources of power, the value of solar power may be expected to appreciate. The only solar engine of large power that has thus far been made effective, or which promises to be effective in the near future, is the waterfall. Already several hundreds of thousands of kilowatts of the world's water-power are electrically converted from waste to utility. In the single instance of Niagara Falls, about 100,000 kilowatts are already utilized, and plans now in progress promise to develop a total of about 500,000 kilowatts more. This electrical power is sold to consumers in the vicinity of the Niagara power-house at about a quarter of a cent per kilowatt-hour, in large quantities, continuously.

One of the greatest advantages which electrical engineering has rendered and is rendering to the people is in cheapening and accelerating transportation by the electric street-car and railroad. In a number of American cities it is possible to travel for five cents any distance in one direction up to 10, 15, or even 20 miles, at a schedule speed of from 7 to 12 miles per hour, and with cars on headway of from 2 to 15 minutes. The reason for the cost of transportation being so low is that the electric street-car is easily controlled, can be started and stopped at small expense, and requires no private roadbed or right of way. The effect of this reduction in time and cost of transportation is to increase the available area and diminish the density of urban population. This rapid transit acts as a distinct check to the modern tendency of overcrowding city districts. It averages more nearly the values of real estate and improves hygienic conditions. In 1902 the number of passengers reported to have been carried by the steam railroads of the United States was about 600 millions; while those carried by the electric railroads was about 4800 millions; or eight times as many. The average steam-railroad distance of travel was 30 miles for a fare of 60 cents or very slightly over 2 cents per mile. The average electric street-railroad fare was very nearly 5 cents. The electric railroads carried the entire population on the average 63 times during the year; while the steam railroads carried the population nearly 8 times. But whereas the steam railroad passengers carried had increased only 5% in the decade prior to 1902, the electric passengers carried had increased 137% in the same time.

Not only has the electric railroad given cheap and convenient urban and suburban traveling; but it has also largely removed the preëxisting discomforts of such travel due to dust and smoke, so that electric railroad traveling is frequently resorted to for pleasure; while steam railroad traveling is usually only resorted to for reaching a destination.

From a constructive standpoint, electrical engineering has had a marked beneficial influence upon other branches of engineering. For example, it has developed the capacity of steam and hydraulic prime movers. The largest stationary steam engines and the largest hydraulic turbines have been called into existence by the demand for electric power distributions. The high-speed reciprocating steam engine was developed to meet the requirements of dynamos. The most recent and highest speed type of steam engine — the steam turbine — could hardly have been utilized or developed for stationary work in the absence of electric power plants. These steam turbines, while only of very recent growth, offer a working efficiency comparable with that of the best reciprocating steam engines; while they have markedly reduced the expense of material, construction, floor-space, foundations, and operation. At the present rate of progress, it would seem as though the reciprocating steam engine would eventually be superseded by the rotary steam engine. Conversely, this improvement in steam engineering is reacting to the benefit of electrical engineering by reducing the size and cost of steam dynamos and the price of electric power in distributing-systems.

The development of any one branch of engineering inevitably stimulates other branches. The reduction in the cost of electric power for machine-driving thus promotes activity in the construction of all kinds of machinery.

The development of electrical engineering has also tended to increase the accuracy and precision of other branches of engineering; first, by simplifying the delivery and measurement of power, and second, by the introduction into engineering of a scientific system of units.

Mechanical power is delivered from one body or system to another through mechanical contact, or the pressure of one material system upon its neighbor. In general, the power transmitted is equal to the product of the effective pressure, or tension, and the velocity at which it is delivered. In most cases it is very difficult to determine the magnitude of the effective pressure. In the electric transmission of power, the power is delivered through an electric conducting circuit, and while in the circuit is equal to the product of a certain voltage and a certain current strength. This product — the electric power — is readily capable of precise measurement. Consequently, the most convenient and accurate method of measuring the delivery of mechanical power is usually by electrical means through the intervention of an electric circuit. Thus the power which a machine receives from moment to moment in the performance of its duty, or the total energy which it receives in the course of a given period of time, may be determined with great convenience and a high degree of commercial accuracy by electrical measuring-instruments placed in the circuit of a motor coupled to the machine. By the accumulation of such observations and experience the knowledge of the behavior of machinery has been greatly augmented since the general introduction of dynamos and motors.

It is a remarkable fact that in spite of our lack of knowledge as to the precise fundamental nature of electricity and magnetism, the knowledge of their action and control should already be so definite and precise. In many instances it is possible to design and predetermine the behavior of electric machines as closely as it is possible to determine their behavior experimentally after being built, under commercial or factory conditions. That is to say, a skilled designer, accustomed to a certain class of dynamo machines, can frequently compute the characteristic properties of a new dynamo or motor, as laid out on paper, to as close a degree of accuracy as those properties can be measured, under commercial conditions, after the machine takes material form. This general precision of electrical engineering has aided engineering in general to become an exact science.

Electrical engineering has adopted by international convention a system of electromagnetic units which is based upon the international metric system, and which has the advantages of being simple, decimal, and international. This has tended to give precision and definiteness to all electrical engineering measurements. In other branches of engineering, the custom varies in different countries. Thus, in hydraulic engineering, the cubic foot (of water), the cubic yard, the short ton, the long ton, the metric ton, the liter, the British gallon and the U. S. gallon are all promiscuously used in such a manner that measurements in one country are frequently unavailable to engineers in other countries without lengthy arithmetical reduction. This is a most unfortunate diversity. Again, in mechanical engineering, the foot-pound-per-second, the foot-ton-per-second (long and short), the British horse-power, the European continental horse-power, the poncelet, and the kilogramme-meter-per-second, are all in use as units of power. Unless qualified as to standard geographic latitude, they are all subject to variation within a quarter of one per cent above or below the mean, owing to the variation in the force of gravitation with terrestrial latitude. On the other hand, the electric unit of power, the watt, is independent of the latitude, or even of the planet, and besides being an international mechanical unit, is also an electrical circuit unit. For these reasons the kilowatt (1000 watts or about 1⅓ horse-power) is at present steadily displacing the horse-power in engineering literature, all over the world.

Electrical engineering has exercised a marked intellectual influence upon the time, in the direction of mathematics. Applied electricity is particularly subservient to simple mathematical law, which is but another way of stating that the present applications of electricity are well understood. Prior to the development of electrical engineering, the useful applications of mathematics to engineering were almost limited to mechanics, statics, and kinetics. Now, electrical engineering has thrown open to application the entire stock of mathematical physics which has been accumulating for several centuries. Consequently, it is now not only difficult to find a department of mathematical science which does not have applications useful in engineering; but engineering has also found, and is constantly discovering, new fields for profitable exploration by the mathematician. In the last few decades, departments of mathematical analysis which had previously been regarded as pure, or inapplicable, are now strained to their known limits for giving practical service to engineers. Moreover, there are many directions in which engineering would be applied, if mathematics could only gain a reliable foothold on the outcrop.

In any new application of science, first comes the fact discoverer, then the mathematician, who quantitatively connects the newly discovered phenomenon with the known environment. Next in succession is the inventor, who grasps the utilitarian possibility of the fact; then the engineer, who grasps the essential portions of the already enunciated mathematical law, and relates the same to commercial and constructional conditions. Finally, the capitalist grasps from the engineer the commercial limitations of the reduced law and estimates the commercial values of the utility, venturing capital upon the new possibility on the risk of its desirability or undesirability. In rare cases it is possible for any successive number, or all of these intellectual stages to be reached in one and the same individual; but it seems to be a general sociological and intellectual law that the capitalist will not risk the savings of past labor on a new application of science until the engineer has intellectually assimilated the problem from an arithmetical standpoint, with due regard to physics and mechanics on the one hand and to the cost of factory processes on the other. In his turn the engineer is often unable to grasp the problem arithmetically until the mathematician has intellectually apprehended and elucidated the quantitative scientific relations of the problem to a reasonable degree of completeness.

Thus, for example, considering the modern dynamo, first came the discovery of the phenomenon of electro-magnetic induction by Faraday; then the work of mathematicians, like Ohm and Ampère, to determine the quantitative relations of the phenomenon to the known cosmos. Thus far the matter was pure science. Then came inventors who conceived the idea of utilizing the new principle for the industrial generation of electricity. Unless, however, the inventor was himself an engineer or was assisted by an engineer, the idea would have been practically unavailing, however important the idea might be in directing attention to the possible use of the new phenomenon. The work of the engineer was next necessary to design the machine. This he could only do effectively according to his apprehension of the mathematical, physical, and mechanical underlying laws already discovered, and the application of those laws in such a manner as to fit factory methods of construction economically. Then came the capitalist ready to venture the accumulated savings of the community he represented, upon the project of building dynamos for commercial purposes, as soon as he was satisfied as to the commercial desirability and economy of the new process.

In reality the modern large dynamo has had to undergo many such successive stages of intellectual and material preparation, in order to reach its present stage of development. Frequently the capitalist would have preferred to install larger dynamos than existed at the time, but could not risk their being unduly enlarged because the engineer could not be sure of the results, and the engineer could not see his way clear for want of existing scientific and mathematical knowledge in the direction considered.

Although the above sequence of relations is generally admitted to be self-evident on consideration, yet the perception of these relations by the community at large seems to be a matter of social and economical importance; because the more clearly that organized society apprehends the steps of the processes by which it ultimately secures what it needs, the more effectively it is likely to stimulate the activities which lead to those steps. It is of importance to the whole world that there should be an adequate distribution of activity in all these stages of effort to secure new gifts from nature. There should be plenty of work in physical and scientific laboratories for the discovery of new facts. There should also be plenty of mathematical work carried on to interweave and connect these facts with the great universe of quantitative relations. There should be plenty of stimulus and reward for inventors to find useful applications for the new facts. There should be plenty of engineering work devoted to controlling the facts by reducing the purely mathematical relations of all time to the commercial mathematical relations of the locality and momentary time. Finally there should be abundant opportunity for the business-men acquainted with the needs of the community to ascertain the results and possibilities of engineering development as well as adequate reward for the successful investment of capital in such enterprises as they consider the engineers can offer and the community will accept.

In line with these ideas it is found that even to-day large industrial corporations finance new scientific applications in their line of work, maintain their own corps of engineers and inventors, and their own research laboratories with scientific experts. Already, therefore, these corporations consider that it is economically desirable to develop simultaneously in their own body all these successive stages of intellectual and material effort. If this be the trend of individual engineering industries, it is reasonable to expect that the future trend of larger communities will be in a similar direction. That is to say, cities or nations may in the future consider it economical to foster either directly or indirectly any or all of these stages of intellectual activity which conjointly lead to new material wealth, on the principle that properly organized activity for any purpose is more effective than spontaneous sporadic and disorganized efforts of individuals in the same direction. Wonderful possibilities lie before organized scientific research and organized creative engineering based upon the same.

From the psychological standpoint, electrical engineering has come to exercise a marked influence upon civilization. These psychological conditions are important, because if we compare the condition of the world to-day with that which is reflected to us from the history of past times, we are impelled to recognize that there are two salient differences between them. One is the increase in later times of material wealth, including processes, utilities, and conveniences, such as steel structures, the railway, or the printing-press. The other is the change in the general mental attitude of human beings toward each other and toward their surroundings. That is to say, one salient change is material in its nature; while the other is psychological. It cannot be denied that both are of great importance to the progress of civilization, and perhaps the one is as important as the other. The attitude of mind of the ancient Egyptians, as reflected in their writings and remanent structures, must have been markedly different from that of the Greeks in the days of Homer, or from that of the Romans under Nero, or from that of Europeans during the Middle Ages, or from that of the peoples in the modern civilized world. In a certain sense, the psychological condition reflected in a community transcends in importance its material conditions. The development of a worthy and potent psychological condition in a people is even more important, from this view-point, than the development of a great and ample material condition. The one is probably necessary to a highly developed state of the other.

The effect of electrical engineering applications on the psychology of the community has been greatly to extend the radius of mental influence of the individual. In the days before the discovery of written language, the intellectual sphere of influence of an individual was limited in radius to that distance at which his voice could be heard. Beyond that distance his influence could only be transmitted either by his personal migration with respect to his neighbors or by the migration of his auditors and their repetition of his ideas from memory. Gradually, after writing became a familiar mental habit, written words superseded repeated speech, and document, tradition. Writing thus vastly increased the effective sphere of psychological influence, although the diffusivity of the new method must have been but small. Engineering steadily enlarged the sphere of influence by developing the press, the railroad, and the steamship, by which the written word could be reduplicated and carried faster and farther. The old semaphore telegraph from hill to hill, still found in various parts of Europe in sequestered desuetude, went a step further and added speed to the travel of thought; but the electric telegraph and telephone have enormously increased the range of mental influence. Even now the fetters of thought are closing upon the arms of the ocean, and wireless telegraphy promises in time to extend the transfer of ideas to the uttermost distances of the sea. The effect is multifold. The tendency is always for the best intelligence to have its influence most widely distributed, considering the best as that which the community esteems best at the time; so that the extension of the range of mental influence always tends for the benefit of the many and the selection of the fittest. The consciousness of the individual being able to influence his neighbors at any distance on the planet gives him greater confidence in the success of undertakings dependent for their effect upon widespread coöperation. The consciousness of the individual that he is always within the sphere of influence of his leader exerts a great psychological supporting influence in times of difficulty and doubt. It is equivalent to a bridging over of the distance between the strong and the weak. Any one who has ever received from land a telegram when far out at sea, either by wireless telegraphy, or by a lifted submarine cable, will testify to the intensity of this psychological influence.

According to the census returns of 1902 the number of telegrams forwarded commercially during that year in the United States was 91,650,000; or 1.2 telegrams per annum per head of population, at an average cost per message of 31.8 cents. In the same year the number of reported telephonic conversations in the United States was nearly 4950 millions, or 65 per head of population, at an average cost per conversation of 1.65 cents.

Along with the swift and extended radius of thought that electrical engineering offers, by the mutual relations of immaterial mentality and the immaterial ether, there is also necessarily involved a reduction of psychological restraint and an extension of psychological freedom. A part at least of the discomfort of human beings often arises from a disconformity between their modes of thought and of their mental relations to those of the individuals surrounding them. Occasionally an individual who is psychologically ill-adjusted to his environment, and who is therefore ineffective in his coöperation with it, may subsequently become more usefully effective in response to a changed mental environment. The greater and swifter the radius of thought activity under the influence of engineering methods, the greater the stimulation to migration that leads from a lesser to a greater harmony of adjustment between the internal and external mental activities of the individual, to the increase of general comfort and well-being. The segregation of associable mental activities is simplified and rendered frictionless by whatever extends the rate and range of ideas.

In its moral effect upon the community at large, electrical engineering must have the same effect as all other branches of engineering; namely, to dispel illusion, dignify all labor, exalt truth and precision, gradually eliminate superstition, bring home to consciousness the infinite simplicity of nature, and indicate that no good thing can be humanly acquired without effort and training.

In a certain sense engineering is destined to assist in effecting the apotheosis of humanity. Every step taken by the people along the path of civilization makes degeneration to dissociative barbarism the more difficult and unlikely. The methods that men adopt to subject the immediate universe to their will react by subjecting their will to the laws of the universe. Centuries ago men dreamed of the civilization that they, by uniting and coöperating, might initiate for their successors to attain. Already that civilization has so far dawned that it has modified us to its requirements, and we live for it as well by it. The difficulty of fitting ourselves for it is greater than that of fitting it for us. Whatever modifications civilization may undergo in the course of time must be molded in accordance with the developments of engineering, which are themselves but the interpretations into human ideals of the attributes of nature.

ELECTRICAL ENGINEERING PROBLEMS OF THE PRESENT TIME

BY MICHAEL IDVORSKY PUPIN

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Engineering problems differ from crude scientific problems by the definiteness of their aim. They are created by the industrial development of the country, and their solution forms the next step in the progress of this development. The problems in pure science do not have this intimate connection with the present state of the technical arts; they affect it in so far only as their solution contributes additional means for the solution of the existing engineering problems and leads gradually to the formulation of new ones. Public demand is the driving force which impels the engineer in his study of any given problem; the loosest kind of a coupling connects the work of the crude scientist with public demand. This does not mean, of course, the existence of any public indifference in this respect. The intelligent public watches with keen interest the steady progress of pure science; partly on account of the intellectual pleasure which one derives from the contemplation of the beautiful mechanism which purely scientific research reveals in the background of various physical phenomena, but principally on account of the recognized fact that the progress of pure science leads to the formulation of new engineering problems, the solution of which is essential to our immediate social progress, our moral and material development. The intelligent public knows with a certainty amounting to mathematical accuracy when the time is ripe for the formulation of new engineering problems, and it is ready then to lend its strong support to the engineer who offers a solution. When Bell discovered a method of obtaining an electrical facsimile of articulate speech, and constructed the first telephone which represented an embodiment of his great discovery, the intelligent public understood readily that the time was ripe for the formulation of a new engineering problem, the problem of transmission of speech over long distances. It was ready then to contribute cheerfully its share to the sacrifices which had to be offered, in order to obtain a satisfactory solution of this great engineering problem. It is, indeed, not a mere accident that the most intelligent state of this union, the state of Massachusetts, contributed far more than any other state to the sacrifices which had to be offered, in order to develop Bell's remarkable discovery and invention into the greatest civilizing agent of modern times.

These are the considerations which guided me in answering the question: Which of the many electrical problems of to-day should be considered as the "Electrical Engineering Problems of the Present Time"? Evidently those electrical problems must be selected the solution of which, in the opinion of all competent judges, represent the next step in the evolutionary progress of the existing electrical industries. Vague and indefinite propositions, such as, for instance, the direct transformation of the chemical energy of burning coal into electrical energy, the generation of cold light by electrical processes, and so forth and so on *ad infinitum*, must be excluded from this discussion. They are not in any sense of the word electrical engineering problems. The problems discussed here relate to the extension of the existing methods, which have been sanctioned by long practice, in electrical traction, electric lighting, telephony, wireless transmission, and ordinary telegraphy.

The Electrical Traction Problem

Electrical traction has been developing steadily during the last twenty-five years and has covered the field well which was originally mapped out for it, namely, the transportation of light traffic over comparatively short distances. Within these limits it has done its work admirably, surpassing even the most sanguine expectations of its original promoters. These results encourage the public and the engineer in the belief that the time is ripe for the formulation of the new electrical traction problem and for its satisfactory solution.

The new electrical traction problem is the problem of substitution of electric power in place of the steam locomotive on trunk lines; it is the problem of heavy electrical traction over long distances. The problem can be more clearly stated by referring to a specific case. Let us suppose that the Pennsylvania Railroad Company has decided to consider the advisability of equipping its lines between New York and Philadelphia with electric power, and that with this end in view it has obtained a sufficiently large number of reports from competent electrical traction experts. Every one of these reports would contain a careful examination of the problem under discussion, that is, the problem of heavy electrical traction over a distance of one hundred miles which, in the present state of the art of heavy electrical traction, is certainly a long distance. It is highly probable that no two out of a large number of these reports would agree even approximately in all the details involved in the problem, because there is no doubt that there are a considerable number of pet schemes in heavy electrical traction, each one of which has its ardent admirers and stanch champions. Nevertheless it is fairly certain that they would all agree on the vital questions involved in the problem. These questions are: First, can the existing methods of electrical power distribution over a distance of a hundred miles take care of heavy traction? Second, would substantial administrative advantages, capable of increasing the capacity of the existing tracks, result from the substitution of electrical power for the steam locomotive? Third, could the continuity of service be sufficiently well secured?

The answer to the first question would undoubtedly be in the affirmative in every one of these reports. The powerful electrical locomotive recently constructed by the General Electric Company for the New York Central Railroad and the experimental results obtained with it leave no room for any reasonable doubt that electrical traction machines can be built, which will take care of any practicable load and at any practicable speed. The Westinghouse Electrical Manufacturing Company of Pittsburg is completing for the Swedish Government a heavy traction electrical locomotive, which is considered by some to be even an advance upon the electrical locomotive of the General Electric Company just referred to.

The answer to the second question would also be decidedly in the affirmative in every one of these reports. Very substantial advantages would certainly arise from the substitution of the electrical motor for the steam locomotive. Our entire experience with electrical traction so far justifies this belief, and these advantages are so numerous and so self-evident, that a specific discussion of every one of them would be entirely beyond the scope of this paper, and would, besides, be entirely superfluous. Suffice it to state here briefly the two chief advantages which would arise. They are, first, the possibility of running smaller trains at much more frequent intervals; secondly, higher speeds with greater safety could be obtained. This means a very substantial saving of time and the resulting great increase in the transportation capacity of the existing tracks.

In the popular mind the substitution of electrical power for the steam locomotive seems to convey the idea that the chief object of this substitution is the saving of power; but nothing is as far from the actual point at issue as a view of this kind. The coal-bill is a small item in the operating expenses of a road, and cuts no figure in the study of the problem before us. The cost of the equipment is a different matter; it does cut a very important figure in the operating expenses of the road, and it seems to be admitted on all sides that the cost of the electrical traction equipment would be considerably higher than that which accompanies the employment of the steam locomotive. But the increased transportation capacity of the tracks and the increased safety of transportation would and should more than balance this increase in the cost of equipment.

The third question is: Can the continuity of service be sufficiently well secured with the prevailing methods of electrical traction? To find a complete and satisfactory answer to this question is the most difficult part of the problem.

With the present method of steam locomotive traction every train with its locomotive is an independent unit, so that an accidental derangement of any one of the units does not interfere very seriously with the operation of the rest of the road. A blizzard or a flood may, to be sure, cause a suspension of operations on the whole road, but nothing short of this inimical action of the elements is capable of producing this result. In electrical traction, on the other hand, the various units on the road are all interconnected through the conducting wires which connect them with the power stations. Any accident which suspends the operativeness of a power station will bring to a standstill the whole traffic on the section which is fed by that particular station. This difficulty, however, exists also in the electrical distribution of power for lighting purposes in large towns, and past experience shows that the present methods of electrical central station construction and management make the risks of discontinuity in the service on this score extremely small. It must be remembered, however, that distribution of power for lighting purposes in large towns employs underground conductors, which is one of the most effective means of protecting the continuity of service against the hostile action of seasons and elements. In heavy electrical traction, underground conductors are out of question for reasons which are so evident that they need no further discussion. This introduces one of the most serious difficulties into our problem.

The third-rail method limits the practicable electrical pressure at which the electrical energy is conveyed into the train; besides, it introduces the very serious difficulty of maintaining a sufficiently good electrical contact during the winter season when the ground is covered with ice and snow, not to mention several other difficulties which, it is generally admitted, render the third-rail method entirely inadequate to heavy electrical traction. The overhead trolley seems, in the opinion of the majority of competent engineers, the only permissible method of conveying electrical energy from the central station to the train. At any rate, this is the meaning conveyed to my mind by the fact that the New York, New Haven and Hartford Railroad Company has asked permission of the legislature to abolish the third rail and substitute in its place the overhead trolley. But if the overhead trolley method is to be adopted, then the smaller the number of wires employed to convey the electrical energy to the train, the better. This seems to me to be the real meaning of the extreme anxiety on the part of the electrical engineer to design an asynchronous single-phase alternating-current motor capable of developing large power. The results obtained in this direction during the last few years are encouraging, and they seem to have brought us very near to the solution of the heavy electrical traction problem. Summing up the considerations discussed above, it seems that the composite judgment of the best technical opinions can be stated somewhat as follows: Convey the electrical energy from the station to the electrical locomotive by means of a single-phase alternating current at high tension, say, 20,000 volts, employing, of course, a single trolley-wire. Let the locomotive serve as a sub-station in which the high-tension current is transformed down to a suitably low tension, and employ either induction motors or direct-current motors to convert the low-tension electrical power into mechanical propulsion.

The possibility of employing single-phase alternating currents contributes very materially to the possibility of securing continuity of service in heavy electrical traction by reducing the multiplicity of contacts to a minimum; theoretically, one contact for each locomotive. But that single contact must be rendered as secure as mechanical art can make it. The trolley-wire hanging with a convex curvature toward the track and supported on wooden poles such as we see on ordinary trolley-roads would never do. In place of the flimsy structures we must have well-anchored steel towers supporting messenger-wires of steel hanging in catenary suspension, and to these the conducting trolley-wires are neatly and securely attached so as to be at all of their points parallel to the track. The whole structure when finished looks like an endless suspension bridge, the steel towers being the piers of the bridge. The messenger-wire represents the gracefully curved span between the piers, and the trolley-wire is the platform over which the traffic of the bridge is maintained. Such trolley-lines have actually been constructed and operated not only out West and in some parts of Europe, as for instance on the famous Berlin-Zossen section, but also on the Long Island Railroad, where electrical traction on a somewhat larger scale is contemplated in the very near future. Structures of this kind are extremely solid and quite capable of defying the most stubborn attacks of the elements, but they are, of course, expensive, and the question arises whether a trunk line, say, between New York City and Philadelphia, equipped for heavy electrical traction in accordance with the most approved methods, so as to secure a rapid transportation of even the heaviest loads in large units as well as in small units at frequent intervals and with perfect security of the continuity of service, — it is a question, I say, whether such a solution of the problem before us is a financially attractive proposition.

There is a strong belief among the progressive members of the engineering profession that the question will be answered in the affirmative in the very near future.

The Electric Lighting Problem

The efficiency of the electrical arc-lamp is satisfactory; its mechanism is somewhat complex, and the sharp shadows produced by a powerful source of light concentrated in a very small volume are objectionable, not to mention the physiological effect upon the eyes of an intense source of this kind. On the whole, however, this form of electric lighting is considered as highly efficient and effective although not quite so cheap as some of the modern chemical methods of light-generation. Electric lighting by incandescent filaments is the field in which the public is awaiting marked improvements. This is the form in which lighting by electricity is distributed in small units. It is ideal in its simplicity and convenience, but it is a luxury in which the rich, only, can indulge; it is too expensive. The so-called fine arts are aristocratic; science and the technical arts are nothing if not democratic. The fruits of their labor must be within reach of everybody; if not, the soil which bears any particular one of these fruits will not be sufficiently cultivated by the public and it will soon become a hothouse product of the rich or cease altogether. To transform incandescent electric lighting into a democratic institution is one of the electrical engineering problems of to-day. Its solution involved many problems in the economy of generation and distribution of electric power, all of which have been satisfactorily solved by the electrical engineer, so that the main solution has converged finally to the following proposition: To find a substance which will have a sufficiently high resistance, will stand a higher temperature than the carbon filament without too rapid deterioration, and the radiation of which at this high temperature will be rich in visible waves. Osmium, tantalum, and some other refractive rare metals have been tried and seem to promise well. But in many respects the most satisfactory results have been obtained by Peter Cooper Hewitt with his mercury vapor lamp. The efficiency of this form of electric lighting, both in large and in small units, is remarkably high, over four times as high as that by ordinary incandescent lighting, and the simplicity of the apparatus is ideal. In addition to its high efficiency the mercury vapor lamp has the great advantage over all other forms of electric lamps in the fact that its light proceeds from a source which is distributed over a large area. This prevents the formation of sharp shadows, a great desideratum in workshops, where it is important that the workman should be able to see all around the object which he is handling. For this reason the lamp is making a rapid headway into factories, draughting-rooms, libraries, and laboratories. Its poverty in red rays will keep it temporarily out of the drawing-room and other places where the complexion of things and of people must be shown off at all cost. This, however, seems to be the only defect of this new form of electric lighting and it is sincerely hoped that this defect will soon be remedied.

The Telephonic Problem

The engineer has to determine how much time, money, and personal convenience the average subscriber is willing to sacrifice, in order to communicate with another subscriber in some other place, and then provide a satisfactory service which will return some profit to the operating company or to the state. The proposition is extremely complex, particularly in this country where unexpected legislative action introduces so many unknown quantities into the calculation of the engineer. Every now and then the legislator takes it into his head that he knows more about the science and art of telephone engineering than anybody else, and then, with a bold stroke of his pen, he cancels the final figures of the engineer, the permissible charge, and substitutes his own, looks wise, and leaves the engineer to lament the loss of the fruits of his laborious calculations and to wish that he lived in autocratic Russia where the telephone system belongs to the Czar and no conceited legislator is allowed to interfere with a business of which he has not even the faintest shadow of anything approaching the semblance of an idea. Thanks, however, to the superior intelligence of the engineers of the American Telephone and Telegraph Company and to their extraordinary courage, telephonic art is progressing very favorably in spite of the arrogant legislator and the wicked demagogue, and of the most annoying and heartbreaking difficulties which they are placing, at almost every step of progress, in the way of the patient and intelligent worker in the telephonic field. The American telephone engineer must reckon with an unknown and unknowable quantity, — the legislator. The only satisfactory way to handle this quantity is to ignore it and to adjust the other elements of telephonic problems in such a way that the result will, in all probability, come out right no matter in what direction the legislative cat may decide to jump.

The European engineer is much more fortunate in this respect. The telephone system belongs to the government. The charge is fixed, and if it brings a profit to the state, well and good; if it does not, the taxpayer makes it right. If some taxpayer kicks because he has to pay for somebody else's telephoning, he is told that the existence of the telephone system is of general benefit to the state. It develops commerce and industry and this improves the moral and material condition of all, both of those who telephone and of those who do not telephone. This sounds like good philosophy, and shifts the burden of the argument upon the taxpayer who, for self-evident reasons, generally prefers to argue no further. The permissible charge is, therefore, eliminated from the engineering problems of telephony, in Europe, because it is a fixed quantity; in America, because it depends upon an unknowable quantity, the legislator and the demagogue, the last one often in form of some sensational newspaper which spares no pains to persuade its readers that the telephone industry in this country is the same kind of an institution as the beef trust, the coal trust, the gas trust, etc., etc.

If there is any technical advance of which this country ought to be proud, it is indeed the art of telephony. In no other branch of engineering or technology has this country maintained its lead as easily as in this, so much so that there is no second, although there is no other kind of engineering which is as highly scientific and technical as telephone engineering; and yet the demagogue paints it in the colors of a beef trust, a coal trust, or some other social aberration of this degenerate age.

Two more essential quantities are left which the telephone engineer weighs in determining the solution of the telephonic problems; these are, — first, the maximum amount of time; secondly, — the maximum amount of personal convenience which the subscriber will sacrifice in order to communicate with another subscriber. The better the service the more will the subscriber sacrifice for it, but at best he is not willing to give up much, and so the final problem of the telephone engineer reduces itself to this:

To provide a first-class service, which will be at all hours and under all conditions of weather at the subscriber's disposal, at a moment's notice and anywhere and with anybody. This problem has been solved in this country and in Germany, as far as local service is concerned, and the great problem in telephone engineering to-day is to do the same thing for the interurban telephonic communication. For example, a telephone subscriber in New York should be able to call up any other telephone subscriber in New York, Boston, Philadelphia, Baltimore, Washington, Wilmington, Trenton, Newark, Paterson, New Haven, Hartford, Providence, or any other populated centre within a radius of about two hundred and fifty miles of New York City, and get just as quick and just as good service as he gets with any subscriber in his own town. The solution of this problem would mean that all these populated centres within a radius of two hundred and fifty miles, covering a territory of a large empire, would form, telephonically, one town, where within a time interval of a few minutes one could call up anybody that is of any account and have a pleasant chat or any other kind of a conversation. A few years ago the solution of this problem would have been impossible, to-day it is, and the engineers of the American Telephone and Telegraph Company are actually working upon it with all the vigor of their young and well-trained intelligence. A similar problem occupies the attention of the engineers of the Siemens and Halske Company of Berlin.

The new method of high potential transmission of electrical waves by conductors of suitably increased inductance has given them a new weapon for attacking the problem, and they are wielding it with extraördinary force and skill. The telephonic union of the thickly populated centres just mentioned into one community covering the area of a large empire means, of course, the stretching of thousands of wires between such towns as New York, Boston, Philadelphia, Baltimore, and Washington, and that means the employment of cables in underground conduits. No pole line could support anything like that multiplicity of wires. Transmission over underground cables over such distances was an impossibility a few years ago, when a distance of twenty miles was considered quite a serious matter. To-day there is a high-tension telephonic transmission cable containing a large number of wires supplying a most satisfactory telephonic transmission between Boston and Worcester, Massachusetts, a distance of over forty miles, and the experimental results obtained with this cable by connecting several circuits in series back and forth between Boston and Worcester justify the confidence of the engineers of the American Telephone and Telegraph Company that they will certainly solve, in the near future, the grand problem of the telephonic union of the great centres of the Atlantic coast. The same confidence is expressed by the engineers of the Siemens and Halske Company of Berlin in their work on the problem of telephonic communication between Berlin and London through a cable over 400 miles under the North Sea.

A side issue of this problem is the problem of establishing a satisfactory telephonic communication between any two important centres of a continent. The new principle of high-tension telephonic transmission, mentioned above, affords a satisfactory solution, provided, however, that the insulation of overhead wires can be maintained above a certain low limit. Investigations in this direction conducted by engineers of the American Telegraph and Telephone Company, and by the engineers of Siemens and Halske of Berlin, have yielded most satisfactory results, so that the question whether we shall soon have telephonic communication with San Francisco and other places on the Pacific slope, or between say St. Petersburg and Madrid, is merely a question of a sufficiently strong commercial demand.

The Wireless Wave Transmission Problem

The public is not yet on terms of familiarity with the wireless transmission scheme. The public is not quite sure that it knows who is the real representative of this new civilizing agent. Is it Marconi? Is it Tesla, or is it some one of the many other dark luminaries? Marconi used to be their wireless hero, but there have sprung up lately so many champions of the cause of other inventors — and the courts have not spoken yet — that the public is somewhat puzzled. Under these conditions of uncertainty the public is not quite sure that the time has yet arrived to decide whether wireless transmission is essential to its present happiness. Besides, the gods of the Army and Navy departments have decided that wireless telegraphy is an essential element of their military equipment and the public must step back. The public can no more be allowed a free play with wireless telegraphy than they can be allowed to keep dynamite in their back yards or to steam about in torpedo boats. The war lords have spoken, and neither the inventor, nor the disappointed stockholder, nor the patent office dare open their mouths. When a United States general or admiral announces with all official solemnity that the scientists of the Army or Navy have devised a wireless method of their own and the intelligent public observes that not only this military wireless system but also that other alleged new wireless systems, recognized and patronized by the Government, and known as the Fessenden, De Forest, Slaby-Arco, Braun, and I do not know what other kind of systems, look in every particular like the familiar old Marconi system, they stand perplexed and ask, — well, who has invented what? For they must either all of them have invented the same thing and do not know the remarkable coincidence, or nobody has invented anything, or one man is the real inventor and the rest are bold-faced fakirs. Each one of these hypotheses seems equally improbable. This mixed-up state of affairs has produced a marked depression of public interest in wireless telegraphy, and consequently it has delayed quite seriously the progress of this beautiful new technical art. But fortunately for the art, it is so attractive that in spite of its associations with many apparently disreputable characters it is still cultivated by serious men of true scientific spirit and devotion. These men know quite well that there is one wireless scheme only, that it is a clean-cut invention of the first order, and being such it is fairly certain that it belongs to one man only, the decrees of the Army and Navy scienticulists notwithstanding; and they also know that it devolves upon them and upon the original inventor, and not upon the scienticulists of the Army and Navy, to solve the present problem of wireless telegraphy, which they feel confident to be a true engineering problem, because its solution is quite within reach of the present state of the electrical art. This problem is: A rapid, reliable, and selective communication between the continents and any point on the Atlantic. A ship on the ocean should always be in electrical touch with land.

That which is needed is an oscillator, sufficiently powerful and persistent to produce strong resonance effects. A wave-train consisting of say thirty complete waves is for all practical purposes as effective in producing strong resonance effects as a continuous train.

In wireless telegraphy oscillators of a frequency of about one million oscillations per second are commonly used. To give a wave train of thirty complete waves the oscillator would have to maintain its vibrations during an interval of approximately one thirty thousandth of a second. An oscillator of this frequency and possessing a condenser of .1 microfarad charged up to 50 thousand volts would during that brief interval of time radiate energy at the rate of approximately 15 thousand horse-power. Assuming that the giant Marconi radiator has an area of 1000 square yards, there would proceed from every square yard during a time-interval of one thirty thousandth of a second radiant energy at the rate of 15 horse-power. The radiant energy sent forth into space by every square yard of the bright surface of the moon, assuming even that it reflects all the sunlight which falls upon it, is sent out at the rate which is less, considerably, than one horse-power. Yet, although its distance from us is so enormous, our eye can feel its radiant energy even some time before the full moon has risen above the horizon and we can measure the relative amount of its radiation, sent to us, by electrical receivers which do not differ essentially from some forms of receivers employed in wireless telegraphy. This simple comparison shows what an intense source of intermittent radiation a Marconi radiator can be when actuated by a sufficiently powerful oscillator. A generator of 15 horse-power would be quite sufficient to charge such an oscillator a hundred times per second, which is sufficient even for the most rapid kind of ordinary telegraphy in actual practical use anywhere. Such an oscillator operating, say at Cape Cod, would very probably be felt at every point of the Atlantic between the European and the American coast, particularly on receiving circuits which are in resonance with the oscillator. Such an oscillator has not yet been constructed and it may not appear quite clear how so much electrostatic capacity can be crowded into an oscillator of the enormous frequency employed in wireless telegraphy. Yet I feel fairly confident that the present state of the electrical science offers abundant means for doing the thing in a very simple manner and that it will be done in the near future. But I am afraid that when it is done the official back of the electrical cat upon which the military and naval scienticulists rely for their charging generator will curve up in mad disorder; there will be an interruption in the very important official wireless communications between naval stations, one requesting the other for a loan of a few yards of rubber hose. A session of the war council would probably be called to decide how this intolerable interruption of official business can be avoided, and after careful consultation with the military scienticulists the war lords would probably decree that the existence of such thundering machines on the seacoasts is a public nuisance because it interferes with the wireless business as conducted by the scienticulists of the Army and Navy and required by the conditions existing in their administration. The wireless problem cannot become a true engineering problem so long as the war office interferes with a technical art of which it has no intelligent grasp. Soldier, stick to your guns; leave wireless telegraphy to people who can handle it with more intelligent grace and skill.

The Telegraph Problem

It is the most difficult electrical engineering problem before us. What is wanted is a system which will perform a large part of the work of the ordinary mail at any rate between thickly populated centres. That means very rapid, efficient, and accurate automatic machine sending and receiving. It also means multiplexing way beyond the performance of the present quaduplex. Theoretically the solution of the problem looks easily possible and actual experimental demonstrations have been given to prove the correctness of the inference drawn from pure theory. Mr. Patrick Delany's work in this particular direction should be honorably mentioned here. But very serious practical difficulties exist, which are known to those only who have been for a long time in actual touch with the telegraph business of this country. This business has developed historically; each epoch in its development marks an epoch in the development of the general business methods which prevail in this country.

In European countries, the telegraph belongs to the Government and its development was influenced very much by the requirements of the war office. Private business had to accommodate itself to the telegraphic conditions created by these requirements.

To illustrate: Many of the trunk lines in this country are leased to private individuals, bankers, brokers, etc. The telegraphic companies do their own business over these leased lines, employing the quadruplex method. In fact not only the telegraph company, but several subscribers are working over the same trunk line simultaneously, each one, except the telegraph company, ignorant of the fact that the other fellows are using the same ethereal channel of communication. This practice is practically unknown in Europe.

It is the opinion of men of recognized ability, who have grown old in the development and management of the telegraph business in this country, that the numerous long-distance lines covering the vast territory of the United States are so costly, both from the standpoint of initial expense for construction, and also from the standpoint of subsequent expense for maintenance, that they would hardly pay if it were not for the rental of these lines to private individuals. The same statement holds good for the transmission of intelligence over long-distance telephone wires. These, too, are rented in very many cases to private individuals for telegraphic purposes, so that long-distance telegraphy and telephony are often carried on simultaneously over the same wires.

Any new improvement which would bring us nearer to the solution of the general telegraphic problem is impracticable if it interferes seriously with the existing conditions under which, according to the preceding rough sketch, telegraphic business is conducted here at present. This explains the well-known fact that several American inventions in telegraphy were adopted abroad and proved themselves valuable, although they failed to find recognition at home on account of their inability to satisfy the requirements of the telegraphic situation existing here. The disappointed inventor can hardly be blamed for feeling sore over the apparent lack of appreciation in his own country. But if he could be prevailed upon to raise himself to a loftier level of objectivity, and thus obtain a broader view of the telegraphic situation at home, he would certainly be less severe in his criticism of what he considers to be the hide-bound methods of the antediluvian telegraphic monopolies which, in his opinion, smother every intellectual activity of inventive genius.

Those who are most familiar with the mathematical theory of transmission of rapid electrical impulses for telegraphic purposes seem to agree fairly well on one point at least; it is this: The alternating current is the most suitable form of electrical transmission for telegraphic purposes. The solution of the general telegraphic problem by means of automatic transmission, and by the adoption of multiplex methods with all the possible refinements of which these methods are capable, cannot be reached unless the alternating-current method of transmission is adopted. But then we should have in telegraphy the same practical difficulties which telephone engineers met in the early days of telephony. These difficulties are summed up by the telephone engineer and condensed into a single word, — cross-talk. It means conveyance of electric energy from one wire to another by electrostatic as well as by electromagnetic induction. It is the more powerful the higher the frequency of the alternating current employed in the transmission. The telephone engineer overcame this difficulty gradually by giving up the employment of the earth as the common return conductor for all his transmission wires, and from that day dates the symmetrical conducting loop of the metallic return circuit. Having adopted this expediency it was then a comparatively easy matter to avoid cross-talk, due to induction, by a suitable transposition of the neighboring circuits with respect to each other.

The introduction of the alternating current into telegraphic transmission would compel the telegraph engineer to resort to this same expediency which was long ago adopted by the telephone engineer, otherwise he would expose himself to the serious difficulties arising from cross-signaling.

Considering the fact that practically all telegraph lines in the country employ the ground return, it is clear that the general introduction of the alternating current into telegraph work would involve practically a reconstruction of a large part of the vast network of telegraph wires in the United States. I do not know of a single telegraph engineer in this country who would have the courage to assume the responsibility of advocating before his board of directors a policy of this kind. And so, as far as this country at least is concerned, the solution of the general telegraphic problem seems to be a matter of the dim and distant future.

SECTION D—MINING ENGINEERING

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(*Hall* 11, *September* 24, 10 *a. m.*)

CHAIRMAN: MR. JOHN HAYS HAMMOND, New York City.
SPEAKERS: PROFESSOR ROBERT H. RICHARDS, Massachusetts Institute of Technology.
PROFESSOR SAMUEL B. CHRISTY, University of California.
SECRETARY: DR. JOSEPH STRUTHERS, New York City.

THE RELATION OF MINING ENGINEERING TO OTHER FIELDS

BY ROBERT HALLOWELL RICHARDS

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THE two papers of this Section appear to call for discussions more or less educational in their intent. The first paper to draw the picture of the various calls the mine makes upon its officers, leading up through the development of the business and finally reaching as a climax the educational requirements to fit the man for the place, deals more particularly with the man. The second, to review the past development, draw the picture of the present, and indicate the lines of progress that are most needed in the near future, deals more particularly with things.

I will begin my story by attempting to show how universally the work of the mining engineer reaches the interests of all. I will then trace from early beginnings the development from the primitive chance find of attractive mineral specimens to the modern, fully equipped mine. I will show how the mine not only supplies wants of all classes but calls upon many lines to respond by contributing to mine development. And, finally, will indicate the educational lines which are developed to bring men to as good an understanding as possible of how to get the most effective results in mining with the least expenditure of material and effort.

The province of the mining engineer may be defined as comprising all the duties and abilities that a mining engineer may be called upon to perform or possess, the end point of which is the extraction of valuable minerals and placing them on the market for the service of man. He brings from the ground into active use values which previously lay dormant and unknown to the uninitiated. He builds, out of apparent nothingness, things which eventually make for use and beauty in the service of men. He has, therefore, wide ethical and philosophical relations with the development of the human race.

Development of the Mining Engineer

Looking back through the eye of the imagination to prehistoric times, we may form a conception of an order of advance in things mining. The primitive man picked up colored stones, bored holes in them, and wore them as amulets for decorative, religious, or medicinal reasons. He found the precious stones and prized them for their decorative effect. He found the gold in nuggets, and later, that he could polish, flatten, and shape it, and made a beginning in the metal manufacturing art.

Gold and precious stones at a very early date must have risen in value and begun to be property, and also begun a career as a medium of exchange. A complete mining plant, at this time, may have been an area of land with ore specimens scattered on the surface of the ground and buried in the surface soil, with a few men digging with pointed sticks and moving the soil with rude wooden shovels. The existence of ownership in the soil and mineral may have developed later.

Stimulated by mineral discoveries, the miner made efforts to define, identify, and name his mineral species and so gave a beginning to the science of mineralogy; and his efforts to establish rules of occurrence of his valuable minerals did the same for geology.

The primitive Asiatic at an early date found the effect of fire on minerals and picked up lead, copper, or iron in the ashes of his camp-fires. Cornwall tin was found in the same way.

The primitive metallurgist then experimented with his fires and got silver by burning up his lead, and bronze by alloying copper and tin.

The possibilities fascinated him, the getting stimulated the desire to get, and the ingenuity to fashion the tools to get with. In fact, the metallurgist has done much to stimulate the development of the chemist. There came to be a systematic use of fires for roasting ore, reverberatories for desulphurizing ore, crucibles for melting, cupels for purifying silver, hearths and shaft-furnaces for smelting.

The miner, pushed by his metallurgical partner, soon got to the end of the loose ore lying on the surface and began breaking it from the ledges with his stone hammers. He found that by heating the ore and quenching it with water it would crumble more easily. In fact, this was probably the chief method of mining for many centuries.

A mine at this period may have been a pit or trench twenty feet deep, more or less, from which the ore and water were carried out on men's backs, using a tree with stubs of branches for a ladder.

In time the metallurgist found that by manipulating his iron in connection with carbon he could harden it and that the hardness was greatly augmented by quenching it in water. He had made the discovery of steel and of tempering.

The miner asked for a better hammer and got one of steel and with it the "point" which by blows of the hammer chips and severs the ore from the ledge. The hammer and point, "Schlegel und Eisen," must have been the standard mining tools for many centuries.

The primitive American mined copper at least 500 years before the discovery of this country by Europeans (Egleston). This is indicated by counting the rings in tree-trunks growing in their old workings. They mined the copper with stone hammers, heating the rock with fire to make it more friable. They mined to a depth of twenty or thirty feet, but rarely went underground; used wooden shovels to move the rock and wooden bowls and bark troughs to dispose of the water. They did not want and could not use pieces of copper larger than a few pounds, which they took as they found them, beat out cold into shapes, leaving the silver attached to the copper. They apparently had no knowledge of concentration or of smelting. They used the copper for tools of the household, of the shop, of the chase, and of war, as well as for decorative purposes.

The making of iron tools enabled the miner to penetrate into the ground. He devised ropes, buckets, and a rude windlass for lifting out ore and water. His roof and walls of rock began to fall in on him and it was necessary to bring in timber props and to leave pillars of ore to hold the walls apart.

About this time the horse-windlass and a better quality of rope must have been designed for hoisting from greater depths. Mines at this time may have reached a depth of hundreds of feet with tunnels and galleries though small in size, yet cut out with a care and finish almost like that of the stonemason's work on public buildings. Such tunnels of three hundred years ago can be seen to-day in the German mines.

The metallurgist asked for cleaner ore, free from earthy and siliceous impurities which hindered or prevented his smelting operations; to effect this, the crude stamp for crushing, and the sweeping buddle for concentrating ores were developed.

As to the periods when the mineralogist, the geologist, and the chemist became separate professions, investigating everything in their lines and contributing from their stores of knowledge to the benefit of the miner, I will not discuss. But the time has never yet been reached when the miner could afford not to have a good working knowledge of those subjects.

The next great step was the use of drill and blasting powder (A. D. 1620). The slow, tedious chipping was replaced by the more rapid boring and blasting out of rock masses, and the speed of mining increased immensely.

A. D. 1776, the steam engine came to the help of the miner. The pumping engine came first, for removing water, and then the hoisting engine.

About A. D. 1840 the locomotive was invented and used for hauling coal and ore.

We sometimes think of all engineering depending on or pertaining to the steam engine, whereas the true engineer is a man who must adapt means to ends, whatever they may be and whether he ever did or did not know of them before. He can use precedent as far as it will go, and must fill in the rest from his brain. He may have to harness up a waterfall on the side of a mountain, bring down the water in a great pipe, and level gravel hills with a water jet more powerful than those used by our city fire departments. Or he may have to use the water to compress air and convey it in pipes to his mine and use it there to drive his powerful hoisting and pumping machinery and his power drills for drilling the rock.

In 1860 nitro-glycerine was introduced as a powerful blasting material, adding to the speed and economy of the work of excavation.

The miner, by his needs of prime movers, transmitting machinery, transporting machinery, and use of water, has contributed much to the development of the mechanical engineer and to a less degree to the railroad and hydraulic engineer.

The miner and the agriculturist really take shares in this development. They are both fundamental callings, taking the good things from the ground. The farmer has probably helped more in the development of the railroad, while the miner's field has given him a greater hand in developing power machinery and hydraulics.

Later these all became independent professions, and having made great advances in their studies they now in their turn contribute advanced ideas to the benefit of the miner.

But here again no mining engineer can afford to be without a good working knowledge of mechanical engineering, constructive engineering, hydraulic engineering, or railroad engineering.

This brings us to the great mines of to-day, and if we draw a few illustrations from the Calumet and Hecla Mine of Lake Superior, it will, perhaps, serve as well as any.

This represents both the primitive and the most modern things in mining. It was discovered by a prehistoric pit evidently worked by a race of advanced intelligence before the Europeans reached this country and it is now equipped with the finest mining machinery in the world. This mine is opened up by some fifteen shafts, more or less, on the slope of the deposit which are about 400 feet apart. The longest shaft is opened about 8000 feet down the slope. A vertical shaft nearly a mile deep connects with this below. Every one hundred feet, going down, there is a level or horizontal tunnel driven along the deposit either way, and these 100 by 400 feet blocks of copper-bearing rock are worked out by drilling and blasting with dynamite. The roof is temporarily supported by carefully designed timbering which holds up the roof until the rock is all worked out, and then gradually crushes, letting the roof fall in. Every one of the levels has been carefully surveyed so they will properly connect with each other and the ends will not go beyond the boundary-lines, and they are supplied with a railroad track and cars. Every shaft has been surveyed, supplied with a track for the hoisting-skip and a hoisting-rope, at the top of the shaft is a rock house with two immense rock breakers, two great sheaves for turning the hoisting rope and a hoisting engine powerful enough to lift at great speed the rope skip and copper rock, weighing many tons, to the surface. Beneath the breakers is a great rock bin and tracks for shipping the rock down to the mills at Lake Linden, five miles away.

Several great air compressors furnish air for the rock drills operated by 3000 miners, more or less, producing 5000 tons or more of copper rock per day.

The mine has waterworks bringing the pure water of Lake Superior up to 600 feet in height, four miles in distance, to supply the boilers and also the company's houses.

A huge revolving fan uses one shaft for ventilating the many miles of shafts, levels, and stopes, giving the miners fresh air and removing the powder smoke.

The mine has machine-shop, foundry, blacksmith-shop, and carpenter-shop, capable of doing the finest work on large or small scale.

Going to the mills at the Lake, we find two large mills with about eleven steam stamps each, 22 in all. Each of these stamps can crush nearly 300 tons of copper rock per day and each has a large number of jigs, Wilfley tables, and revolving tables for concentrating the crushed rock. They appear like monster factories filled with busy machines, and treat between 5000 and 6000 tons of copper rock per day.

There are two immense pumps lifting a quantity of water, sufficient for one of our large Eastern cities, for the mill work.

The shops of the mine are in the main duplicated at the mills. An idea of the importance of this mine to the people may be obtained when it is stated that the Calumet and Tamarack mines together support a population of about 13,000, and the mills about 5000 more, speaking some seventeen different languages, who are being transformed into American citizens. They have their schools and churches, and furnish a market for farm and garden produce. All of this would not have existed but for the mines.

The development of gold placer-working is of interest and deserves to stand out by itself. The miner washed his sand or gravel in a pan; settling the gold to the bottom, and working off the gravel over the edge, he recovered a few particles of gold from each panful. It was back-breaking work, and he could only pan perhaps a few hundred pounds per day. The rocker or cradle with little depression or riffles followed with two tons per day, the tom or little sluices with riffles with ten or twenty tons, the riffle-sluice with a capacity measured only by its width and the quantity of gravel that could be brought to it. The increased quantity was obtained by the giant or jet of water issuing from a nozzle five to nine inches in diameter under a head of 200 to 1000 feet, capable of moving thousands of tons of gravel to the riffle-sluice several miles long, saving many thousands of dollars of gold. At this stage an opposing interest appeared in the farmer on the low land whose river was filled with débris and his farm flooded with water. To overcome this difficulty, various schemes of retaining-dams were devised and found to a very limited degree successful. Later came the dredger, which for certain deposits holds the field to-day. It is a flat-boat floating on its own little pond with a chain-bucket dredging-tool at the bow, a screen and riffle-tables to save the gold, and a stacker or elevator to pile up the refuse at the stern. This boat performs the curious feat of traveling across the country carrying its pond with it, cutting away the gravel in front and building it up behind. These dredgers mine, for about six cents per cubic yard, 2000 yards per day, and the gravel may run from ten cents to one dollar per cubic yard.

The dredger is self-contained, saves the gold, and does not infringe upon the rights of the farmer.

Summing up Development

And so through the various stages, the development of mining has gone on until we have the large modern mine equipped with fine machinery for excavating and tramming, those with powerful hoisting engines for lifting hundreds of tons from thousands of feet in depth, with great ore-breakers for crushing the rock, and fine concentrating machinery for enriching the ore; furnished, also, with monster pumps for removing the water from great depths and for furnishing the concentrators and fans for taking out the powder smoke and other dangerous gases, preserving the lives of hundreds of men; furnishing problems for the mechanical engineer in the handling of great masses of material with rapidity and economy; with problems in surveying the most difficult the civil engineer ever has to encounter, for example to fix exact property boundaries or to unite subterranean galleries thousands of feet below the surface, and in hydraulics for the handling of immense volumes of water to be made use of or to be got rid of, and in electricity for the transmission of power many miles from distant mountain streams to excavate, tram, hoist, pump, ventilate, and light the mines, the construction of great buildings for housing his machinery or his plants; adapting crushing and concentration plants for the most successful concentration of the ore and of smelting to extract the metal with the least cost and greatest efficiency and purity; the wise selection of subordinates for efficiency and loyalty; the handling of the men to get a day's work and keep them contented and happy; the financiering of the mine to get the money for opening up and developing, to keep up the dividends and the repairs and development work and sinking fund all at the same time so that the owners may feel that they get interest on their investment and get their money back after the mine is worked out.

This completed picture seems to call for a combination of mineralogist, geologist, of a mining, mechanical, civil, and electrical engineer, of a chemist and metallurgist, of a builder, a manager, and a financier, a man with literary ability and personal magnetism. Such a combination seems absurd at first glance, life is n't long enough to accomplish it, and yet, with certain provisos, it is exactly what is done.

Mining enterprises occur of all sizes from very small to very large. It transpires, then, that in the small mining venture the mining man must be able to handle all the departments specified; while on the other hand in a large mine he has many departments with department heads, mechanical, civil, and electrical engineers, builder, chemist, and others, but he has to direct all, so that a good working knowledge along the various lines is quite as important if not more so than in the case of the smaller mine.

The question may now well arise, On what lines and how should a man fit himself for this class of position? How can he best master this wide relationship of the mining engineer to the other fields?

I will attempt to answer this question in some detail. The accomplishments he needs are comprised substantially in this list:

English: He should speak, read, and write the English language well, to convey intelligently his plans and suggestions to his superiors, his wishes to his subordinates, and to read up his authorities on matters professional.

Language: He should know foreign languages for ease in conversing with foreigners and reading their works.

Literature: He should be familiar with good literature, to give him ease in meeting people.

Logic: He should understand the basis of argument, the relations of cause and effect, both as to men and things.

Mathematics: He should be able to use mathematics for clear thinking, demonstrating, and estimating.

Physics: He should be familiar with the laws of physics; mechanics, heat, light, electricity, sound, pneumatics, hydraulics, to help him act wisely in professional matters.

Chemistry: He must understand the laws of chemistry, not only as to effects of humid operations but as to effects of fire.

Drawing: He must have a good working knowledge of drawing for clear thinking, for making designs, for expounding plans to others, and for directing work.

Power: He must know the prime movers in their operation, their economy, and efficiency.

Machinery: He must understand the transmitting machinery, to bring his power to the commercial end point with the greatest economy.

Railroads: He must understand the laying out and running of railroads, including cuts, fills, tunnels, grades, tracks, switches, bridges, rolling-stock, locomotives for conveying his material.

Surveying: He must understand surveying for defining underground boundaries, for meeting underground workings, for locating, grading, roads, buildings, machines, water-pipes, ditches, wires, etc.

Mineralogy: He must know and be able to determine the minerals of economic importance, to recognize and take advantage of values when and where opportunity occurs.

Geology: He must be skilled in geology for locating deposits, in preliminary work, and for predicting the whereabouts of ore-deposits in existing mines.

Materials: He must know the materials of engineering — what, when, where, and how to use them, and also to preserve them.

Structures: He must know the principles upon which structures are built and the practice in building.

Law: He must be up in the law of contracts and of titles, to see that his company gets its rights in purchasing materials, selling materials, and in ownership of its property.

Labor: He must know the value of a day's work and see to it that his men know that he knows. He must study the labor problem so as to deal wisely in the time of need.

Business: He must understand the principles on which business is transacted so as to get fair treatment and yet keep his customers.

Finance: He must understand the principles of banking, and of establishing and holding credit.

Mining: He must understand the mining operations, safely to mine, prepare, and ship the ore or coal.

Metallurgy: He must understand the chief metallurgical operations for the common metals so as to suit the metallurgist with his ores or become a metallurgist if opportunity and inclination lead him that way.

He will equip himself along as many of these lines as he can, and establish connections for supplying those which he has not acquired.

We will now look to see what he does in return for favors received.

If we look about us, scarce an object can be seen to the production of which the miner and metallurgist have not contributed. Metal objects owe their strength to the iron or the copper alloys of the miner, their purity to the metallurgist, their beauty and decorative effect to gold, silver, brass, bronze, stone, pottery, and wood, all of them got from the mine or fashioned by metal tools from the mine. Our carriages, automobiles, locomotives move us from place to place; our wires carry our telephone and telegraph messages; our sewing-machines make and mend our garments; our saw-mills make the lumber for our houses; our harvests of wheat, corn, and potatoes, our pots and pans, knives, forks and spoons for cooking and serving food, all either themselves come from the hands of the miner or the tools for fashioning or getting them are the result of his labor; our diplomatists after doing their all with wits come as last resort to the battleship, the guns, the riffles, and the lead from mines. And, finally, the medium of all finance with which we run our mines, our factories, and with which we purchase our wares and supply our wants, whether for peace or war, is the gold from the miner's pick and shovel. We may say, then, that the work of the miner reaches the interests of all.

Coming now to the schools in which he is to prepare himself for his life's work: there appear to be three plans of education which deal with the problem of equipping men along mining engineering and metallurgical lines.

(1) The school of practice, supplemented by the correspondence school.

(2) The technological school.

(3) The university followed by the technical school.

Some pupils of all three plans reach the highest pitch of professional responsibility, as the whole question is more one of the man than of the plan. We have no reliable statistics showing percentages of success of or proportional success. One is obliged to resort to opinion, and the opinion of no two may agree.

The especially strong point in the first plan is the intimate knowledge that is acquired of the employee class and of the minute details, — knowledge of work which is obtained in the doing of it.

The especially weak point in the first plan is that it is narrow and that progress is slow. Experiments may be more expensive to the company and in consequence a greater conservatism rules and lack of readiness to adopt new ideas even when proved.

The second plan has the advantage that in four years from the high school the student is equipped and strengthened along a sufficient number of lines so that he can do the rest if he is reasonably energetic and sensible. He may tumble down because he has not made a sufficient study of the employee class. He can perfectly well avoid this, however, by taking hold of manual work as a laborer or a miner for a sufficient time to acquire the knowledge of what men are, what they do, and how they do it. He may tumble down because he has not made a sufficient study of how to deal with men who are his superiors, or of the capitalist class. This he can avoid if he will accept every opportunity to meet men, and keep himself well read up on the progress of his profession and on affairs of public interest, together with reading of good literature.

The third plan takes six, seven, or eight years from the high school and may lead to crystallization of the man even to the point of inability to adapt himself to what is wanted of him. This is the weakest point of this school. His best prevention or cure will be to take hold of work as the laborer and miner and make an intimate study of the employee class by doing the work side by side with them. In regard to the professional work, the third plan may or may not have an advantage over the second in consequence of maturity. The logical advantage may be offset by the time lost and by hurtful crystallization. "The college student may have learned to do nothing thoroughly well, and if he enter the scientific school after graduation may be less fit to do its work than he was four years earlier. He may have learned to depend on text-books rather than observation, and on authority rather than on evidence." The strongest point of the third plan is the knowledge the student gets of men of influence who later become capitalists. If, however, the member of the second school is energetic and sensible in working for this, it is doubtful if even this is a sufficiently strong point in favor of the third plan to give it preference over the second.

The circumstance of opportunity may come about differently in these plans of education. A fine engineer may be hidden away in some obscure position who would, if circumstances had favored him, have become renowned all over the world by the greatness of his capacity. The third plan may have some advantage in this respect, in finding out the great man and bringing him to the front. This is more an incident than a virtue of the third plan due to the men who follow it.

PRESENT PROBLEMS IN THE TRAINING OF MINING ENGINEERS

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"THE man is always greater than his work." The training of the men who are to develop the mineral resources of the world is the most important problem connected with mining engineering. It becomes ever more important to civilization as the mineral wealth of the earth approaches exhaustion. I have therefore decided to consider a few of the more important problems arising in the training of the mining engineer, and especially those arising in America.

The Peculiar Nature of Mineral Wealth

Mining and agriculture are the two fundamental arts. Without the latter our existence would be precarious; without the former, our civilization impossible. Agriculture furnishes that regular supply of food and raiment which leads to the growth of large communities in which cultivated leisure first becomes possible; while mining furnishes the metallic thread from which is woven that complex fabric we call civilization.

But in these two arts the conditions for success are widely different. Most of the crops that the farmer reaps may be harvested year after year, and, the proper fertilizers being added, he may continue the annual harvest indefinitely, while, as a result of cultivation, his farm becomes yearly more valuable.

But the crop the miner reaps can be harvested but once in the history of the race. Our mineral wealth has taken unknown ages to mature in the bosom of the earth. The ripened fruit can be plucked but once. There are no fertilizers for worked-out mines. It never pays to work over a mine that has been "robbed," either through ignorance or lack of skill; and a worked-out mine is utterly worthless.

These differences between the two kinds of natural wealth have been long recognized, and have led in the Old World to a very conservative policy in the utilization of mineral wealth.

Though the fragmentary history of primitive mining-law is full of contradictions, it would seem that the development of the mineral wealth of the world was at first everywhere due to the free initiative of the miner, whose exertions were stimulated by the right to possess what his energies discovered. But everywhere in the Old World the mailed hand of the sovereign soon seized this important source of wealth and power. It was used at first exclusively for his own benefit, but as more enlightened views of the duty of the sovereign to his people spread through Europe at the end of the Middle Ages, these special rights and privileges have been used more and more for the benefit of the whole people. At the present time in some of the Continental countries individual initiative and ownership has asserted itself once more; still, it is generally true that in most of the countries of Continental Europe the mines are either owned or are worked under the direction of the Government. In these matters the policy of Great Britain and her colonies has been, in general, intermediate between that of the United States and of Continental Europe. Hence, in what follows I shall dwell chiefly on the differences between Continental and American customs.

Continental and American Mining-Schools

When European mining-schools were first organized they also came naturally under Government control, and there consequently resulted a close union between the mines and the mining-schools. This in turn led to many other important consequences. A regular career was opened for the graduates of the mining-schools either by their direct employment in mines operated by the Government or in the inspection and direction of the working of mines under Government control. As a consequence of this policy, well-trained men have always had the management of the mines under a sort of civil service system. And also a wise conservation of the mineral wealth of these countries has resulted; the mines are worked systematically and have often kept producing a steady output for several hundred years, while in our country they would have been worked-out and abandoned in one or two decades. While, according to our ideas, there are drawbacks to the Continental policy, it certainly lends a restraining influence to the natural uncertainties of mining life; it gives a more certain tenure of office to the mining officials; and, consequently, results in a more conservative policy in the management. It effects a more complete extraction of all the ore in the deposit, a better avoidance of wastes and a more complete utilization of all the side products. On the whole, the system, when wisely administered, leads to excellent results.

Its effects on the early development of the mining-schools were also favorable. The close relation between the mines and the mining-schools made it easy for the one to assist the other. The graduates of the mining-schools were as sure of employment in an honorable profession as are the graduates from our Government military and naval academies at West Point and Annapolis. Historically, this connection has lent the air of distinction that clings to the profession of the mining engineer apart from his function as a mere money-getter.

On the Continent two grades of mining-schools have grown up. The *Bergschule* and the *Bergakademie.* The *Bergschule* trains working miners for the duties of mine foremen, while the *Bergakademie* trains young men of the educated class for the duties of the mining engineer.

The system here outlined possesses many advantages and is admirably adapted to the countries where it originated. But it would be impossible in America. In the first place our Government gives away its mines and does not attempt to control either them or the mining-schools. No official connection either exists or is possible between them. Moreover, though there is much to be said in its favor, the sharp distinction drawn between the *Bergschule* and the *Bergakademie* in Europe is at variance with American ideals of democracy.

It has become an axiom with us that not only genius, but also talent, ability, and capacity of any kind, are too precious to the entire community to allow them to go to waste. We err, indeed, by going to the other extreme. But there is no doubt that the wonderful industrial progress of America is largely due to that equality of opportunity that is here practically open to every young man of ability.

The American Temperament

It has often been claimed that the American temperament is due to our peculiar climatic conditions. As a matter of fact nearly all the climates of the globe characterize our country. And in order to disprove this theory one has only to cross the narrow line that bounds our country either to the north or to the south to find a relief from the strenuosity of the American temperament. The American temperament is due, not to climatic conditions, but to a mental attitude toward life. When a man feels that his future depends not so much upon his own efforts, but mainly upon the position to which he was born, he is, if not contented with his lot, at least more likely to be reconciled to it; for he feels it idle to waste himself in useless effort. But if you can convince such a man that there is no limit to his ambition but that of his own powers, you have fired him with the most powerful stimulant that can influence human nature. It is this stimulant, working day and night for over a century upon men descended from every race in Europe, that has produced the American temperament.

It is a temperament that was not unknown in Greece in its great democratic days. Republican Rome felt it too. But in monarchies its influence is mostly confined to the army and the navy. For in war times the best man must be had regardless of his birth. Napoleon overran Europe by declaring to his men: "Every soldier carries the Marshal's bâton in his knapsack."

The Rôle of "the Practical Miner" in America

Nowhere in America has this influence been more keenly felt than in the mining industry, particularly in the Western States. The policy of our Government in throwing open to the hardy prospector its ownership in the mineral wealth of these states has stimulated men without previous technical education and training to accomplish what in older countries would be regarded as physical impossibilities.

It is true that the path has been marked with waste of money, labor, and life. Blunders, failures there have been, and still are, innumerable. But the accomplishment is all the more remarkable when we recognize these facts, for it testifies to the almost superhuman energy with which these obstacles have been overcome.

We are greatly indebted to the Old World for its contributions to the mining and metallurgic art, but we are beginning to repay the loan with generous interest. And, to tell the truth, it is largely due to the plain average American, without college education or training, that many of these advances have been made. Every one who has mixed much with American miners has met and honored many such uncrowned kings. *And unless the graduate of American mining schools is ready and willing to meet with this kind of competition without fear or favor, he will surely and deservedly fail.*

This was the first great problem that confronted the American mining schools and it has proved their greatest advantage. There is no royal road for their graduates. They cannot depend on the Government for places in the mines, because the Government neither owns, works, nor attempts to control the mines. Neither can they look to their diplomas as a guarantee of employment.

The American attitude on this question has hitherto been very different from the European. Credentials, degrees, diplomas, and recommendations that in Europe carry great weight, in America often receive but scant attention. The American often amuses himself with titles, but deep down in his nature is an instinctive distrust of any one who takes them seriously. Among the men who have done most to develop the mineral wealth of our country this feeling is particularly strong. What a man is, is more important to them than who is he. What a man knows interests them but little; it concerns them much more, what use he can make of this knowledge.

Herbert Spencer, a radical in so many of his opinions, was quite in sympathy with this point of view. I quote from his *Autobiography*, vol. I, p. 199, beginning with a passage from a letter to Herbert Spencer from his father:

"'I am glad you find your inventive powers are beginning to develop themselves. Indulge a grateful feeling for it. Recollect, also, the never-ceasing pains taken with you on that point in early life.'"

Herbert Spencer then adds:

"The last sentence is quoted not only in justice to my father, but also as conveying a lesson to educators. Though the results which drew forth his remark were in the main due to that activity of the constructive imagination which I inherited from him, yet his discipline during my boyhood and youth doubtless served to increase it. Culture of the humdrum sort, given by those who ordinarily pass for teachers, would have left the faculty undeveloped."

Footnote by Mr. Spencer: "Let me name a significant fact, published while the proof of this paper is under correction. In *The Speaker* for April 9, 1892, Mr. Poulteney Bigelow gives an account of an interview with Mr. Edison, the celebrated American inventor. Here are some quotations from it: 'To my question as to where he found the best young men to train as his assistants, he answered emphatically: 'The college-bred ones are not worth a ——! I don't know why, but they don't seem able to begin at the beginning and give their whole heart to the work.' Mr. Edison did not conceal his contempt for the college training of the present day in so far as it failed to make boys practical and fit to earn their living. With this opinion may be joined two startling facts: the one that Mr. Edison, probably the most remarkable inventor who ever lived, is himself a self-trained man; and the other that Sir Benjamin Baker, the designer and constructor of the Forth Bridge, the grandest and most original bridge in the world, received no regular engineering education."

Mr. Spencer might have added himself to this list of remarkable self-made men, for his schooling, though excellent as far as it went, was very meagre, and he made himself what he came to be.

In the words: "*I don't know why, but they don't seem able to begin at the beginning and give their whole heart to the work,*" Mr. Edison has put his finger with singular acuteness on the principal failing of improperly trained college students. The reason why they are not willing "to begin at the beginning and give their whole heart to the work" is because their education has often been so exclusively theoretical that they are filled with the conceit of learning, and they have an inordinate idea of their untried abilities. Hence their unwillingness "to begin at the beginning." They feel that they ought to begin at the end and be put in charge of everything. If, in their training, theory and practice had gone hand in hand, this conceit, which is natural to all young men, would have been soon dissipated by the hard realities of practice, and the young men would have been more willing "to begin at the beginning," and more ready and able "to give their whole heart to the work."

At the same time I cannot help thinking that Mr. Edison must have been unfortunate in his choice of "college-bred assistants," or in the colleges that trained them; for in opposition to his experience may be quoted the practice of a large number of his important rivals in the electrical business and of an increasing number of iron and steel railway bridge construction, and mining and smelting companies, to draw upon the graduates of engineering schools for their assistants; and where they wisely insist on the men beginning at the bottom and working their way up according to merit, the results have been, on the whole, more and more satisfactory as the engineering schools have adjusted themselves more closely to their environment. I have given these strong statements of the failings of college-bred men, not to indorse them, but because they contain an important truth that must be recognized and met.

This condition of public opinion has from the very first forced the American mining schools to stand on their own merits. Whatever success they have achieved has been due to this hard necessity.[1] The atmosphere surrounding European mining schools is so different from

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[1] I append in this connection the following concise and caustic note from the *Engineering and Mining Journal*, p. 403, June 12, 1880, which shows the condition of affairs in America only 25 years ago. The hope expressed in the last paragraph has since been largely realized to the benefit of all concerned.

"A correspondent writes us, asking 'If it is absolutely necessary to be a graduate of a school of mines before being able to engage in the business of a mining engineer.' Certainly not; in fact, before engaging in the business of mining engineering it does not appear to be absolutely necessary that a man should know anything at all, as our correspondent can very well satisfy himself by visiting nine out of ten of the mines nearest to him, wherever he may be. Had our correspondent asked, whether it would be desirable that a man should be a graduate of a school of mines before engaging in mining engineering, we should have answered in the affirmative, for the simple reason that the course of study in a school of mines is calculated to give the elementary education necessary for a mining engineer, and, other things being equal, should give its recipient an advantage over those who have learned the business only in practice. The course of study in a school of mines is not, however, sufficient to qualify a mining engineer to take charge of important works; but it forms an excellent foundation upon which to build a practical knowledge of the business.

"Many of our mines are now under the direction of competent engineers and the results of this policy are justifying the hope that, before very long, all companies of good standing will place their mines in charge of men specially trained for the discharge of the responsible and important duties of a mining engineer."

that in America that graduates from such schools have always found in America much to be unlearned. The American mining schools have already adapted themselves so well to their environment that this year, for the first time in nearly a century, there were no American mining students in the great Saxon Mining School at Freiberg. And already some of the American mining schools have exceeded in wealth, in equipment, and in attendance, this most famous of all mining schools.

Is Theoretical Training Worth While?

But, it may be urged, if practical men without theoretical training have accomplished so much, what is the use of theoretical training? Why not confine the education of the mining engineer to the purely practical part, omitting all the theory? The answer is not far to reach. The purely practical man has indeed accomplished wonders, but at the cost of enormous waste of money, labor, and human lives. For every success that he has made there are a thousand failures which only the thoughtful notice. There is no profession where practical experience is more essential than in mining, but the necessity of a sound scientific training is even more indispensable. A hard-headed Arizona miner once put the matter very tersely when the superiority of the "practical man" was being strongly urged, by saying: "I have had thirty years' practical experience in mining, and I would give twenty-five of those years to have had a good technical education to begin with." He was clearly right, for a man well trained in fundamentals has a broader grasp and can more intelligently and rapidly utilize his experience than a man without this training.

Either theory or practice alone is helpless; united they are invincible. And the brilliant success of the American mining engineer in so many fields has been because these two important elements have been so thoroughly blended in his training.

Specialization, How Much and When?

This problem arises from the great breadth of training which has been necessary to the American mining engineer. Like the soldier or sailor, he must go to the ends of the earth. His work often lies beyond the borders of civilization, where, like Prospero upon his lonely isle, he must conjure up his resources from the vasty deep; and he must act in turn as geologist and as civil, mechanical, hydraulic, electrical, mining, or metallurgical engineer. The problem is: What degree of specialization shall be undertaken in an undergraduate mining course? Shall we endeavor to turn out at graduation specialists, each completely equipped for work in some narrow line, or shall we rather attempt to establish a broad basal training in the physical sciences on which the future engineer may safely build, as circumstances may require?

The former system is the European practice, such parallel courses as mining engineering (further subdivided into coal- and metal-mining), metallurgical engineering (also subdivided into two branches), mine-surveying, mine-geology, and the like, being commonly recognized departments within which the student specializes in an undergraduate course.

In an old community, where the mines are under Government control, and customs have crystallized, such a specialization is wise. Each student can estimate with certainty the need for the specialty he chooses, and be sure of employment in his own line.

But under American conditions (with a few notable exceptions, where conditions have become relatively stable), it is unsafe to specialize too soon and on too narrow a basis. Here the mere specialist, outside of his specialty, is as helpless as a hermit crab outside of his shell, and unless he possesses the ability to adapt himself speedily to a rapidly changing environment, is sure to go under. The present age in America is one of rapid change in all industrial and engineering methods, such as has never been seen in the world before. Old established processes are being continually swept aside and replaced by new ones. These changes occur with kaleidoscopic speed and unexpectedness; and the man who has painfully armed himself with precedent and ancient lore finds himself hopelessly beaten before he can even make a start in the race. The American has always been characterized by his fertility of resource and power of adaptation. This has been his strength; his weakness has been his impatience to plunge into practice without a sufficiently broad and deep scientific training.

Fundamentals First

I believe that we can trust to the American instinct of adaptability without much further attention. But that which is most necessary is to insist more and more on a solid foundation of scientific training to begin with. If we can secure for the American mining student a foundation training broad, deep, and thorough in mathematics, physics, and chemistry, he needs little else to make him invincible. The mining engineer must have a broader basal training than either the civil or the mechanical engineer, even though he specialize less. Mathematics, physics, and chemistry are necessary for all engineers; but for the civil engineer mathematics is fundamental, for the mechanical engineer physics is equally so, while for the mining engineer we must not only add physics, but also chemistry, with her closely related allies, mineralogy and geology.

The training of the mining engineer cannot be too thorough in all these subjects. Each is an essential support to any superstructure that he may desire to build in the future.

Mathematics should include the differential and integral calculus, the theory of probabilities, and the methods and criteria of approximations. A firm grasp of space-relations as developed in descriptive geometry is peculiarly important in following geological structure and vein-formations in the deeps of the earth. The mathematical work should be made familiar by numerous applications to concrete cases in which numerical results should be insisted upon. In this connection it is particularly important that the engineer should be made to realize that the most important part of his numerical result is the position of the decimal point, and only after that, the value of the first significant figure. Mathematical instructors too often neglect this, to the engineer, most vital matter. The sense of it should be made instinctive. It is much more important that mathematical instruction should be thorough as far as it goes than that it should feebly cover a large territory. The subject should be so thoroughly mastered that it comes to fit the hand like a well-worn tool.

No man is fit to teach mathematics to engineers who has not had some experience in its applications either to engineering, to physics, or to astronomy. For only such a man knows just what to emphasize and what to omit, how to sympathize with, and how to inspire his students.

Men of prime ability in the mathematical faculty are absolutely the first essential in any engineering school. It is wonderful how difficulties melt away like wax in the fire with a really able mathematical teacher. By such a teacher mathematics can be made as interesting as a romance to the average man; while it is often regarded as hopelessly difficult merely on account of the poor hands in which it is placed. To make new discoveries in the field of mathematics requires genius of a high order; but to master all the mathematics necessary for the intelligent practice of engineering requires no faculties beyond those of a logical mind, a certain power of imagination, and a reasonable degree of application. I have always found that the students who do well in mathematics do well in everything else that requires close thinking.

Instruction in physics and in mathematics should go on side by side; and the two courses should be so arranged that the mathematical principles may be at once applied to physical problems of a useful nature. The importance of actual numerical results should be always insisted upon. The student should be trained in the arts of observation and in inductive as well as deductive reasoning. He should acquire practice in the theory of approximations and should form the habit of judging or "weighing" his own results and of checking them by independent methods.

While the whole field of physics is important, the fundamental conceptions of analytic mechanics (acceleration work, kinetic and potential energy) and their applications in hydraulics, thermodynamics, electricity, and the like are vital, and cannot be too much emphasized.

Instruction in chemistry should be given parallel with mathematics and physics. It offers a fine training in inductive reasoning. Besides the usual courses in general and analytic chemistry, the modern methods of physical chemistry, as developed by such masters as Arrhenius, Ostwald, Nernst, and van 't Hoff should be brought to the attention of the student, as soon as, by his collateral training, he is made able to understand them. It is not too much to say that the hope of the future, not only in biology, medicine, and hygiene, but also in physical geology, the science of ore-deposits, and the art of metallurgy, lies in this direction.

Such subjects as drawing, surveying, and mapping may also be carried on simultaneously with mathematics and physics, each supplementing the other. Similarly, assaying and mineralogy give a new interest to chemical principles, to which they serve as useful applications. Geology, itself, important as is this noble subject, not only through its intrinsic interest, but also in its practical bearings, is really only an application of the principles of physics and chemistry to the study of the evolution of the earth. And it can be mastered only by him who has this training to build upon.

The same is true of every branch of engineering. Each is only the outgrowth of the application of the principles of the fundamental physical sciences to the needs of man. He who has this training has the master-key to the door of every industry.

The necessity for thoroughness in this fundamental work cannot be too much emphasized in American mining schools. The impetuous preference of young Americans for what they deem "practical" is a serious hindrance to real achievement; and the only way to remove it is to convince them at the very start of the power and value of science. This can best be done by leading them, from the beginning, to apply science to some useful purpose. In short, they must be taught by experience the truth of Ostwald's saying: "The science of to-day is the practice of to-morrow."

There is much to be said in favor of the study of science for its own sake. We have all sympathized with the sentiment of the mathematical professor who "thanked God that he had at last discovered something that never could be put to any practical use." Still, it is a healthful instinct that leads most men to estimate the value of ideas by the use that can be made of them, and whether we approve it or not, the world will continue to do that, and we may as well adapt our plans to the fact.

To the man thus fundamentally trained nothing is impossible. He may still need to be made familiar with the general scope of each of the main branches of engineering, their relations to each other, the nature of the problems that each is called upon to solve, and the leading methods which, in each branch, have stood the test of time; and he should be made sufficiently familiar with the literature of the subject to know where to go for needed particulars; but any attempt to cram his memory with the details of methods that may become obsolete, before he is called upon to use them, is a distinct and fatal mistake.

The Organizing Faculty

The successful engineer is a creative artist in the use of materials and energy. In this class, he stands first who with the smallest means produces the greatest results. Success will come most surely to him who clearly sees the nature of each concrete problem, and, from the widest outlook, chooses just the right methods, materials, and forces of men and nature, to bring his undertaking to a successful issue.

Among engineers the creative or organizing faculty is a natural gift as rare as any other kind of genius. But fortunately it is a faculty most Americans have, at least in embryo, and it can be cultivated. All the work of a mining school, whether in the basal sciences or in the technical branches, may be utilized to develop it. Instead of possessors of encyclopedic erudition, there is needed a type of man that may mechanically remember less but can do more. Such a man learns to analyze each problem that comes before him; when necessary, he runs down the literature bearing upon it; selects the good; rejects the bad; supplies by ready invention the missing link; decides what must be done, — and *does it*, cleanly, rapidly, and with certainty, while the "encyclopedia maniac" is still digesting his erudition.

This kind of training, repeated again and again with every subject studied in the college course (at first in small and simple problems, later in larger and more complicated ones), does more to create the engineering faculty than anything else that can be devised. It is only by actually doing things that we learn how to do them. Action must follow reflection, and reflection must precede action for successful and useful life. Unless action follows reflection, life is "sicklied o'er with the pale cast of thought." Unless reflection precedes action we have all the ills that follow impetuosity, of which anarchy is the final and the bitter fruit. From this point of view the training of engineers has a moral effect on the whole body politic, since it tends to create a solid, well-balanced element in the community. Nothing develops a good man sooner than responsibility, which forces not only reflection, but action also. And the sense of power that comes with the successful exercise of the creative faculties in the engineering arts is one of the purest and keenest pleasures of which our nature is capable.

The greatest service those in charge of the higher technical branches of the mining school can render their students is to show them how to apply their scientific knowledge to such practical problems as come before them. He who can do this for his students, and can give them a taste of that sense of power that comes from a mastery of the forces of nature, can trust them to go the rest of the road without a finger-post to point the way.

Personal Contact with Working-Conditions

I have said that the mining engineer should learn to see clearly the problems that he must solve; that he must be familiar with the materials and the forces, not only of nature, but of human nature, with which he must work. How shall he gain this knowledge? There is only one way: To become familiar with them by actual contact.

Should this experience come before, during, or after the college course? It is most useful when it comes in all three ways. But coming only after the college course, it is altogether too late. Before that course, it can be usually gained only at the sacrifice of that general training, particularly in the languages and the humanities, that is so important to us all; and, moreover, before college-age the student is usually physically too immature to undertake such work. For these reasons it is usually best to let this experience begin with entrance into the mining-school. In each college year, as commonly arranged, from three to four months are given to vacations, which, occurring at regular periods in summer and winter, are admirably adapted to a progressive course of practical work in surveying, mining, and metallurgy, in which the student can familiarize himself with practical conditions in different localities. For the reasons already given, this work should begin with the school course, and be carried on progressively, at regular intervals, with the theoretical work. It is thus practicable for the student to gain nearly a year of experience in a considerable range of methods. He is thus in a position to determine his own fitness for the work; to learn the branches for which he is best adapted, and for which there is most demand; and to make acquaintances that will be useful to him afterwards. If he shows aptitude for the work, he is reasonably certain of finding the place for which he is suited; and if he does not, he can adjust himself to some other calling without further waste of time.

The importance of this training for the mining engineer is greater than in any other branch of engineering; for the conditions that he must meet are entirely different from those of any other calling. But it has been much more difficult to secure it under American than under European conditions. Besides the lack of official connection between the mines and the mining schools, there has been a strong prejudice against college students on the part of practical men. This is partly due to experience with men trained exclusively in the old classical course, and almost helpless in practical affairs, because absolutely without knowledge or sympathy with nature. But it is also partly due to the self-assertion, flippancy, and conceit of which young men just out of college are often guilty.

The "Mining Laboratory"

Several solutions have been proposed to meet this difficulty. The first and most original is the so-called mining laboratory, perfected through the pioneer work of Prof. R. H. Richards of the Massachusetts Institute of Technology. This has since become a prominent characteristic of American mining schools generally, and is now being adopted in Europe. According to this plan, the leading operations of crushing, concentrating, and working ores are executed by the students on a small working-scale in the laboratories of the school itself. In this way the schools have become partly independent of the mines, so far as the study of metallurgy and ore-dressing is concerned. In purely mining practice the problem is more difficult. I have for ten years, with some success, made an attempt in this direction, so far as rock-drilling and blasting are concerned. For this purpose, a mining laboratory has been provided, in which the operations of sharpening, hardening, and tempering drills, and the single- and double-hand drilling of blastholes, as well as machine-drilling, are illustrated on a working-scale. Later, with the aid of an experienced miner, the operations of blasting are conducted by the students in a neighboring quarry. In the new mining building, provided for the University of California by the generosity of Mrs. Hearst, it is proposed to extend this work, as far as practicable, to other branches. These devices have all proved very useful in familiarizing students with important current methods, under conditions where they may be controlled and studied in detail, even better than in the hurly-burly of practice. The mining laboratory is one of the most important of the efforts of American schools to adjust themselves to their environment.

The Summer School of Practical Mining

But helpful as this method has proved to be, it still fails to bring the student face to face with the actual conditions of mining practice. The next important step was taken by Prof. Henry S. Munroe, of the Columbia School of Mines. For many years he has devoted much labor, with notable foresight, judgment, tact, and discrimination, to the system now known as the Summer School of Practical Mining. To him, more than to any other one man, we owe this very useful adjunct, which has been adopted, with various modifications, by most American mining schools. It is an outgrowth of the geological excursion, so long practiced in German mining schools. But here it has been made to comprise the study, by a body of students, under the direction of their professors, of the leading operations of mining, dressing, and working ores. One or more mining districts and several mines are visited, during a trip of a month or more. Surveys are made; sketches and notes are taken; and the student begins to acquire a first-hand knowledge of many conditions which he must afterwards meet.

An interesting modification of this method has just been attempted jointly, at the suggestion of Prof. John Hays Hammond, of the Sheffield School, and under the direction of Prof. H. S. Munroe, of Columbia, by the mining schools of Columbia, Colorado, Harvard, the Massachusetts Institute of Technology, and Yale. It consists in hiring a mine for the summer, and putting the students at work under proper direction at the various operations of practical mining. In this way the mine for the time being is turned into a sort of school for the young men. This change certainly has many advantages. It comes as near the European conditions as is possible in America. It enables the operations of the mine to be subordinated for the time being to the needs of instruction. This, for beginners, is certainly a great advantage. The method is, however, an expensive one; and several years of experience are necessary before it can be finally judged.

There is another modification of the summer school idea, perhaps even more difficult of general application, with which I have had the most experience, and from which I hope much in the future. I began by visiting with my students various mining districts each year; but I found in this plan not only many advantages, but also many serious difficulties. One of the most fundamental of the latter was, that there is an important element which a man does not get by merely looking on. He often thinks he understands a thing that he sees another do; but such superficial knowledge is not to be trusted. It may suffice for amateurs and *dilettanti ;* but real professional knowledge and power are not so obtained. It leads to that false sense of knowledge that makes practical men so disgusted with the man just out of college. It is the thorough, ingrained mastery which long familiarity with his work has given the practical man that makes him superior in any emergency to the mere "looker-on in Venice." Moreover, traveling with a large body of students tends to emphasize the difference between the students and the miners, and to make each party self-conscious, and, to a certain extent, antagonistic. When many students travel together, they carry with them the college atmosphere, which is the very thing they need most to get away from, in their vacations. It is only when such a body of students is so diluted by dispersal among a large number of mines and miners who are *working* and *not playing* at mining, that they can be made to realize that they are not "the whole thing;" then, and then only, are they in a position to derive any real benefit from their experience.

These views were gradually forced upon me, as they doubtless have been forced on others, by a study of results. Moreover, as the number of students in the classes increased, I found it more and more difficult to secure accommodations for them in any but a few large mining centres. This greatly limited the practicable scope and variety of the work.

But the cause that finally decided me to make a change was the lack of means, among some of the best students, to pay the expenses of such trips, in addition to those of the college course. Some of these men asked to be permitted to work for wages, instead of attending the summer school. This was done in certain cases; and I found at once such an improvement in the subsequent work of these students that I decided to alter my general plan accordingly.

The method, as thus far worked out, is to require that each student shall spend at least a month underground in the study of practical mining. As a matter of fact, most of the students thus spend from six to eight months during their college course, and many of them even more. Each must prepare a well-written account of his experiences, together with an essay, on a subject chosen by himself from among those that interested him most. These papers are read before the whole class and are discussed and criticised by all. Many of them have been extremely interesting and instructive.

The students are not required to work for wages, and are even discouraged from doing so, unless they are physically mature, and have some familiarity with the work. But all are strongly urged to attempt this before they graduate. Most of them need very little encouragement; in fact, they take to it as naturally as ducks to water. There is a time in the development of a young man when hard work seems to be a physical necessity — an assertion of his manhood. It has even come to pass among us that the young man who, from physical or other disability, does not do so, loses caste among his fellows.

There is of course a certain disadvantage in working for wages. A man has to do the same thing over and over again and is usually too tired to think much while doing it. But this objection is easily removed; for when, by a month or more of hard work, a man has established himself and paid his way, it is very easy for him to take further time at his own expense to get a general view of the work as a whole. Some men are of course physically unable to perform manual labor for wages. But unless they are unusually well adapted for the profession in other ways, such bodily weakness is generally an indication that they had better adopt a less strenuous occupation. I have never found that the men have been lacking in mental grasp from having to work; though naturally one cannot do hard labor and take voluminous notes on the same day.

On the other hand, there are certain great advantages in working for wages. It gives a man a just self-confidence, as nothing else can. He feels that no matter where he may be he can hold his own among men as a man. He learns the point of view of the working miner, and how to win his confidence and respect. He gains an inside knowledge of the errors and successes of mine administration. He comes to know the meaning of "a day's work," the tricks and subterfuges by which inefficient workmen seek to evade doing their duty, and the way to treat such cases without unnecessary friction. Such an experience is sure to prove invaluable, when, as he grows older, he is himself intrusted with the management of men. He will be more likely to know how to avoid unnecessary conflicts with his men from having himself "borne the heat and the burden of the day."

As a rule, men without previous experience are put first at loading and tramming cars, and later, at single- or double-hand drilling, or as helpers on a machine-drill; while in small mines they often have experience at timbering or at the pumps. Many of the men are really able to earn full wages as miners, before they get through. Often, when hard pressed for resources, they work a year, or even two years, underground, thus earning enough to pay their way through college. This seems rarely expedient, except in cases of necessity. But there are some cases in which an excess of animal spirits finds in such a rustication a natural outlet, and the man is really made over again by such an experience.

The men are advised not to go in groups, but usually in pairs, since, in case of illness or accident, a faithful "pardner" is a great source of comfort. They are also advised to scatter in a thin skirmish-line over the whole mining region west of the Rockies. Some go as far south as Mexico, others find their way to Cape Nome and the Klondike. Thus, like bees from the hive, they scatter over a wide area; each brings back honey of a slightly different flavor; and all benefit by this richer store.

Many difficulties were encountered, particularly at the beginning, in carrying out this plan. Many still remain to be overcome before it can be perfected. It depends for success, not only on the good will of the miner and the mine-owner, but also upon the discretion and tact of the student. I have always found the miner, and nearly always the mine-owner, willing to help any young man of good physique and good nature who was not overcome with a sense of his own great knowledge and importance. But when a very young man sets out, unasked, to show another man, old enough to be his father, how to run a mine, there is naturally trouble, — as there ought to be. For the first lesson a young man has to learn is the necessity of adapting himself to his surroundings, and of fitting himself into his place in the greater mechanism; and until he learns this, his lot is likely to prove rougher in the mining world than anywhere else.

There is much to justify the prejudice against a man who goes to college simply to escape doing his share of the world's work. Consequently, I have advised my students never to ask for work *because* they were college students, but simply because they were able and willing to earn what they were paid. In short, I have advised them to secure in their vacations the advantages of the "Wanderjahren" of the German apprentice. By scattering over a wide territory they are absorbed very naturally, and, as a rule, without much difficulty. Some of them have learned hard lessons not down in books, but it has done them good.

The men are all advised as to the principal precautions to be taken to preserve their health, the dangers they will have to meet, and how to meet them. They are plainly told that unless they are ready to take the hard chances of the miner's life they had better choose some other occupation.

Among more than a thousand students who have participated in this work during the last fifteen years there have been but two serious accidents. Both of these were fatal. The victims were young men who had been working for nearly a year in the endeavor to earn enough money to pay their way through college. One was caught in a cave. The other, in firing a blast, had his candle blown out by the spitting fuse, and, in the darkness, was unable to reach a place of safety. But these very accidents have served to convince the mining public that the California boys were enough in earnest to face the dangers of the miner's life.

This attempt at a solution of the problem is not presented as a general one; it is probably better adapted to Western than to Eastern mining conditions. It can only be applied when there exist a large number of mining camps within easy reach of the mining school. Its best feature is, that it falls in with the American idea of free initiative. Moreover, it serves admirably to select the fit and reject the unfit without loss of time. It also automatically adjusts those questions of supply and demand that are so hard to settle.

In spite of its many imperfections, the system is beginning to bear fruit. The opposition to college men is growing gradually less. It is found that most of them are in earnest, and are willing and able to work, and that some of them have ability. Before the term of work is over a man is frequently told: "When you have finished college, I may have something for you to do." Many a man has dropped in this way into just the place for which he was adapted.

In short, if the college man can overcome the prejudice against him that often exists all too justly among men of affairs, by showing that he really is a man, modest, willing, and capable, his education will have its chance to count in the end, as it does more easily at the beginning, under Old-World conditions. The only chance to make his start that the American mining student has, is to meet the practical man on his own ground. He can always do this if he has the courage to break the ice. It is better and easier for him to do this before he graduates than afterwards.

Physical and Moral Soundness and the Coöperative Spirit

Experience on these lines has emphasized the importance to the mining student of a sound and, if possible, a robust physique. By this I do not mean heavy muscles merely, but essential soundness of the vital organs, particularly those of digestion, circulation, and breathing, and also the senses of sight and hearing. Important as these possessions are to all, to the mining engineer they are indispensable. An early physical examination by an experienced physician should reject all defective candidates as rigorously as is done in the army and navy. This should be followed by a thorough physical training, whose aim should be the production of a sound and healthy man. Some instruction in the fundamentals of hygiene, the precautions necessary in the use of food and water, the precautions to be taken in malarial regions and some knowledge of the "first aid to the injured," are very useful to men who must often serve as leaders of a forlorn hope in a strange land.

Even more important than physical soundness is moral soundness. It is absolutely necessary that mining engineers not only see the truth, but speak it. Scientific training, when thorough, always develops one important moral trait. It helps to elevate the love of truth into a religion. This is its greatest moral service to society.

In this connection we are all under indebtedness to the late Mr. A. M. Wellington for his able articles on "The Ideal Engineering School."[1]

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[1] *Engineering News*,—1893.

Speaking of the young engineer, he says: "He must be truthful and worthy of trust, must mean what he says and say what he means. If he cannot do this he must be silent." And again: "All men whose advancement depends on those above them must not only *be*, but also *seem*, faithful to those above them."

He calls attention to the fact that the lawyer, the physician, and, to some extent also, the clergyman, depends for his success almost entirely upon his individual knowledge and intellectual abilities. Such a man may or may not be personally agreeable to those for whom he works; it is his knowledge and his technical skill that we wish to utilize in an emergency. These are his own possessions, and he can utilize them unaided and without the co-operation of others.

But with the engineer this is not the case. His work cannot be done except through the friendly aid, not only of many engineering co-workers, but also through the help of capital and labor, the two most difficult elements in our civilization. From the inception of the original idea to its final completion, men and money, brains and brawn, nature and human nature, must work together without friction for a common purpose.

The young engineer must win the confidence of his superiors by a faithfulness and loyalty, free from subservience; he must secure the good will and liking of his equals by frankness and openness of nature; he must command the respect of his subordinates by his evident mastery of his business, his sense of justice, his freedom from petty meanness, and his fearlessness in the discharge of duty. The man who cannot meet the requirements of any one of these three relations, no matter what his knowledge and technical skill, is sure to fail. And because they possess these qualities in a high degree, many men of very ordinary abilities often succeed as engineers, when men of superior genius lamentably fail.

When men must work together day and night, side by side, in intimate personal contact, where relations of subordination and command necessarily must exist, there must be no friction. Even a slight uncouthness of nature, or rudeness of manner, objectionable personal habits, or lack of tact, become simply unbearable at such close quarters.

All this is most emphatically true of the mining engineer. No men except soldiers, sailors, explorers, and astronomers are subject to such a strain on their endurance.

As was also pointed out by Mr. Wellington, the necessity for the cultivation of the social graces and amenities of life, for habits of personal neatness, for self-control and uniform good nature under conditions of hardship and privation, have always been recognized as essential qualities in the army and the navy. That it is possible to cultivate these qualities, even in the most heterogeneous material, is evidenced by the success of our military and naval academies in producing them in the average American youth. The raw material they have to work on is not different from that which goes to our engineering schools. But the results they attain in this respect are so decidedly better that there is no comparison. In most engineering schools these important qualities are simply ignored, and no attempt is made to cultivate them.

Where, as in many of the so-called "Land Grant Colleges," a certain amount of military instruction and discipline is required, the means exist by which these qualities may be cultivated to some extent. In the University of California such is the case, and I have always found that the mining students who, by attention to such matters, succeed as officers, invariably take high rank in their profession in executive positions. It is one of the few chances men have in college of learning the arts of controlling themselves and others. There is no agent so effective in forcing men to realize the means and advantages of coöperation as rigid military discipline; for the wars and struggles of our race since primeval times have polished and perfected this method till it has reached a high state of efficiency. But it is difficult for engineering schools to give the time and attention to it that is possible in a purely military school.

Another important means of reaching this end is to be found in all athletic sports in which, as in baseball, boating, and especially in football, team-work plays an important part.

Organizing students into parties for surveying and other field and laboratory investigations, where each in turn acts as aid and as chief, is another effective means. In short, any agency that develops the instinct of coöperation, of team-work, of the faculties of self-control, courtesy, fidelity, and faithfulness, will prove effective. It will be more difficult to secure these qualities in America than it is abroad, because of the strong instincts of individualism and self-assertion that are such marked characteristics of American youth. Nevertheless, the uniform success of Annapolis and West Point in these matters testifies to its possibility. There is great room for improvement along these lines in all American engineering schools.

Sundry Minor Essentials

There are also certain minor matters, too often neglected by both students and professors, which are peculiarly important to the young engineer in his first work after graduation, and all of which can easily be mastered in college; such as, neatness in drawing, mapping, and lettering, certainty and rapidity in numerical work; in the measurement of angles and distances in surveying; and in sampling, assaying, and the common methods of analysis. At first, accuracy is more important than speed. But the latter is, in practice, only less important, and should be insisted on from the beginning. A sound judgment on the degree of precision needed for the particular purpose in question is also indispensable. The student should be sure, on the one hand, that his errors do not exceed this limit, and, on the other hand, that he does not waste time in needless refinement when approximations suffice. He should form the habit of always checking his measurements and calculations by at least two independent methods. The only way to insure this standard of accuracy and dispatch is to hold him to the hard standard that he will have to meet in practice, and to make him realize that for carelessness or blunders no explanations can be accepted. Rigid discipline on these lines should begin in the mathematical, physical, and chemical departments, and should run right through the higher technical work with increasing severity. Tolerance of blunders is cruelty in the end.

General Training

The mining engineer needs a certain fundamental training in economics, by reason of his position as an intermediary between capital and labor; his necessary dealings with merchants and contractors; and his handling of questions as to the valuation of mining properties and the financing of mines. Besides the broad questions of money, interest, wages, and other leading topics of economics, it is also important that he should be familiar with the laws of specifications and contracts, of ordinary business usage, the science of accounting, and the law of mines and water.

The broader the general culture with which a student comes to the mining school the better. The minimum entrance requirement should include some familiarity with general history, with the best of English literature, and the command of a simple, clear, and forcible English style. A reading power of the leading modern languages is only less necessary than a mastery of one's mother tongue.

As the training of the mining engineer must of necessity be chiefly scientific and technical, its natural tendency is to put him somewhat out of sympathy with the gentler side of human culture. It is important to counteract this tendency by keeping him in touch with the finer arts, by which life is mellowed, enriched, and ennobled.

Where, as is frequently the case in America, the mining school is an integral part of a great university whose scope includes all the activities of our nature, this end is easily and naturally reached by the association of mining students with other students who are devoting their lives to the arts, to philosophy, and letters. The student is thus forced to become familiar with a wider outlook. Some touch with one of the finer arts, such as music, painting, or sculpture, that will bring out the innate love of ideal beauty that exists in every man, is necessary to a well-balanced nature. Perhaps the most important of these influences is the cultivation of a taste for general literature, whose possession is a refreshment to the soul. The mining engineer who possesses it takes with him to the ends of the earth an inspiration that must make him an agency of moral and spiritual uplift wherever he may be.

Location of Mining Schools

Which is the better location for a mining school, — a mining centre or a commercial one? Successful mining schools have been established in the older countries in both situations; Freiberg, Clausthal, Przibram, and Leoben are examples of the former; and Paris, Berlin and London of the latter. Historically, the first to be established were in the mining centres, which have the advantage of surrounding the student with a professional atmosphere, in which all the activities and ambitions of life gather about this one industry. When means of communication were poor, such a location was almost indispensable.

But such a location tends to make the training of the mining engineer provincial when it should be universal. Moreover, even in Europe, an end comes at last to a mining district, and the mining school becomes stranded in a dying community. Some of the most famous of the European schools are already approaching this condition, which yearly becomes more desperate.

It is for this reason that the modern tendency is in the opposite direction. The most permanent of human institutions are the great commercial centres, made so by natural physiographic features, that facilitate intercourse, which is the life of trade. The capital that develops mines comes from these centres, and the profits from the mines return to them. The enterprise that undertakes great ventures has its source there, and thence, confining itself to no national boundaries, reaches out to grasp the natural wealth of the world.

It is becoming more and more important that a mining school should be located at the heart of things; for it needs to be not only permanent, but permanently strong; to maintain relations with capital not less than labor; and to have a cosmopolitan rather than a provincial outlook and sphere. It is as necessary as ever that the mining school should be in close touch with many operating mines. But in modern times this is much more easily effected from commercial than from mining centres. For these reasons, I believe that in the near future the positions of commanding importance will be held by mining schools located near large commercial centres, particularly when these command not one, but many mining districts.

Over-Supply of Mining Schools in America

In a paper on "The Growth of American Mining Schools and their Relation to the Mining Industry," read at the Engineering Congress at the World's Fair at Chicago in 1893,[1] I have already called attention to the relatively small proportion of miners among the wage-earners of the United States. According to the Tenth Census, the number was only 1.82 per cent of the wage-earners, or 0.63 per cent of the total population. The Eleventh Census showed a similar relation. The figures of the Twelfth Census show the total number of miners and quarry-men to have increased to 1.95 per cent of the total wage-earners, or 0.75 per cent of the population. It is impossible to determine from this report the exact number engaged in metallurgical work, but after a careful study of the data given, a liberal estimate for metallurgical laborers shows that the total cannot be for both industries much more than 2.5 per cent of the wage-earners, or 0.95 per cent of the population.

On the basis of the Eleventh Census (which contained no enumeration of mining or metallurgical engineers) I estimate that there could not have been at that time over 6000 persons in the United States who practiced these professions; and that to keep up the supply would require about 200 new men per year. In the Twelfth Census the mining engineers were enumerated for the first time and the number given is only 2908. Metallurgical engineers are not specified; but under the head of "Chemists, Assayers and Metallurgists" the number is 8887. It is plain that a liberal outside estimate of mining engineers and metallurgists would be ten thousand; and to keep up the supply would take about 330 new men each year. By including assayers, mine-surveyors, and the various minor officials of mining and quarry companies, who might require some technical training, this number might possibly be doubled or even trebled. But when we remember that for many of these positions very little training is required, and that they are open to any one who wishes to attempt the work, including many mining students who fail to graduate, it must be evident that there is a legitimate field for not much over 300 mining-school graduates each year. In 1893 I showed that there already existed in the United States a much larger number of mining schools than was really needed; and the number is now much greater. The attendance at many of these schools has already increased enormously. At the University of California, for instance, the gain has

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[1] *Transactions*, XXIII, 444; also, *Transactions* of the Society for the Promotion of Engineering Education, vol. I, 1893.

been nearly 1400 per cent since 1887. There is no doubt that the demand for mining engineers in America can easily be supplied by the existing schools. It would be a distinct advantage if they could be restricted to a very much smaller number. Not more than six, or at most a dozen, favorably distributed according to the needs of the mining communities, could do all the work demanded of them much better than a larger number. Under American conditions no regulation but that of natural competition is possible. Much could be gained, however, if the existing schools would coöperate to fix a common standard for the degrees given. While no official relation with the mines is possible, the moral effect of such a step would be very great.

Degrees

One of the reasons that so little attention has been paid in America to college degrees in the past is the great unevenness of the requirements for them in different parts of the country. Wherever a degree, or its equivalent, has come to mean something definite, as with our military and naval academies, it has received full recognition.

Still, there are indications of a general change in the public estimate of degrees. This has been most marked in regard to the degrees of Doctor of Philosophy and of Science. These have come to mean a capacity for original investigation in some branch of science or letters. It would be a distinct advantage to the mining schools, and to the mining profession, if a similar definite meaning always went with that of the degree of mining engineer.

At present the practice of American mining schools differs greatly in this matter. Some give the degree of mining engineer at the end of a four years' undergraduate course. One even gives it in three years; one has attempted a five years' course, but has unfortunately gone out of existence. Others give, for much the same amount of work, only the degree of Bachelor of Science at the end of the undergraduate course, and reserve the degree of mining engineer for advanced work.

I am convinced that no matter how excellent the course of a mining school, it is a distinct mistake to give the degree of mining engineer on the same basis as that of the bachelor's degree. Some engineering schools, recognizing this difficulty, have attempted to institute as a mark of greater attainment the absurd degree of doctor of engineering.

The highest degree given by a mining school should be that of Mining Engineer. This degree should be put on the same basis as that of Doctor of Philosophy, or of Science. It should be confined to those who have not only mastered the fundamental training, but have shown by actual accomplishment that they possess, in addition, the precious qualities of initiative and capacity as leaders in engineering, and also that maturity of mind and character which one naturally associates with the profession of the engineer. If this standard could be maintained, the degree of Mining Engineer from an American mining school, in spite of its disconnection with Government service, would soon stand higher than that of any other country in the world.

It must be evident that it is not possible to crowd a complete technical education into a four years' course, without neglecting the broad basal training that is necessary for advanced work. But if some such plan as I have outlined were adopted by the leading American mining schools, a great advance would be made.

A large number of men could then take advantage of the undergraduate course which would then, in a new sense, and in a much higher form, take the place of the *Bergschule*. In this school all would receive the fundamental training necessary for the mining engineer, together with some knowledge of the various technical branches. After finishing this course of four years, and receiving the bachelor's degree, the best thing for all to do would be, as a rule, to plunge directly into the realities of the mining life. All could then step at once into the lower ranks of the profession. Most would undoubtedly be contented to remain there, filling a useful place in the general scheme, now occupied by men without either scientific or technical training; thus raising the standard of the entire industry. But the chosen few who possess the creative faculty of the engineer should be encouraged to find their special bent and field as soon as possible, and then to throw their whole strength into a real mastery of the chosen specialty. A man is then in a position to specialize as much as may be necessary without becoming narrow. Three years of mature work along these special lines, in graduate work, either in college, or, under proper conditions, outside of it, should lead to the production of a piece of original work which would justly entitle him to the degree of Mining Engineer.

Such a policy would parallel, without imitating, the methods that have been so successful in encouraging advanced and independent workers in our universities. It would create an American *Bergakademie* that would be superior to anything of the kind in Europe. And it would secure for America, by a process of natural selection, a body of mining engineers worthy of their natural heritage.

SHORT PAPER

Professor James D. Hague, of New York City, presented a paper to this Section on "Mining Engineering and Mining Law."

SECTION E — TECHNICAL CHEMISTRY

SECTION E — TECHNICAL CHEMISTRY

(*Hall* 16, *September* 23, 10 *a. m.*)

CHAIRMAN: DR. H. W. WILEY, U. S. Department of Agriculture.
SPEAKERS: PROFESSOR CHARLES E. MUNROE, George Washington University.
PROFESSOR WILLIAM H. WALKER, Massachusetts Institute of Technology.
SECRETARY: DR. MARCUS BENJAMIN, U. S. National Museum.

THE RELATIONS OF TECHNICAL CHEMISTRY TO OTHER SCIENCES

BY CHARLES EDWARD MUNROE

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As the term technical chemistry is usually used, it refers to the commercial production of substances through a change in the chemical composition of the matter employed in their manufacture. All manufacturing operations are either chemical or physical ones or both chemical and physical. The manufacture is a chemical one when the substance or substances acted upon undergo a change in composition. The manufacture is a physical one when the substance acted upon undergoes a change in form, state, state of aggregation, appearance, or properties without any change in its composition. Many manufacturers, probably the majority, include both chemical and physical processes in their operations. In most manufactures the chemical processes are the basic ones producing the material, which is afterward shaped and assembled by physical means in the form in which it is to be used.

The variety of substances embraced in chemical technology is seen in such a work as Wagner's *Chemical Technology*, but no statistics indicating its magnitude are to be found, except in the reports of the United States Census, this being the only country which takes a census of manufactures. Following the classification of Wagner, I have compiled these statistics for the years 1890 and 1900:

Statistics of Chemical Manufactures in the United States, 1890 *and* 1900.

Year.	Number of establishments.	Number of wage-earners.	Total wages.	Cost of materials used.	Value of products.
1900	84,172	1,038,543	$469,848,022	$3,392,211,974	$4,962,715,787
1890	58,195	710,485	311,369,495	2,177,443,777	3,165,768,188

The term technical chemistry may, however, properly be extended to include the work done by chemists not engaged in manufacturing, but which aims at a utilitarian application of the results. First in order of development among these is the class of chemists engaged in the work of chemically inspecting material from all sources to ascertain its suitability for its proposed uses, or its purity, or its conformity with the specifications under which it was purchased. All economically managed and well conducted operations of any magnitude to-day are subjected to this check. In fact we may say that, since governments by legislation specify the fineness as well as the weights of the gold and silver coins they issue, and since the fineness of these coins as well as of the bullion in the Treasury is constantly proved by analyses, therefore every commercial transaction throughout the civilized world is eventually based upon the results of chemical tests. The historian Du Cange gives the credit for "inventing" assaying to Roger, Bishop of Salisbury, during the reign of Henry I. Be this as it may, it is owing to the accurate analyses of assayers such as Tillet, Stas, Graham, Torrey, Eckfeldt, Roberts-Austen, and their successors that the credit of our metallic currency has been and is maintained. The office of public analyst and assayer, or, as it is often styled, "State Assayer," is of long standing, Charles XI of Sweden having, in 1686,[1] established a technical laboratory for the chemical examination of natural products and the working-out of processes for their practical utilization. The Census of 1900 reports that there were 8847 persons practicing in the United States in that year as chemists, assayers, and metallurgists, and it is gratifying to observe that this class of technical analytical chemists is rapidly increasing in numbers and importance.

Second in the order of development is the work done in the technical research laboratories, where methods are tested and criticised,

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[1] *History of Chemistry*, E. von Meyer, p. 138.

processes are developed, apparatus and machinery invented, new products discovered, new applications for known products found, and where yields and costs are ascertained. Notable among these are the famous research laboratories of the Badische Anilin und Soda Fabrik, the Welcome Research Laboratories, and many others that may be readily called to mind, and so fruitful and valuable have these establishments proven that similar ones are rapidly being established about manufacturing works. Their success seems also to have suggested the formation of the independent research companies, formed explicitly to combine research with practical application, especially in electro-chemistry, one such located in this country having, among others, developed processes for the manufacture of barium hydroxide, synthetic camphor, and nitric acid from atmospheric nitrogen.

Of necessity many of the arts preceded the sciences, and this was especially the case in chemistry, as many of the arts embraced in technical chemistry, such as the utilization of fuel as a source of energy, the manufacture of alcoholic beverages, bread, soap, glass, and dyestuffs, the isolation of metals, the expression of oils, and the extraction of sugar, starch, gums, glucosides, and alkaloids, among others, were practiced, in an empirical way, long before the science of chemistry took form. In 1724, after chemistry had emerged from alchemy, Boerhave defined chemistry as "an art which teaches the manner of performing certain physical operations whereby bodies cognizable to the senses or capable of being rendered cognizable or contained in vessels are so changed by means of proper instruments as to produce certain determined effects, and at the same time discover the causes thereof for service in the arts."

The science of chemistry was a growth from the art and gradually developed. It was a crude science when the phlogiston theory was propounded, and many of the advocates of this theory, such as Stahl, Marggraf, Scheele, Bergmann, Priestley, Cavendish, and Black contributed much valuable experimental and observational data from their researches. But it takes date as a recognized science when Lavoisier provided it with a systematic notation and nomenclature, Dalton enunciated his atomic theory, and Berzelius demonstrated the constancy of combining proportions and of constitution, and its growth since the beginning of the nineteenth century has been almost marvelous.

The distinction between pure and applied chemistry was universally recognized toward the middle of the eighteenth century, special text-books on technical chemistry, in which theory was combined with practice, and embracing analytical processes, particularly as they related to ores, being issued. In fact, from the outset technical chemistry has naturally drawn continually upon pure chemistry for products, processes, and apparatus, modifying the processes and apparatus to meet the conditions of factory practice. So rapid, however, has this adoption of the appliances of the university laboratory by the technical chemists become in these recent years, since university-bred chemists have been received in continually increasing numbers in technical chemistry, that it has proved a source of embarrassment to teachers of chemistry in this country and for the following reason:

From the founding of the United States it has been a settled policy of the Government to foster education, and therefore the first Congress, in legislating on the tariff, exempted from duties philosophical apparatus and instruments imported for use in education, and this legislation was reënacted with enlarged provisions in every tariff act passed by Congress, except during the Civil War, and once, in 1846, when it was apparently omitted by inadvertence. This provision seemed to serve all intended purposes until some thirty years ago, partly because there were but few active laboratories for the teaching of chemistry, with a small number of students, and that the supplies were imported for only a part of these laboratories. However, with the increase in research laboratories in universities and technical schools, the introduction of laboratory courses for the large classes of pupils in the secondary schools, and especially the appointment of a considerable number of teachers of chemistry who had been educated abroad, the demand for foreign-made apparatus and supplies became quite considerable, and as the importations grew in magnitude and frequency differences arose between the customs officials and the importers as to whether the goods imported were actually those designated in the act; the customs officials, as was natural, considering their functions, ruling for that interpretation of the laws which would yield the Government the greatest revenue. Controversy, which became quite heated, arose particularly as to the meaning of the terms "philosophical and scientific apparatus, instruments, and preparations," and in 1884 the Secretary of the Treasury, to avoid any appearance of arbitrarily overruling his subordinates, which would have been subversive of discipline, took counsel of the National Academy of Sciences; but its opinion as rendered, while perfectly correct, failed of effect, and the controversies got into the courts on issues between merchants and the customs service in such form as to lead to decisions which the customs officials regarded as supporting their controversies against the schools. Such were the conditions in 1893, when the American Chemical Society appointed a Committee on Duty-Free Importations, which made an exhaustive search into the legislation, an inquiry into the litigation, and a study of the entire situation, until, finding a favorable opportunity in an issue brought before the proper tribunal, it convinced the judges that there were no instruments, apparatus, or preparations which to-day were exclusively used in teaching or research; that, on the contrary, our manufacturers and practitioners are so keen to utilize every resource at command that they are the first usually to test, and if found profitable, to adopt any new invention in apparatus or discovery in preparation, while teachers must usually await the voting of appropriations or gifts from benefactors before they can possess them, and that as no distinction can be drawn either arbitrarily or from the rule of "principal use," we must revert to the "evident intent" of Congress to exempt education from the burden of the tariff, and in each instance the levying of duties or admission of the goods free must be determined solely by the fact as to whether or not they are to be used in the institutions designated by the act for educational purposes and research. It is pleasant to record that the board of appraisers, after thoroughly reviewing the history, adopted this view, and that during the present year Assistant Secretary Armstrong, in charge of the customs service, has promulgated it in a very satisfactory form for the instruction of his subordinates.

This is but one instance of a multitude which may be cited showing how technical chemistry "treads on the heels" of pure chemistry. It depends especially on the votaries of the latter for accurate determinations of chemical constants. Prof. F. W. Clarke has emphasized the importance of this in the case of atomic weights, taking the case of chromium[1] as an example. He says: "The older and less accurate determinations for chromium led to the figure 52.5. The more recent and more accurate have given 52.1 as the number. The European technical analysts, who analyze chromium ores for the sellers, use the first-mentioned number; the chemists for the consumers in this country use the latter number, with the result that the difference in value on a cargo of ore weighing 3500 tons is $367.50."

The technical chemist has been keen to appreciate the necessity for authoritative standards by which his work might be controlled and to which matters in controversy might be referred. He has especially welcomed and willingly assisted in the formation of standard bureaus. In fact, the movement for the creation of a National Bureau of Standards in the United States originated in the Association of Official Agricultural Chemists through Mr. Ewell, and though when, on the motion of this gentleman, the plan was afterwards indorsed by the American Chemical Society, it received the complete approval of the pure chemists, Dr. William McMurtrie and Dr. Charles B. Dudley, who stand in the front rank as tech-

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[1] *Journal of American Chemical Society*, vol. XIX, p. 359, 1897.

nical chemists, were most active in its promotion and successful in convincing our national legislators of the economic advantages which would result from the establishment of such an institution invested by law with the proper authority.

Technical chemistry is indebted to pure chemistry for much precise information regarding the properties of substances, especially as to their behavior toward reagents, and for accurate and carefully investigated analytical methods like those with which the honored name of Wolcott Gibbs is associated. But the technical chemist revises these methods and adapts them to his special needs, as shown in the standard work of Blair on the *Chemical Analysis of Iron*, and in others that might be cited, while he verifies the published data as to the particular substances with which he has to deal. Realizing that "time is money," he has devised, with the aid of the collected information, rapid methods of analysis[1] which enable one to arrive at an approximately true and in some instances a very precise result in a few moments, when the academic methods require hours and perhaps days to arrive at the same conclusion. It is true that methods of this nature, devised to meet technical needs, have been generalized and made more available in the university laboratory. As an early example of this we have volumetric analysis, devised by Descroizille and Vaquelin, investigated and generalized by Gay Lussac, and as a recent example we have the use of a rotating electrode in electrolysis, long employed in the arts, critically studied and generalized by Smith, by Gooch, and by their pupils. Yet the systematic treatment of the accumulated material, the working-out of a comprehensive scheme of qualitative analysis, and the collating, the sifting, and the arrangement of correlated methods for quantitative determinations in a connected manner are due to C. Remigius Fresenius, who for so long conducted a technical analytical laboratory at Wiesbaden, and his publications are classics.

But technical chemistry has especially looked to the pure chemist, with leisure for thought and work and with libraries and other facilities at command, to correlate and discuss data, to trace relations, suggest hypotheses, invent theories, and discover laws which the technical chemist has been ready to test and, when proved, to be guided by. To-day we find the technical chemists earnestly studying Arrhenius's theory of electrolytic dissociation, Willard Gibbs's phase-rule, van 't Hoff's law governing osmotic pressure, Guldberg and Waage's law of mass-action, and the many other valuable generalizations which have resulted from the systematic

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[1] The number of determinations made in one week in the laboratory of the Bethlehem Iron Company amounted to 2444; accurate analyses of carbon being made in 12 minutes, of manganese in 10 minutes, and of phosphorus and silicon in 30 minutes. *Engineering & Mining Journal*, LX, 375, 1895.

cultivation of the borderland between the sciences of physics and chemistry that has been going on with increasing activity during the past quarter of a century. It is safe to say that the series of text-books of physical chemistry now being edited by Sir William Ramsay, and of which the *Phase Rule and its Application*, by Alex. Findlay, is the pioneer, will find their way largely into the libraries of the technical chemists. Many examples may be cited of the utilization of these generalizations in the solution of problems in technical chemistry, but Christy's[1] admirable researches into the rationale of the cyanide processes for the recovery of gold from its ores will suffice. The experience of the past has repeatedly demonstrated the commercial possibilities that are latent in scientific theories. A famous example is found in the commercial development of benzene. Lachman, in 1898, after referring to its discovery by Faraday in 1825, and its production from benzoic acid by Mitscherlich nine years later, says:[2] "These famous chemists little thought that their limpid oil would once lay claim to be the most important substance in organic chemistry; that it would give birth to untold thousands of compounds; that it would revolutionize science and technology. The technical development of benzene and its derivatives employs over fifteen thousand workmen in Germany alone; the commercial value of the products reaches tens of millions of dollars; by far the greater portion of the research work done to-day is concerned with the same group of substances. Nearly all of this tremendous activity is due to a single idea, advanced in a masterly treatise by August Kekule in the year 1865. Twenty-five years sufficed for the chemists of all nations to recognize the inestimable importance of the benzene theory, for in 1890 they came together at Berlin to do honor to the man who had created a new epoch in the science." There is abundant verification of Hoffmann's statement that "the technologist is not likely to leave long without utilization any fact of science which may be developed and made valuable from the technical side," and of Ostwald's saying "that the science of to-day is the practice of to-morrow."

In his most attractive book, *Physical Chemistry in the Service of the Sciences*, van 't Hoff says: "There exists in Germany a very beneficial coöperation between laboratory work and technical work. Both go as far as possible hand in hand. After physical chemistry had made several important advances and was firmly established in such a way that pure chemistry was assisted by coöperation with it, Ostwald judged correctly that this coöpera-

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[1] *Transactions*, Am. Inst. Mining Eng., vol. XXVI, p. 735, 1897, and vol. XXX, p. 864, 1901.

[2] *Spirit of Organic Chemistry*, p. 21.

tion would also be valuable in technical directions," and these views led to the founding of what is now the German Bunsen Society for Applied Physical Chemistry, whose considerable membership comprises both men of pure science and representatives of technical science. The suggestions of applications from men such as Ostwald, van 't Hoff, Bancroft, and others, accompanied as they are by striking demonstrations, are always most welcome and appreciated. But it is no new custom for the most eminent exponents of pure science for a while to step into the field of application. We have but to cite the names of Baeyer, Berzelius, Bunsen, Davy, Debus, Dumas, Faraday, Fischer, Frankland, Hoffmann, Liebig, Mabery, Remsen (to whom the medal of the Society of Chemical Industry has just been awarded), Williamson, and Wurtz as examples. Or, taking a single technical subject, such as the explosives industry, we have Lavoisier perfecting the manufacture of gunpowder; Gay Lussac serving on the advisory committee of powders and saltpeter; Berthollet inventing chlorate powders; Liebig investigating the fulminates and devising means by which the commercial manufacture and use of mercuric fulminate was made possible; Schoenbein discovering gun-cotton and introducing it for use as a propellent; Bunsen, with Schischkoff, making researches on the composition of powder gases and powder residues; Berthelot, led by a patriotic desire to serve his country in time of peril, exhaustively experimenting with explosives of every description, collecting and correlating the data of his own experiments with that previously recorded and combining this with the descriptions of the attendant phenomena and the theories he had deduced from analyses of all this material in his *Force of Explosive Substances*, and Mendeléeff and Dewar developing the smokeless powders adopted by the countries of which they respectively are citizens.

While technical chemistry is under manifold obligations to pure chemistry, the indebtedness does not stand unrequited. I would amplify this branch of my subject but that it has been so admirably done by Dr. William McMurtrie in his address on "The Relations of the Industries to the Advancement of Chemical Science,"[1] in which it is shown that many discoveries which have materially affected pure chemistry have been made in the factories. It is a well-known fact and quite in the nature of things that the pure chemist is dependent upon the technical chemist for most of the material used in his researches, and the publications contain frequent acknowledgments of this fact.

Technical chemistry in common with pure chemistry is under

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[1] *Proceedings*, American Association for the Advancement of Science, vol. XLIV pp. 65–85, 1896.

lasting obligations to physics. It makes use of the physical properties of matter for purposes of identification and separation. It employs her instruments, such as the spectroscope, the polariscope, the microscope, the photometer, and a multitude of others, in analytical operations. It utilizes the various manifestations of energy in accordance with the physical laws which govern them, adopting the methods of transformation, conveyance, and application which the physicist has shown to be most efficient, convenient, and safe, though adapting them to the particular circumstances which obtain. It relies upon the physicist for the verification of its standards of mensuration, and, as previously stated, it employs physical, together with chemical, processes in its treatment of material in manufacture. A modern instance of this relation of technical chemistry to physics is found in the electro-chemical industry. Starting with the remarkable experiments of Sir Humphry Davy in 1807, which resulted in the isolation of sodium and potassium, the commercial utilization awaited the discovery of an adequately cheap source of available electrical energy, which was realized on the invention of the dynamo in 1867. When its practicability was demonstrated, and especially after it had been shown that a head of water could be employed as the primary source of this energy, the electro-chemical industry began and achieved such proportions that in the year 1900, in the United States alone, phosphorous, sodium, and other metals, not including aluminium, were isolated, and caustic soda, bleaching powder, and other bleaching agents, bromine and potassium bromide, potassium chlorate, litharge, graphite, calcium carbide, carborundum, and carbon disulphide, amounting in value to $2,045,535, were manufactured by electro-chemical methods. Many other products have been obtained by this means in the laboratory and have been expected in the industry; but while the industry is a growing one it is not growing as rapidly in the variety of its products as some have been led to anticipate. Much depends upon the extent to which low-cost sources of energy are to be commanded, and on this point the following from J. W. Richards's presidential address to the American Electrochemical Society in 1903 is pertinent. He says:

"Niagara Falls is the most accessible of our great water-powers, and has therefore drawn into its fold the majority of our electrochemical industries. But another source of surplus power is distributed over a large part of our country in a condition at present as undeveloped as was Niagara's power when Columbus touched our shores. I refer to the surplus power from blast-furnaces, obtainable by using gas-engines. Every blast-furnace burns its gases to heat its blast and to raise steam for its power. The two thirds of its gases used for the latter purpose generate just about the power needed for the blowing-engines, pumps, hoists, etc., an amount equal on an average to 2500 horse-power for a furnace making 500 tons of iron per day. If the gas thus used was used in gas-engines there would be an average surplus power, over and above all requirements of the furnace itself, of 10,000 horse-power. The gas-engine plant needed to produce this power does not cost over $50 per horse-power investment. This compares favorably with the cost of developing water-powers, which varies from $25 to $100 per horse-power. It is thus deducible that there are scattered over the United States, in some of our most flourishing industrial centres, undeveloped powers which aggregate over 1,000,000 horse-power, which can be developed at no more cost than the average water-power can be generated just at the spots where they can be most favorably utilized, and without any more drain on our natural resources than the harnessing of a new water-power, for not a pound of coal more would have to be burnt than is used at present.

"Other possible sources of power are the waste surplus gases from by-product coking-ovens and the utilization of gas-producers, using cheap, almost waste, coal in connection with gas-engines. Power therefore is available in immense quantities in places and in countries not blessed with Niagaras in their midst, and the industrial development of such sources will be one of the most marked industrial movements of the next ten years."

While recognizing these many obligations to physics, as a *quid pro quo*, technical chemistry supplies her devotees with all the "manufactured" materials which are the subject of their experiments and observations, or used in the construction of their instruments, or as sources of energy — such as coal-gas, acetylene, alcohol, and others, and the substances used for primary and secondary batteries. Many physical topics have originated with or been extended by the technical chemist.

The technical chemist looks to the forester, the farmer, and the miner for his raw materials, but he returns to the former alkaloids, wood alcohol, acetic acid and acetates, acetone, formaldehyde, paints, rubber articles, and a multitude of other products of manufacture; he returns to the farmer starch, sugar, artificial manures with which to reinvigorate his soil, fibers bleached or dyed, the suint from his sheep, the pepsin, pancreatin, and antitoxines from his swine and cattle, and through the agricultural chemist specific directions as to methods for the treatment of his soil and his crops. Since Liebig began the investigations which resulted, in 1840, in his book on *Chemistry in its Application to Agriculture and Physiology*, no one science has probably benefited more from the labors of the technical chemist than agricultural science; for well-equipped research laboratories with well-organized forces of chemists have been devoted by legislation to this purpose to a greater extent than to any other, and the publications from Dr. Wiley's laboratory alone indicate how valuable this has proven to be. As one among many examples, we may cite the sugar industry, which owes its existence to-day in this country, whether the source be sugar-cane or beet, or starch from maize or potato, to the technical chemist.

The technical chemist returns to the miner the metals isolated from his ores in the form of tools and machinery, or coins, or converted into compound substances available as medicines, as disinfectants, as detergents, and for a variety of purposes, and he supplies him with his explosives through which his labor is rendered much less arduous and his life more secure.

The technical chemist looks to the civil engineer to provide the means for the transportation of his raw material and his manufactured products, and to the mechanical engineer for his constructions and his machinery, but he supplies them with all the manufactured materials used in their work, and guarantees by analysis the quality and character of the natural as well as the artificial materials required. So rapid has this method of chemical supervision come into vogue in the last half-century that the engineer, whether he is to build an hotel, a ship, a locomotive, a gun, or a bridge, to lay a concrete foundation, or to surface a road, now introduces into his specifications the chemical requirements which the material must satisfy in order to be accepted for use, and he depends upon explosives to enable him to drive his tunnels, sink his shafts, and remove obstructions from his course. It has excited no particular remark that a chemical laboratory has been established as a part of the preparations essential to the building of a tunnel under the Hudson River.

To the metallurgist technical chemistry has been invaluable, as it has improved the quality, decreased the cost, and increased the speed of production of his materials. The story is an interesting one as we follow it either among the precious or the common metals. As set forth by Bridge in the *Inside History of the Carnegie Steel Company*, where we trace the growth from the Kloman forge of 1853, worth complete, $4800, to the Carnegie Company of 1899, valued at about $500,000,000, the story is a fascinating one in many ways, but in none more than in such rivalries as that between the blast-furnaces started by the Lucy and Isabella furnaces and entered into by the Edgar Thompson, the Carrie, and the Youngstown furnaces, by which the output of pig-iron was increased from 50 tons in each 24 hours to 901 tons in the same period, while the coke consumption per ton of iron was reduced by 50 per cent. No one with sporting blood in his veins but feels a thrill as he follows these records at the blast-furnace, the Bessemer converter, the open-hearth, and the rolling-mill, and especially as he realizes the tremendous issues involved and the enormous amounts of money at stake, and everywhere he finds it is only by the close and constant supervision of the chemist that these results could have been attained while the quality of the product was assured. The authority of the chemist in these enterprises has been extending over a continually widening territory and becoming more positively recognized; so that, taking again the blast-furnace as an example, where at first he was occasionally employed to analyze the ore used or the pig-iron produced, he now analyzes all of the fuel, flux, and ore that goes in at the throat, and the gases, slag, and metal that are produced in the furnace. One has but to examine casually a modern technical work such as Harbord's *Metallurgy of Steel* to be convinced of the absolute dependence of the modern steel-maker upon the technical chemist. Mr. Carnegie admits that he owes his success in steel-making to having been among the first to employ chemists throughout his establishments; and we find that the other industrial combinations, such as the Standard Oil Company, Amalgamated Copper, and the like, which consider no detail of business too small to be ignored, employ chemists at all points, auditing their operations, accounting for their materials at all stages, stopping wastes, diminishing costs, improving the quality and increasing the speed of manufacture.

Technical chemistry, then, invades the domains of economics, of politics, and of diplomacy. A striking example of its effects in economics and politics is found in the settlement of the silver question. Gold is a most widely diffused metal. It has, for instance, been shown by assayers at the U. S. Mint at Philadelphia that if the gold in the clay of the bricks of which the buildings of the Quaker City are built could be brought to the surface, the fronts would all be gilded. In the past our processes for the isolation of this metal have been so costly that only the richer ores would bear treatment. Large bodies of low-grade ores which have been discovered and mountains of tailings carrying values were looked upon as worthless, while enormous quantities of copper, lead, and other metals containing gold were sent into the market to be devoted to common uses, because the cost of separation was greater than the value of the separated products. Eight years ago, when the "silver question" was made the national issue, while the orators were declaiming from the stump, the chemists were quietly working at the problem in their laboratories and factories. Manhé's process for bessemerizing copper ores was combined with the electrolytic refining of the product, so that even traces of gold were economically recovered, while the cyanide processes, such as the MacArthur-Forrest, the Siemens-Halske, the Pelatan-Clerici, and others for the extraction and recovery of gold from low-grade ores and tailings, were successfully worked out and put into practical operation to such effect that by the cyanide processes alone gold to the value of $7,917,129 was recovered in the United States in 1902, which is more than was ever won throughout the whole world by all methods in any one year up to 1661, and probably up to 1701. The data for other processes is not at hand for 1902, but the returns for 1900 show that gold to the value of $88,985,218 was recovered in the treatment of lead and copper ores in the United States, of which $56,566,971 worth was recovered in refining. It has but recently been publicly proclaimed in this city of St. Louis that the "silver question" is settled, and it is settled, but it was settled largely through the efforts of the technical chemist and metallurgist.

Technical chemistry renders important services to medicine in furnishing it with an enormous variety of remedial agents, anesthetics, and other supplies. It is an important factor in the public-health service, supplying disinfectants and deodorizers, inspecting food-supplies, supervising water-supplies, devising methods for the purification of sewage, the treatment of wastes, and the prevention of the pollution of the atmosphere. We have but to mention the names of Pasteur and Pettenkorfer, of Letheby and Wanklyn, and of Drown, Chandler, and Mrs. Richards to emphasize the importance of the chemical factor.

Chemistry is an equally important factor in public safety. A glance at von Schwartz's *Fire and Explosion Risks* will show how varied and extensive but a single one of these fields of activity is. Every one of you as you came here by boat or rail owed a large measure of your safe conveyance to the technical chemist. The regular utilization of these valuable services in this interest is of quite recent date. It was in 1875 that some of the officials of the Pennsylvania Railroad Company, finding that the oil used in their signal-lamps and headlightswas unreliable, and that all empirical methods of examination failed, determined to employ a chemist. Dr. Charles B. Dudley was called, a laboratory was opened at Altoona, and in the face of the skepticism of the "practical" man, the work began and was carried to so successful an issue that a multitude of problems relating to railroad administration have been referred to the chemist, his force of skilled assistants has been steadily increased, and the position of the chemist in the organization is second to none in importance. Other railroad companies, recognizing the gain in economy and efficiency, have also instituted chemical laboratories, until in thirty years it has become common practice. While the Pennsylvania Railroad Company was wrestling with the question of testing oil, the U. S. Light-House Board was having trouble from the same cause, the lamps in the light-houses and beacons along our coast, harbors, and navigable waters having become quite unreliable from the character of the oil furnished, and it, too, sought the aid of the chemist, with such result that it has ever since relied upon chemical science to define and pronounce upon the quality of its supplies.

It has been said that the state of civilization of any country may be determined by the amount of soap which it consumes. Lord Beaconsfield considered that the condition of the chemical trades constituted the best industrial barometer. In his pamphlet on *The American Invasion, or England's Commercial Peril,* when discussing "the best index of a nation's prosperity," B. H. Thwaite says: "Had he [Beaconsfield] selected the iron and steel trades, he would have made a far better choice." I have given these citations from the many at command as illustrating the tribute paid by the thoughtful to technical chemistry. Technical chemistry promotes civilization, profoundly modifies national policies, and influences diplomatic proceedings. The most frequent cause of friction between nations to-day is found in the endeavor of each of the world-powers to control territory for the exploitation of their products or as sources of their raw materials.

Technical chemistry, as practiced in the past from the dawn of manufacture, is a most important subject for consideration by the anthropologist, which has unfortunately been too much neglected. Its study will bring rich yields to the anthropologist who comes to it with the proper preparation, for he will find in the arts embraced in technical chemistry the best gauge of the extent of civilization of a people. Historians agree that no one material thing has more profoundly influenced civilization than gunpowder has. Over fifty years ago, under circumstances somewhat similar to those which obtain here, a body of scholars under the leadership of Dr. Whewell, Master of Trinity College, reviewed the results of the famous exhibition which had just been held in London. I desire to call the attention of the anthropologists to the address there given by Sir Lyon Playfair on the *Chemical Principles Involved in the Manufactures of the Exhibition.*

In the autumn of 1874 I was so fortunate as to be the guest, at his residence in the Smithsonian Institution, of Joseph Henry, its first secretary and executive officer from 1846, and I had the precious privilege of hearing from his lips a most detailed account of the development of the Institution from the time when he was assigned the duty of devising and carrying out the plans by which Smithson's wishes should be realized and the provisions of the legislative act creating the Institution complied with, and particularly of the various obstacles which he had encountered and surmounted in his endeavor to use the fund for "the increase and diffusion of knowledge among men" in the spirit in which Smithson, as Henry understood it, intended it should be used. Naturally my interest in this famous Institution was greatly quickened, and I have watched somewhat more keenly the subsequent career of this Institution, and of the organizations such as the Library of Congress, the U. S. Department of Agriculture, the National Museum, and others created or fostered by it. From the outset, however, I have remarked upon the absence from the Museum of any collection relating to technical chemistry, which is so profoundly connected with the history and development of civilization, and which has undergone itself, in its development, so many changes that its tools and appliances and methods disappear completely from view unless preserved in some such historical collection as those made by the museums. I have endeavored, by suggestion to have this oversight remedied, but have been met by the reply that the present building is overcrowded and its resources overtaxed by the mass of material collected in branches at present cultivated. As now the Museum is starting on a new career of usefulness and a new structure of greatly increased capacity is being built, this seems an opportune time to seek publicly this recognition for industrial chemistry, at least in the anthropological collections, and particularly when, as now, to a greater degree than at any other period, such rapid changes are going on in long established and important industries, such as the sulphuric acid and the alkali industries, that the processes of the last century may become among the lost arts of the next century.

Within the present year the remains of Smithson have been removed from the soil of Italy, in which they so long rested, and been reverently and fittingly interred within the confines of the noble and beneficent institution that he founded. The revival of personal interest in Smithson which this removal has aroused has led to the suggestion that a monument be erected to his memory. The Smithsonian Institution is itself an enduring monument; but if another be created could it not, considering that Smithson was a chemist, fittingly take the form of a chemical collection in the Museum which so long benefited by his bequest.

SOME PRESENT PROBLEMS IN TECHNICAL CHEMISTRY

BY WILLIAM HULTZ WALKER

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Technical chemistry may be regarded as the performance of a chemical reaction or series of reactions on a scale sufficiently large and by a method sufficiently economical to enable the product to be sold at a profit. The problems which confront the investigators in this field of endeavor may, therefore, be divided into two classes, according as they pertain to the chemical reaction involved or to the process to be employed in carrying on this reaction. The first division is pure chemistry, even though the results of the solution be utilitarian; the second is chemical engineering. Although in the Programme of this Congress, the utilitarian side of chemistry is widely separated from the subject of general chemistry, there is in reality no dividing-line between the two. It would be difficult to find an investigator in the field of pure science who does not hope, and indeed believe, that the results of his labor will at some time prove of value to humanity; may ultimately be utilitarian. On the other hand, few, if any, chemical manufacturers would admit that in solving their chemical problems they do not utilize the most scientific methods at their command. The research assistant is in the last analysis utilitarian; while the successful chemical engineer is preëminently scientific.

Probably in no country have the problems confronting the chemical industries been so successfully met as in Germany; yet Germany does not excel in chemical engineers. Engineering enterprises, mechanical, civil, and electrical, as well as chemical, are carried on as successfully in England and America as they are in Germany, and still the latter leads the world in her chemical manufacturers. The explanation for this lies in the fact that Germany pays the greatest attention to the first class of problems, as above divided, and recognizes that pure chemistry is inseparably connected with her industries; that the application of new facts and principles follow rapidly when once these facts and principles are known. Most of her problems in technical chemistry are first considered as problems in pure chemistry and studied in accordance with recognized methods of modern research by men fully trained in pure science. If these men are also chemical engineers the ultimate solution of the problem is proportionately hastened; but they are first of all men trained in the spirit and methods of scientific research.

In general, an investigation may be prompted by either or both of two incentives; either by the pleasure to be derived from achievement and the love of scientific study for itself, or by the hope that from the investigation some immediately useful result may be obtained. Yet between the product of the first motive — pure chemistry — and the ultimate result of the second — technical chemistry — a difference does not necessarily exist. The fact that a piece of work is undertaken and carried on with the predetermined purpose of applying the results to a practical or commercial end does not in itself render it any the less a study in pure chemistry. The method of thought and action employed will be that of the investigator in pure science, whatever the ultimate object may be. To make the result of the work an achievement in technical chemistry an important contribution must then be made by the chemical engineer, in order that the conditions forming the definitions of the term "technical chemistry" as already stated may be fulfilled. In trying to point out some of the important problems in technical chemistry, no attempt will be made to distinguish between the part which must first be played by pure chemistry in their solution, and that which will still remain to be done by the chemical engineer to make this contribution utilitarian.

There is always a tendency to measure the importance of a subject by the extent of one's knowledge of it and the depth of the interest one has in it. In order, therefore, that we may obtain a proper perspective, we must consider a problem important in proportion as it affects the greatest number of people; of moment according as the results of its solution will be far-reaching in their effects, or be but of local benefit.

From this point of view the first industry to demand attention is the manufacture of fertilizers. In the last ten years the product of this industry in the United States alone has increased from 1,900,000 tons to 2,900,000 tons, an increase of over fifty per cent. This increase is probably more marked in America than in the older countries of Europe, because the necessity of replenishing the virgin soil was there reached long ago, while with us it is only begun. The magnitude of the industries which are dependent directly or indirectly upon agricultural products is so well recognized that it needs no discussion here. That the supply of crude material from which plant-life derives its nourishment should be maintained is therefore a source of responsibility for the present, as well as for future generations. Of this, as of every great industry it may be said that the supply of raw material for to-morrow is a problem for to-day.

Dr. H. W. Wiley, of the United States Department of Agriculture, has pointed out the surprisingly large amount of potash, phosphoric acid, and nitrogen which is yearly taken up by the agricultural crops alone. The average percentage of ash in all of the important crops has been accurately determined and their percentage composition in respect to potash and phosphoric acid is known. In addition to this we have a satisfactory knowledge of the percentage of albuminous matter contained in the more important agricultural products. From these figures and the reports of the United States Department of Agriculture we can calculate the amount of potash, phosphoric acid, and nitrogen consumed each year. Allowing a value of 4 cents a pound for potash, 5 cents for phosphoric acid, and 12 cents for nitrogen, the total value of these ingredients for a single year amounts to the enormous sum of $3,200,000,000. To be sure this is not all removed from the farm and lost to the soil; but that which remains in the form of straw and manure is but a small percentage of the whole. Straw is generally burned, while the soluble salts of the manure-heaps are often allowed to leach out and go to waste. When in addition we consider the terrible waste involved in the modern methods of sewage disposals where, instead of being returned to the soil, these valuable constituents are carried to the ocean, the net loss of these chemicals can be easily appreciated.

Of these three most important ingredients making up a fertilizer for general purposes, phosphoric acid alone seems to be at hand in practically inexhaustible quantities. Slag, rich in phosphoric acid from certain metallurgical processes, is already much used as a source of the material. Fresh deposits of phosphate rock of such enormous extent are being brought to light almost every day that our supply of this material may give us little immediate concern.

Although the Strassfurt region of Germany may continue to ship undiminished quantities of potash salts, the second important ingredient of a fertilizer, the world's supply cannot be said to be on a perfectly satisfactory basis until independent sources are developed. In the year 1902 the value of the potash salts imported into the United States amounted to $4,500,000. The recovery of potash from wood ashes, while once an important industry, must diminish as the value of hard wood increases. While there are doubtless natural beds of potassium salt still to be discovered, the time seems rapidly approaching when we should render more readily available the great amount of potassium distributed throughout the mineral kingdom. Rhodin had already accomplished much toward this end when he showed that feldspar could be made to yield the greater part of its potash when it was heated with lime and common salt. Clark has found that when the mineral leucite, with its 21 per cent potassium oxide is heated with ammonium chloride, the potassium is converted into chloride and is easily separated from the melt. If this reaction could be extended to orthoclase and the ammonia recovered by treatment with lime, the enormous quantity of potash contained in this mineral would be at our service.

It is, however, to the supply of available nitrogen that the greatest importance attaches. The sodium nitrate producing countries of South America exported last year 1,300,000 tons, a large percentage of which came to America. Egypt and the Southwestern United States have nitrate deposits, but of their extent and value little is as yet known. Of the other form of available nitrogen, ammonia, our main supply is at present from the destructive distillation of coal. Although the introduction of by-product coke-ovens has increased this supply, our domestic production is now not over 40,000 tons a year.

In the atmosphere, however, we have a never-failing source of nitrogen which needs only to be converted into other forms to be of the greatest value. It is interesting to note that even as long ago as 1840 this same problem was the subject of considerable experimentation and the basis of several technical processes. In this year there was erected in France a plant for the manufacture of potassium ferro-cyanide, which depended on the atmosphere for the supply of nitrogen, and which at one time turned out almost a ton of product per day. From this time until the present, the utilization of this inexpensive and inexhaustible supply of raw material has been an attractive field, and has held the attention of many investigators. It had long been known that while carbon and nitrogen alone could not be made to unite, the union was effected when these elements were brought together in the presence of a strong alkali. The technical difficulties in the way of successfully applying this reaction seem to have been the rapid destruction of the retorts and the loss of alkali through volatilization. With the advent of cheap electricity and the consequent development of the electric furnace, this idea was made the basis of further work. The destruction of the retorts was largely overcome by generating the heat within the apparatus rather than without. When a non-volatile alkali was used to eliminate the loss from this source and a higher temperature maintained, it was found that a carbide was formed as an intermediate product and that nitrogen readily reacted with the carbon thus held in combination.

Among the investigators who have thus far taken advantage of this reaction may be mentioned the Ampere Chemical Company located at Niagara Falls, and the group of men represented by the Siemens-Halske Company of Berlin. The former first produces a carbide of barium and then converts it into barium-cyanide by passing over it air from which the oxygen has either been removed or converted into carbon monoxide. Robert Bunsen long ago showed that by using steam the nitrogen in all alkaline cyanide may be converted into ammonia. In this case barium oxide would be left to be returned to the furnace, and to continue the cycle. When advantage is taken of the process discovered by Professor Ostwald, by which ammonia is converted into nitric acid through the medium of a catalyzing or contact agent, the production of nitrates by way of the cyanide reaction is easily foreseen.

The Siemens-Halske Company prepared, in addition to cyanide and ammonia, by use of the carbide-nitrogen reaction, a new compound in technical chemistry, calcium cyanamide. In contradistinction to the cyanides the nitrogen of this compound is available for plant-food and can take the place of the more common nitrogen salts in commercial fertilizers. The technical difficulties in the way of the economic application of these processes are doubtless very great, but when one considers the advance which has been made in the last five years he has ample reasons to believe that it will not be a great while before the synthetic preparation of the cyanides, ammonia, and nitric acid from atmospheric nitrogen will be on a commercial basis.

The old reaction by which nitrogen and oxygen were made to unite through the agency of a high potential electric discharge has been made the basis of a process for the manufacture of nitric acid by the Atmospheric Products Company, operating at Niagara Falls. For agricultural purposes it is proposed to absorb the nitric acid thus formed in milk of lime, and so produce an exceptionally cheap product. There still remains much to be done before this can be called a technical process.

A very much less technical, but, so far as our knowledge at present goes, a more promising method of fixing atmospheric nitrogen in the form of nitrates is through the agency of bacteria. While it is true that one group of bacteria has the power of breaking down nitrates with the production of nitrogen gas, there are other groups which are equally able to absorb elementary nitrogen with the production of nitrates. A great deal of excellent work has recently been done by the United States Department of Agriculture with the result that cultures for the artificial inoculation of the soil may now be obtained in considerable quantity. It has been found that these bacteria when grown upon nitrogen free media may be dried without losing their high activity. When immersed in water they are easily revived. A dry culture similar to a yeast-cake, and of about the same size, can thus be sent out and used to prepare a fluid in which the original nitrogen-fixing bacteria may be multiplied sufficiently to inoculate a number of acres of land. The amount of material thus obtained is limited only by the quantity of the nutrient water-solution used in increasing the germs. Field experiments have shown the wonderful activity of these bacteria in fixing atmospheric nitrogen and the splendid crops which may be grown upon what would otherwise be almost sterile soil.

In this one problem of our future supply of available nitrogen for agriculture as well as general manufacturing purposes, we note the aid which technical chemistry draws from the other departments of natural science. The electrical engineer and biologist have already contributed a great share in its solution. There remains, however, no small amount of work for the technical chemist to perform before the desired end is reached.

In an address on "Chemical Problems of To-day," delivered by Victor Meyer in 1889, the author pointed out that, although the synthesis of starch from carbon dioxide and water was a result not to be expected in the near future, yet, he says, "we may reasonably hope that chemistry will teach us to make the fiber of wood the source of human food." While we do not consider that this is a problem of technical chemistry for the present, the possible use of cellulose as a raw material from which to make food, renders more acute a problem which is to-day clamoring for solution, namely, the preservation of our forests. The influence which the forests of a country have upon its civilization is a topic which has been much discussed of late. That there is an intimate relation between the woodland of a district and the regularity of its rainfall, the absence of floods and freshets, and the general climatic conditions, there seems now to be little doubt. But the consumption of forest products continues to increase far out of proportion to the growth of new timber. The substitution of other raw material in chemical industries which now use wood for this purpose becomes, therefore, an economic problem for the solution of which the chemist is held responsible.

The production of cellulose from raw materials other than wood is the first important factor in the chemical side of the question. The weight of wood consumed for the production of chemical fiber for the year 1902 was something over two million tons, while one and a half million tons were used for the manufacture of ground wood-pulp. While from some points of view our American forests are sufficient to supply the demand for many years to come, it does not excuse us for the terrible waste of cellulose in forms other than wood, which we are constantly suffering.

On our flax-fields of the West we are annually burning thousands of tons of flax-straw which contains a large percentage of cellulose in a most valuable form. Considerable work has already been done on the utilization of this straw in the production of fiber, and some success has met the efforts of the By-Products Paper Company, now located at Niagara Falls. There is, however, still much room for improvements. In the straw of our wheat and oat crops, which is to-day largely destroyed on the fields, we have another source of cellulose of which we avail ourselves but little. In Europe the production of straw fiber is carried on to some extent, but is capable of great extension should sufficient economy in the process for treating it be introduced. The high content of silica has ever been a source of loss, owing to the fact that the formation of sodium silicate prevents the recovery of the soda now used in the digestion of the straw.

By far the greatest loss of valuable cellulose, however, is found in waste cornstalks and in bagasse or the sugar-cane after the soluble portions have been removed. There is a close analogy between these two products, in that there is associated with the woody portion carrying the cellulose a large amount of non-usable pith. Rapid progress has been made in the utilization of both of these raw materials within the last few years, and the indications are that before long they will prove a source of value rather than a nuisance, as is frequently the case at present. The market price of bleached cellulose fiber is to-day from 2½ to 3½ cents per pound. Starch may be bought for from 2½ to 4 cents, according to its source. It is seen, therefore, that there is little manufacturing margin in the conversion of cellulose to starch or sugar until the cost of the former has been considerably reduced. This can come about only through new processes designed to operate more economically than those at present in use, and to use as raw products the cellulose at present wasted on the fields.

It would seem that a more economical step toward the production of food from wood might be through its ligneous or non-cellulose constituents. For every ton of cellulose produced there must be used two tons of wood; that is, an equal weight is wasted. In the soda process, as now conducted, these non-cellulose materials are burned to recover the soda which is held in combination with them. In the sulphite process this enormous amount of material, aggregating for America alone in a single year almost one million tons, finds its way into the water-courses and ultimately to the ocean. This organic matter is most complex in its composition, but consists largely of one class of substances closely allied to the sugars, and another class having the general characteristics of tannins. That these sugar-like substances could be made to yield a food material is, from their nature, quite possible; so far as we know, however, but little has been accomplished in this direction. A number of uses have from time to time been proposed for this waste, but as yet none have been of practical value. Among the more promising may be mentioned a preparation to be used in tanning leather, a sizing material for paper, and a substitute for dextrine in calico printing, and as an adhesive.

In addition to our annual supply of 4,000,000 tons of paper stock, we depend upon the forests for our supply of acetic acid, methyl alcohol, and acetone. In countries where there is not the exorbitant tax upon fermented mash that exists in the United States, there would seem to be an opening for a process for the production of acetic acid from alcohol in a more concentrated form than can be produced through the aid of *mycoderma aceti.* It would, it is true, in the end depend upon the supply of fermentative material; but there are being wasted every year in the semi-tropical countries many thousand tons of crude molasses that could thus serve an economic end. For many uses acetic acid may be displaced by formic acid, a compound which admits of synthesis from carbon and water. The farther this substitution is carried the more acetic acid will be available for the manufacture of acetone and other compounds where the acetyl group is a necessity.

Concurrent with the disappearing forests is the increasing scarcity of vegetable tanning material. Hemlock and oak bark, sumac and chestnut wood are still the most important sources of tannins, although quebracho from South America and canaigre from Mexico and Texas are daily playing a more important part. The introduction of chrome tannage for upper leathers had a marked influence upon this industry, inasmuch as it furnished a cheap substitute for those finer tanning materials which are constantly increasing in price. A mineral tannage for heavy hides, along the lines so successfully followed for upper leather, has, however, not been developed; the product lacks the rigidity and firmness combined with the flexibility which is characteristic of oak or hemlock tanned leather. There must exist methods for supplying to the hide materials having an action analogous to these vegetable tannins; it remains but to seek them out in order that a new and profitable industry may be established.

It is thus seen that technical chemistry can do much for the conservation of our forests; along many lines the time for action has already come.

When the consumption of a given article is in excess of its supply, the market price must rise. In accordance with this law we have seen the price of crude India rubber more than double in the last few years. The consumer of the finished article must pay this advance or accept an inferior grade of goods. Generally he does both.

The tropical forests of Africa and South America still contain untold quantities of India rubber; but so does sea-water contain gold.

For manufacturing purposes both might as well not exist. The only human beings that can live under the conditions obtaining in these tropical jungles are the natives; but the distance to which the natives can transport the rubber is comparatively limited. Although rubber-bearing trees are now being cultivated in the more easily inhabitable portion of the tropics, it will be a long time before this source of supply is an important factor in the market. And thus it comes that the synthesis of India rubber presents to-day from at least the technical side, one of the most promising problems in chemistry.

The investigation of India rubber is greatly handicapped by the fact that it exists only in the colloidal state. The difficulties are perhaps more largely physical than chemical; that is, it is the molecular aggregation rather than the atomic structure of the individual molecule which presents such almost insurmountable difficulties. There are no clearly defined melting-points, boiling-points, tendencies to crystallize or any of those means of separating mixtures or characterizing individuals which aid in the investigation of most organic compounds. The researches of Weber and Harries, resulting in the establishment of the much-needed methods of analyses, have been of incalculable advantage to all those working with either the raw or the manufactured article. In many directions also, the paths along which important results are to be obtained have already been blazed by these investigators. Probably no other field presents such difficulties of manipulation, in addition to such profound problems of organic chemistry, as does the investigation of India rubber; but on the other hand, few such unlimited opportunities for valuable work are offered in the field of chemical research.

Under the general head of utilization of trade-wastes may be considered a large number of technical problems, the solution of which would not only add wonderfully to the economic resources of the country, but would aid in the solution of that much vexed question, river-pollution. We have already mentioned the soda and sulphite liquor resulting from the manufacture of cellulose fiber from wood. Of almost equal importance is the waste yeast which is daily produced in the brewing of beer and ale. An extract of this yeast has a food value, as shown by analysis, equal to the best meat extracts. As the quantity of yeast allowed to go to waste is from one to two pounds for every barrel of beer brewed, we can form estimates of the great amount of this material at hand. Arsenic sulphide from the purification of crude acids, grease from the washing of wool, the utilization of city garbage and many other problems of this order are everywhere in evidence. It is not within the compass of this discussion to mention these almost innumerable sources of manufacturing waste which exist in the chemical industry; but keen competition on the one hand, and the State Boards of Health on the other, are constant stimuli to increased effort toward their utilization.

Although I have endeavored to select the above examples of unsolved problems with a view to touching upon as large a portion of the field of technical chemistry as possible, I could doubtless, with equal propriety, have selected others. We can simply mention such important questions as the hygienic preservation of food, the flame-proofing and preservation of wood, prevention of the corrosion of structural iron and steel, the great problems of chemical metallurgy, etc. We must, however, note some of the more recently developed forces and phenomena of nature, the application of which to technical chemistry forms problems for to-day. One of the most important of these is electricity. Thanks to the triumphs of modern electrical engineering we are now able to call to our aid unlimited amounts of this agent at a cost comparable to that of other forms of energy. Possibly the simplest, though not the earliest method of utilizing electrical energy in chemical processes is in supplying the heat necessary to carry on a reaction directly at the point where the reaction takes place. In a number of chemical industries (for example, the manufacture of phosphorus) it was previously necessary to produce within thick-walled retorts a very high temperature. The result was that a great deal of heat was wasted, the retorts deteriorated very rapidly, and the reaction was carried on at a low efficiency. By using an electric furnace for the manufacture of phosphorus these expensive retorts are eliminated. In addition much cheaper raw materials may be used, the process is made continuous, and a high efficiency obtained. By the substitution of electrical heating for the closed retorts previously used in the preparation of carbon bisulphide the manufacture of this chemical has been placed upon an entirely new basis. The economy introduced by supplying the heat at the point where the union of carbon and sulphur takes place is clearly indicated by the low price at which this material can now be sold and its enormously increased consumption.

With the ability to obtain temperatures far above that which is possible by the ordinary combustion of fuel, there was opened up a new field in synthetic chemistry. Reactions which it was impossible to carry out on a technical scale, and others, the existence of which was not suspected, have now, through the application of electrical energy, become the bases of large manufacturng enterprises. Calcium carbide, carborundum, artificial graphite, and many hitherto unknown alloys are the commercial products of the electric furnace where temperatures in the neighborhood of 3000° C. obtain.

The third and more strictly chemical application of electrical energy is in the use of the current for electrolysis. Faraday long ago determined the laws according to which chemical compounds break up when subjected to the passage of an electric current. It is only in recent years, however, that the cost of electrical energy has made it possible to apply the knowledge thus furnished by this great investigator. Among the many important advances due to this use of electricity may be mentioned the manufacture of caustic soda and bleaching powder by the electrolysis of brine. The percentage of the world's supply of these two standard articles, which is now made by this process is already a formidable figure, and constantly increasing. In the electrolytic production of aluminium we have seen an entirely new industry develop, until it is now one of magnificent proportions.

What the application of electricity will do for technical chemistry in the future can be predicted only by estimating the results of the past. In many fields it is practically virgin soil over which only the pioneers have trod, and which is still waiting to be tilled.

Under the name of catalysis or contact action is included the other force that we can mention this afternoon, the usefulness of which the technical chemist is only beginning to appreciate.

These substances which are capable of so wonderfully increasing or decreasing the speed of a reaction without themselves appearing in its final products vary in their nature from such simple ones as metallic platinum or ferric oxide to the most delicately constituted ferments or enzymes. The manufacture of concentrated sulphuric acid by such a process is perhaps the most striking example of the application of this idea, although, to be sure, the finely divided platinum used at present plays but the rôle which the oxides of nitrogen have done so successfully in the past. The reproduction of photographic negatives by substituting for the action of light on sensitized paper the contact action of certain chemical compounds, is a process worthy of its distinguished discoverer, Professor Ostwald. For this application of catalysis even the most pessimistic must prophesy a great future. Still another phase of this question is found in the hydrolysis of fats by the enzyme found in the seeds of the castor-oil plant. Instead of the application of acid, heat, and pressure the same result is obtained at room temperature by the quiet action of this catalytic body. The advantages to be reaped by the development of these phenomena can scarcely be foreseen. Even the wildest dreamer might easily do injustice to the possibilities of this wonderful agent when intelligently used by the technical chemist.

We probably should not invite criticism were we to state that wherever we find a manufacturing establishment based upon chemical processes, there also exist problems in technical chemistry. That one factor which is so apparent that it scarcely needs mentioning, namely, the increase in the yield of processes now in operation, is enough to substantiate this assertion. The paramount question before us is therefore how can these problems best be solved. In any answer to this question there are two factors both of which deeply affect the future growth of chemical industry. The first is the attitude of the manufacturer towards science and scientific work; the second is the training of the coming chemist.

When a few years ago England awakened to the fact that many industries in which she was the pioneer and at one time the leader were in the main passing to other countries, there went up a great cry for "technical education." The nature of the industrial stimulus which has borne such magnificent fruit in Germany was not understood. In the minds of many a panacea for all their difficulties was to be found in the technical education of the working classes. But this is unquestionably a mistake. Until there is a love of science for its own sake and an appreciation of the value of scientific method among the leaders of chemical industry, the fruits of technical education cannot be reaped. Carl Otto Weber, speaking of this move toward a more general scientific education in England, says: "Until the nation, as a whole, recognizes that the prosecution of scientific study as a mere means of money-making is a profanation defeating its own end, the history of industrial developments in England will afford the same melancholy spectacle in this as in the last century, technical education notwithstanding."

The time is past when a factory can be run by rule of thumb; when the chemist is looked down upon simply as a testing-machine to be kept at a distance and generally mistrusted. It is true that there are many men to-day who pass under the name of chemists who are little more than testing-machines; men who possess the ability to do nothing more than the most strictly routine analysis; but such men will never solve the technical problems of the present or any other time. I would not impugn the dignity or intrinsic value of analytical work — it is the corner-stone of all chemical investigation. But I would emphasize the fact, for it is a fact, that the manufacturer who employs a so-called chemist, one trained to "do" coppers or carbons, or acids, and who at the same time expects this chemist to improve his process and keep his business in the skirmish-line of the industrial battle, must eventually be numbered among the "not accounted for."

The second factor in this answer is the training of the coming chemist. What is the reply to that now so oft-repeated question: What is the best preparation for a technical chemist? I am personally of the opinion that it is not to be found in the teaching of applied chemistry as this term is generally understood. This training must provide for something more than simply copying the present — doing as well as others do; it must build for the future. We must provide men who are prepared to solve the unsolved problems. Within the last few months much has been said and written in America about the lack of adequate instruction in technical chemistry in our universities and colleges. It is assumed that American industries, based on chemical processes, do not flourish for lack of men trained in this branch of science. This, however, is not the case. It is not more instruction in applied chemistry that America needs, but rather a deeper and broader knowledge of pure chemistry with a more extended training in original research.

In many of the problems we have already noticed, the solution depends upon the discovery of new compounds — the investigation and study of new reactions and relationships. This is the province of pure organic and inorganic chemistry. The foundations of these two departments cannot be too firmly or too broadly laid. The method of attack best followed in each cannot be too well understood. But it is not sufficient that we study only the initial and the final products. It is all important to learn the influence of the variable factors on the process; to study the reaction for itself. This is the province of physical chemistry, a department of science, the importance of which to technical chemistry cannot be overestimated. To be able actually to apply the laws of chemistry and to predict the course of reactions from general principles already proven is a tremendous economy of both time and energy.

After we have acquired the tools, however, we must learn to use them; after we possess a sound knowledge of inorganic, organic, and physical chemistry we must have adequate training in work requiring original and independent thought.

As I have already noted, the training to be derived from an investigation may be the same even though the incentive for its undertaking may be different. While I believe that so far as possible the student should be influenced to work for the love of knowledge and for the mastery of science for itself, yet especially in his later years of study there are advantages in allowing him to combine with this a utilitarian aim. In America, at least, most men enter our technical schools with the intention of fitting themselves as rapidly as possible for some useful calling in life. They have a feverish desire to get through and to enter the creative industries and accomplish something. They will work with enthusiasm upon whatever they can be made to recognize as contributing to this end, but by their very directness are intolerant of supposed digressions from their chosen path. The presence of too much of this spirit is to be regretted; but it is a power to be turned to service, not to be opposed. It does not follow that for a training in scientific method and for broadening the mental horizon a research which can have little, if any, practical value is superior to one, the solution of which can find immediate application. For advanced work, as much pure organic chemistry, for example, can be learned from an attempt to convert safrol into eugenol (a consummation in itself devoutly to be wished) as in the transformation of some other compound with a much longer name but with no higher destiny than to fill a place in Beilstein. So also in physical chemistry. A careful, painstaking investigation of some of our already established industrial processes with a view to determining the maximum yield at the minimum cost is of the greatest educational value. In other words, a problem for research may have a distinctly practical bearing without being any the less a study in pure science, or without having thereby an inferior educational value.

In other problems, we have noted, the solution largely depends upon the process, not the reaction. This demands the chemical engineer, a man who combines a broad knowledge of chemistry with the essentials of mechanical engineering. He must be well schooled in the economics of chemistry; have a knowledge of the strength and chemical resistance of materials; be able to design and operate the mechanical means for carrying out on a commercial scale the reactions discovered, and duplicating the conditions already determined.

All this training cannot be combined in the one man who takes a four years college course. Either he must study an additional year or two, or he must replace some of his chemical work with mechanical engineering. But such a man must contribute a great share in the ultimate success of chemical industries, for on him depends the solution of the problems comprising the second division of our subject.

With men whose foundations are thus broadly and deeply laid, anxious to enter the industrial arena, and with a generous appreciation of the scientific man on the part of the manufacturer, coupled with a willingness to grant him an adequate return on the money invested in such an education, the problems in technical chemistry of the present must rapidly become the achievements of the past.

SHORT PAPERS

Dr. Samuel P. Sadtler, of Philadelphia, Pennsylvania, read a paper before this Section on "Flameless Wood," and discussed the various processes of fireproof treatment.

The following paper on "The Relation of Technical Chemistry to Human Progress" was presented by Dr. Harvey W. Wiley, of the United States Department of Agriculture, and Chairman of the Section of Technical Chemistry:

I yield to no one in my admiration for that part of our science which is perhaps sometimes improperly denominated "Pure Chemistry." To be sure, we need not object to the use of the word "pure" as applied to chemistry, and it seems to me it can be applied to all branches with equal propriety. The term "pure" as used above, however, refers solely to chemistry when considered entirely apart from any practical application or general utility. And yet it is almost impossible to consider chemistry in that light. No matter how abstract the investigation may be as a rule it treats in some way of human interests. In other words it is quite impossible — it seems to me — to divorce chemistry from the humanities. Technical chemistry perhaps more than any other branch of our science lies quite close to human hopes and human progress. The application of chemical investigations forms the foundation of sanitation and hygiene. It provides the remedies which are used in diseases. It produces antitoxins which counteract biological poisons, and builds up the technique which renders their manufacture and distribution possible. It determines the purity of the water-supply and of the air. It discovers the forms of food adulteration which are injurious to health and presides over the inspection which prevents them, and in a dozen other ways ministers to the public health. It is evident that technical chemistry in this aspect tends to prolong human life and make it more useful. After all, life is the one great desire of man and thus in prolonging it technical chemistry ministers to man's supreme desire more than any other branch of chemistry or of any other science. Technical chemistry opens the wilderness to civilization. By its means have been built those marvelous lines of communication between distant parts of the same country and countries separated by the seas. The railway and all its appliances are creatures of technical chemistry. The steamship is no less so. Thus technical chemistry is the most important of the sciences lying at the basis of transportation. Associated with its sister science, "Physics," chemistry has helped to build up the great industry of the applications of electricity to the arts. Electro-chemistry is intimately associated with all that the mastery of electrical science has done for human progress. It may not be much to its credit, but chemistry is the dominant science in the art of war. It not only makes the explosives but also the guns which carry them, and while it is true that chemistry has thus made war more deadly, it has without doubt made it more humane. The fierce personal hatred and enmity which must have characterized the hand-to-hand fighting of antiquity is now an incident rather than the whole of battle. No sooner, however, has technical chemistry made as efficient as possible the implements of destruction than it turns, on the other hand, to ameliorating the suffering of the wounded and thus softens the pangs of the hospital and saves thousands of lives which otherwise would have succumbed to wounds. There is perhaps no more remarkable contrast than these two applications of technical chemistry, on the one hand to destroy and on the other to save. In the art of agriculture, technical chemistry is one of the chief factors, and agriculture must be recognized as the basic industry of all that relates to the welfare of man. We might get along without the facilities of transportation, we might do away with the adaptations of the electrical force to industry, we might dispense with the perfected armaments of modern battleships, but we cannot do without food and clothing, and these scientific agriculture furnish. While almost every science contributes something to agriculture, and while we recognize the contributions of all fully, we must admit that chemistry takes the lead. Chemistry determines the fertility of the soil, the character of the materials removed by the crop, and furnishes the means to restore the plant-foods which are removed. It studies the processes of nutrition and shows how foods can be used to secure the best economical results. It improves the yield of old fields by the scientific application of fertilizers combined with systematic mechanical treatment. It adapts the raw material of agriculture to specific uses. It develops great industries which without it would be forever dormant, as, for instance, the beet-sugar industry, which is, it may be said, almost purely a chemical product. In fact the applications of chemistry to agriculture are so numerous and important that only a volume could adequately portray them. If, therefore, it be adjudged proper to call abstract chemistry pure, we must claim that it is only appropriate that technical chemistry should be called perfect.

After all, man is the chief thing to be valued in this world and all that ministers to his welfare, to his progress, and to his happiness should receive the special favor of human thought. That application or effort which does not do something for the advancement of man — directly or indirectly — is hardly to be thought worthy of occupying the time of man. We, therefore, deem it only fitting that the authorities in charge of the Programme of this Congress should have made a special division of this, in some respects, the most important part of our science.

Dr. Marcus Benjamin, of the United States National Museum, and Secretary of the Section of Technical Chemistry, presented the following valuable paper on "The Historical Development of Technical Chemistry in the United States:"

The inventive genius of the American people is universally conceded. The necessity of accomplishing things quickly, incidental to the growth of a new country, such as ours, has naturally led to the invention of many forms of labor-saving machinery, and so with improved appliances have come improved methods. The technical chemist is, however, less fortunate than his brother in the professorial chair whose merits are made known by his students, thus attracting an ever-increasing following to his laboratory, and perhaps he is also less fortunate than his associate who devotes himself to research work; for to him are given medals and honorary memberships, which are properly the "blue ribbons" of science; hence it is that the discoveries of the technical chemist, especially where they are commercially meritorious, remain too frequently unknown, and the profits of the improvement go to swell the dividends of the corporation to which he owes his allegiance while he receives no public recognition. It naturally follows, therefore, that any summary of the achievements in the development of technical chemistry must be very incomplete.

To say when chemistry begins is not generally possible, for its origin wanders back into alchemy and pharmacy on the one side and into physics on the other, and there are no sharp lines of separation among the various branches of science, for they gradually merge one into the other. In this country, however, we have grown to accept the date of the arrival of Joseph Priestley, June 4, 1794, as a most excellent time at which to begin the modern history of chemistry.

The younger Silliman's masterly *American Contributions to Chemistry*[1] gives me the right, therefore, to mention first Benjamin Thompson, Count Rumford

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[1] *American Chemist*, 1874, vol. v, p. 70.

(1751–1814),[1] whose studies in heat and fuel were as practical as they were important. His early knowledge of science was acquired from John Winthrop (1717–1779), who held the chair of mathematics and natural philosophy at Harvard from 1738 till his death. Of Count Rumford I have said elsewhere:[2] "He investigated the properties and management of heat, and the amount of it that was produced by the combustion of different kinds of fuel, by means of a calorimeter of his own invention." By reconstructing the fireplace he so improved the methods of warming apartments and cooking food that a saving of fuel of almost one half was effected. He improved the construction of stoves, cooking-ranges, coal-grates, and chimneys, and showed that the non-conducting power of cloth is due to the air that is inclosed in its fibers. Silliman well says of him: "No writer of his time has left a nobler record of original power in physical science than Rumford." It will also be remembered that by will he provided funds "to teach by regular courses of academical and public lectures, accompanied by proper experiments, the utility of the physical and mathematical sciences for the improvement of the useful arts, and for the extension of the industry, prosperity, happiness, and well-being of society."[3] Let me also remind you that Wolcott Gibbs, the oldest and now the Nestor of American chemists, held the Rumford chair in the Lawrence Scientific School of Harvard from 1863 till 1888, during which time many of those who are now leaders in chemistry were students under him.

The last century was only a year old when Robert Hare (1781–1858) communicated his discovery of the oxyhydrogen blowpipe to the Chemical Society of Philadelphia. This instrument held a foremost place for the production of artificial heat until the recent introduction of the electric furnace. The application of the principle invented by Hare still finds extensive use for lighthouse illumination and similar purposes under the names of "Drumond light" and "calcium light." It is interesting to recall in this connection that Hare was the first to receive the Rumford medals from the Academy of Arts and Sciences.

Hare was also the inventor in 1816 of a calorimotor, a form of battery by which a large amount of heat was generated, and four years later he modified this apparatus, with which, then known as Hare's deflagrator, in 1823 he first demonstrated the volatilization and fusion of carbon. His memoir on the *Explosiveness of Niter*, which was published by the Smithsonian Institution in 1850, was one of the earliest contributions by an American to the literature of explosives.[4]

The original discovery of chloroform is clearly of American origin and must be credited to Samuel Guthrie (1782–1848), of Sacketts Harbor, New York, whose researches anticipated those of Soubeiran, Liebig, and Dumas by nearly a year.

A committee of the Medico-chirurgical Society of Edinburgh gave him the credit for having first published an account of the therapeutic effects of chloroform as a diffusive stimulant. Dr. Guthrie was likewise the inventor of a process for the rapid conversion of potato starch into sugar. He also experimented with considerable boldness in the domain of explosives, inventing various fulminating compounds, which he developed commercially.[5]

Among early technical chemists Samuel Luther Dana[6] (1795–1868) stands

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[1] See *Memoir of Sir Benjamin Thompson, Count Rumford, with Notices of his Daughter*, by George E. Ellis; also *Complete Works of Count Rumford*, 4 vols. published by the American Academy of Arts and Sciences (Boston, 1876).

[2] *Cyclopædia of American Biography*, vol. v, p. 345, article Rumford, Benjamin Thompson, Count.

[3] *American Chemist*, vol. v, 1874, p. 73.

[4] *Smithsonian Miscellaneous Collections*, vol. II, 1895. Also see the memoir of him by the elder Silliman in the *American Journal of Science* (2), XXVI, 1858, p. 100.

[5] An account of his career has been published in pamphlet form by his descendant, Ossian Guthrie.

[6] See sketch of Samuel Luther Dana in *Pioneers of Science in America* (New York, 1896), pp. 311–318.

deservedly high. His friend, Dr. A. A. Hayes, has testified to "his great fertility in original devices for general and technological work." While chemist to the Merrimac Manufacturing Company of Lowell, Massachusetts, he undertook systematic researches on the action of the dung of beeves — then used for removing the excess of mordant in printing calicoes with madder — which resulted in the discovery that crude phosphates in a bath with bran are a complete substitute for the expensive material before deemed indispensable. This important discovery led the way to the commercial employment of "dung substitutes." His studies of the chemical changes involved in the process of bleaching cotton brought about the universal adoption of the methods recommended and resulted in the recognition of the American method of bleaching which, according to the French chemist Persez, "realizes the perfection of chemical operations."

It would be an ungracious task to discuss in this paper the much-controverted "ether discussion," but I may say, without fear of doing injustice to any of the several claimants for the honor of the discovery of this important anesthetic, that Charles Thomas Jackson (1805–1880), said to be one of the foremost chemists of his time in this country, claimed, from experiments made by himself during the winter of 1841–42 in his own laboratory, that he obtained results showing "that a surgical operation could be performed on the patient under the full influence of sulphuric ether without giving him any pain." Four years later (in 1846) this was successfully accomplished by Dr. William T. G. Morton, who had studied chemistry in Dr. Jackson's laboratory. The French Academy of Sciences decreed one of the Montyon prizes to Jackson for his discovery of etherization and one to Morton for his application of that discovery to surgical operations.[1]

Metallurgy is little more than the application of chemical knowledge to the extraction of metals from their ores, and I, therefore, beg to claim for the United States the first commercial production of steel. Zerah Colburn, the well-known engineer, gives William Kelly (1811–1888), an ironmaster of the Suwannee furnaces of Lyon County, Kentucky, the credit for the "first experiments in the conversion of melted cast-iron into malleable steel by blowing air in jets through the mass in fusion." Later, when Sir Henry Bessemer made efforts to secure the patent of the process that bears his name, it was decided by the United States Patent Office that William Kelly was the first inventor and entitled to the patent, which was promptly issued to him. In 1871, when application was made for a renewal of the patents originally issued to Bessemer, Mushet, and Kelly, the last was successful, while the claims of the first were rejected.[2]

The successful electro-deposition of nickel and its commercial development are chiefly due to the energy of Isaac Adams, a resident of Cambridge, Massachusetts. He carefully studied the subject and found that the failure to obtain satisfactory results was caused by the presence of nitrates in the nickel solutions previously used. His invention gave rise to prolonged litigation, but in the end he was victorious. Dr. Chandler thus describes it in the following words: "The novel proposition was presented to the court, of a patent for not doing something,

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[1] Dr. Jackson published a *Manual of Etherization, with the History of this Discovery* (Boston, 1861), and much interesting information is to be had from a "Report of the House of Representatives of the United States of America, vindicating the rights of Charles T. Jackson on the Discovery of the Anesthetic Effect of Ether Vapor." The other side of the controversy is given in *The Discovery of Modern Anesthetics: By whom was it made?* by Laird W. Nevius, New York, 1894.

[2] Much has been written of the claims of Kelly, and nearly all of the leading American metallurgists agree in conceding his priority. Swank and various writers in the *Transactions* of the American Institute of Mining Engineers may be consulted. Kelly's own story, as he gave it to the present writer, appears in the *Iron Age*, February 23, 1888, p. 339.

namely, for not permitting nitrates to find their way into the nickel solutions employed in nickel-plating, and the court held that the exclusion of nitrates was an essential condition of successful nickel-plating, and that a process involving this condition was just as patentable as a process involving any other special condition necessary for successful execution, and the patent was sustained."[1]

In passing I may mention the name of Joseph Wharton (1826–), whose experiments in producing nickel in a pure and malleable condition so that it could be worked like iron, culminated in the first production, in 1865, of malleable nickel.

Chemistry owes a great debt of gratitude to the genius of Thomas Sterry Hunt (1826–1892), and one of his most notable contributions to technology is the permanent green ink which he invented in 1859 and which is used in the printing of our national bank-notes and from the appearance of which the well-known term of "greenback" was derived. The Hunt and Douglas process for the precipitation of copper by iron, for a time so extensively used for the extraction of copper from low-grade ores, is an invention the credit of which he shares with the well-known metallurgist, James Douglas.

The vulcanization of India rubber by sulphur is the invention of Charles Goodyear (1800–60), who was so persistent in his efforts as to become an object of ridicule. Indeed, he was called an India rubber maniac and was described as a "man with an India rubber coat on, India rubber shoes, and in his pocket an India rubber purse, and not a cent in it." His invention consisted in mixing with the rubber a small quantity of sulphur, fashioning the articles from the plastic material, and curing or vulcanizing the mixture by exposure to the temperature of 265–270° F.[2]

Of almost equal importance was the invention of hard rubber or vulcanite, for which Nelson Goodyear (1811–57), a brother of Charles Goodyear, obtained a patent in 1851, claiming that the hard, stiff, inflexible compound could be best obtained by heating a mixture of rubber, sulphur, magnesia, etc., but this never became an article of commerce. In 1858 Austin Goodyear Day (1824–89) patented a mixture of two parts of rubber and one of sulphur, which, when heated to 275–300° F., yielded the flexible and elastic product now generally known as hard rubber.[3]

Dr. Leander Bishop has said: "In the art of modifying the curious native properties of caoutchouc and gutta-percha, and of molding their plastic elements into a thousand forms of beauty and utility, whether hard or soft, smooth or corrugated, rigid or elastic, American ingenuity and patient experiment have never been excelled."[4]

Exceedingly valuable to the industries of this country was the influence of James Curtis Booth (1810–88), who from 1849 till his death was melter and refiner in the United States Mint. In 1836 he established a laboratory in Philadelphia for instruction in chemical analysis and chemistry applied to the arts, and in the course of a few years gathered around him nearly forty students, among whom were Martin H. Boyé, John F. Frazer, Thomas H. Garrett, Richard C. McCulloh and Campbell and Clarence Morfit, all of whom have achieved eminence as chemists. It was said of him "that Mr. Booth had few, if any, superiors as a teacher of practical chemistry." From 1836 till 1845 he held the chair of chemistry applied to the arts

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[1] *Journal of the Society of Chemical Industry*, vol. XIX, p. 611, 1900.

[2] His life has been published by Bradford K. Peirce with the title, *Trials of the Inventor*, New York, 1860.

[3] *American Chemist*, vol. II, p. 330, 1872.

[4] *A History of American Manufactures*, by J. Leander Bishop (Philadelphia, 1860).

in the Franklin Institute, delivering three courses of lectures extending over three years each. He was the author of an *Encyclopedia of Chemistry* (Philadelphia, 1850) and with Campbell Morfit of a report *On Recent Improvements in the Chemical Arts*, published by the Smithsonian Institution in 1852. His appointment to the mint was coincident with the discovery of gold in California, and the new processes required to prepare the bullion for coinage were largely of his own invention and many of them, to use his own words, "were not known outside the mint."[1]

It is well known that prior to 1850 and for some time thereafter Philadelphia was the acknowledged centre for the manufacture of chemicals for medicinal use. To collect the details of the many improved methods for the production of these chemicals would be a long and difficult task, and would require more space than I have at my command in this article. The names of such firms as Powers and Weightman and Rosengarten and Sons are readily recognized as those of manufacturers of standard chemicals. M. I. Wilbert has recently published a paper entitled *Early Chemical Manufacturers: A Contribution to the History and Rise of the Development of Chemical Industries in America*, to which I must refer you for further information concerning their growth and progress.[2]

I am reminded in this connection that the name of Edward Robinson Squibb (1819–1900) is one well worthy of deserved recognition among manufacturers of chemicals. The ether prepared by him by processes of his own invention has long been accepted as standard. For a brief period during the early fifties of the last century Dr. Squibb was associated with J. Lawrence Smith (1818–83) in Louisville, Kentucky, in the commercial production of chemical reagents and of the rarer pharmaceutical preparations.[3] It is also proper to add the name of the Baker and Adamson Chemical Company of Easton, Pennsylvania, as that of a corporation which has established a reputation for the manufacture of pure chemicals by processes, many of which are of their own devising. The success of this young firm is generally admitted to be largely due to Edward Hart[4] (1854–), who fills the chair of chemistry in Lafayette College.

Eben Norton Horsford (1818–93) made distinct contributions to technical chemistry and among these may be mentioned his invention of condensed milk. According to Charles L. Jackson, he originally prepared that most valuable article of food for use in Dr. Kane's Arctic expedition and afterwards presented the process to one of his assistants, who then sold it to Gail Borden. His name, however, is more commonly associated with his invention of a phosphatic yeast powder, the object of which is to return to the bread the phosphates lost in bolting the flour, and which, as is well known, form such an essential constituent of the food of animals. He also devised "a marvelously compact and light marching

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[1] A sketch of his career by Patterson Du Bois was presented before the American Philosophical Society on October 5, 1888, and has since been issued in a pamphlet of eight pages.

[2] *Journal of the Franklin Institute*, vol. CLVII, p. 365, 1904.

[3] See *Original Researches in Mineralogy and Chemistry*, by J. Lawrence Smith (Louisville, Kentucky, 1884), p. xxxviii.

[4] Since this address was written I have learned that credit is due to Professor Hart for a complete process for the manufacture of nitric acid from Chili saltpeter, by means of which it is possible to distill the acid continuously and to make it of any strength and any degree of purity. This process is not only used by the Baker and Adamson Company but also by a number of powder concerns both in this country and abroad. Professor Hart is also the inventor of a complete process for the manufacture of hydrochloric acid which is being used in Easton. One of his earliest patents was for the manufacture of a pure hydrofluoric acid which he put on the market in a container, for which he received the John Scott legacy medal and premium of the Franklin Institute in Philadelphia.

ration of compressed beef and parched wheat-grits," which found some use at the time of the Civil War, and his name is also attached to the preparation of "acid phosphate," so commonly used with summer beverages.[1]

The development of the mineral resources of our country has been due largely to those who from their knowledge of chemistry were able to recognize the commercial value of the natural deposits in the vicinity of their homes. This has been conspicuously the case with the great fertilizer industry of the South, and especially so in South Carolina, where the names of Charles Upham Shepard (1804–86) and St. Julien Ravenel (1819–82) are recognized as those of pioneers in that important branch of chemical industry.

To quote from Silliman again, and he is always an acceptable authority, "No observation or original research of Dr. Shepard has been fruitful of so much good in its consequences as his discovery of the deposits of phosphate of lime in the Eocene marl of South Carolina and the distinct recognition of its great value for agriculture." [2] It was Dr. Ravenel, however, whose experiments made it possible to transform these phosphate rocks into commercial fertilizers, and of him the younger Shepard wrote in 1882: "Well might this community erect a public monument in honor of the man to whom preëminently is due the inauguration of that phosphate industry which has proven of such incalculable value to ourselves and others. As the statue of Berzelius adorns beautiful Stockholm, let us commemorate [similarly] the founder of Charleston's greatest industry." It may be added that Dr. Ravenel differed from the agricultural chemists of his time in devoting greater attention to the physiological phases of the application of fertilizers to plants than to the mere chemistry of the subject; this was naturally due to his early training in medicine.[3]

It would lead me too far from chemistry, perhaps, to discuss the work of the younger Shepard (1842–) in successfully introducing tea culture into the United States, but his farm in Summerville, South Carolina, is a monument to the application of his chemical knowledge to a new industry, and well may his fellow countrymen be proud of the results.

It is desirable to mention at this place the remarkable successes achieved by a small band of chemists who spent the four years of our Civil War in their southland. George Washington Raines (1817–98), John Le Conte (1818–91), Joseph Le Conte (1823–91), and John William Mallett (1832–) are among the more conspicuous names that occur to me. It was Raines who erected at Augusta, Georgia, the Confederate powder-works, which at the close of the war were regarded "as among the best in the world."[4]

The Confederate Government appointed John Le Conte to the superintendency of the extensive niter-works established in Columbia, South Carolina, which place he retained during the war.[5] Joseph Le Conte, a younger brother, served as chemist to the Confederate laboratory for the manufacture of medicines in 1862–63, and also in a similar capacity to the niter and mining bureau in 1864–65. Professor Mallett was in charge of the ordnance bureau of the Con-

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[1] A sketch of his career prepared by Charles L. Jackson appeared in the *Proceedings* of the American Academy of Arts and Science, vol. XXVIII, p. 34, 1903.

[2] *American Chemist*, vol. v, p. 96, 1874.

[3] Two memorial pamphlets of Dr. Ravenel have been published. One, entitled *In Memoriam, St. Julien Ravenel, M.D.* (9 pp.), is a reprint of an editorial from the Charleston *News and Courier* of March 18, 1882. The other, entitled *Dr. St. Julien Ravenel*, is a memorial published by the Agricultural Society of South Carolina, Charleston (54 pp.).

[4] He published in pamphlet form a *History of the Confederate Powder Works* (Augusta, 1882).

[5] *Biographical Memoirs*, National Academy of Sciences, vol. III, p. 369.

federate States, serving with the rank of colonel. He has described his experience under the title *Applied Chemistry in the South during the Civil War*,[1] which he has delivered as a lecture before various chemical societies.

A history of the manufacture of explosives in this country would carry us far into the past, for the oldest of the still existing powder-mills was established in 1802 by Eleuthére Irene Du Pont and the name of Du Pont is still honorably associated with the industry, for so recently as 1893 two of that name received a patent for a smokeless powder which is now largely made at works near Wilmington, Delaware.

During the years 1862–64, Robert Ogden Doremus (1824–1906) developed the use of compressed granulated gunpowder, which was adopted by the French Government. It was concerning this inventor that Sir Frederick A. Abel in 1890, in his retiring address before the British Association, said that Doremus "had proposed the employment in heavy guns of charges consisting of large pellets in prismatic form." Charles Edward Munroe (1848–) must be recognized as the first in the world to prepare "a smokeless powder that consisted of a single substance in a state of chemical purity." This explosive, which he invented while chemist at the United States Torpedo Station, Rhode Island, and which became known as the "naval smokeless powder," was referred to by Secretary of War Tracy, in 1892, as presenting "results considerably in advance of those hitherto obtained in foreign countries."[2]

Of later development is the Bernadou powder invented by John Baptiste Bernadou (1858–), of the United States Navy, and which it is claimed has been adopted for use in the naval branch of the service.

No contribution to the history of technical chemistry in the United States would be complete without some reference to the development of coal-oil and petroleum. It seems almost impossible to realize that scarcely half a century ago the only use of petroleum was as a cure for rheumatism under the name of Seneca oil. The commercial exploitation of this important illuminant is, of course, largely due to the Standard Oil Company, and to the expert chemists in their employ credit should be given for the production of the many beautiful by-products that are now made. A full description of these, with proper reference to the chemist to whom we are indebted for them, would, indeed, be valuable, but even for a simple enumeration of the products in tabular form giving their immediate origin I must refer you to the text-books on industrial chemistry.[3]

One of the most interesting of these many compounds is vaseline, whose use in pharmacy is so prevalent. It was invented in 1870 by Robert Augustus Chesborough (1837–). Charles Frederick Mabery (1850–) has been an indefatigable worker in the theoretical branch of the subject, especially on the composition of petroleum, in the study of which he has been aided with grants from the C. M. Warren Fund for Chemical Research of the American Academy of Arts and Sciences. Stephen Farnam Peckham (1839–) has been a prolific contributor to the literature of the technology of the subject, and his report on petroleum, prepared for the Tenth Census (Washington, 1880), is standard authority. Another chemist who has studied petroleum both in the laboratory and from a commercial point of view as well is Samuel Philip Sadtler (1847–). His *Industrial*

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[1] An abstract of this paper, with the title *Industrial Chemistry in the South during the Civil War*, is contained in the *Scientific American* for July 25, 1903.

[2] The history of the *Development of Smokeless Powders* was the subject of Dr. Munroe's presidential address before the Washington Section of the American Chemical Society in 1896. See *Journal of the American Chemical Society*, vol. XVIII, p. 819, 1896.

[3] See *A Handbook of Industrial Chemistry*, by Samuel P. Sadtler (Philadelphia, 1900), p. 21.

Organic Chemistry (Philadelphia, 1900) gives a very satisfactory survey of the subject with an admirable bibliography. Among the younger men I learn that William Cathcart Day (1857–1905) has succeeded by carrying out operations of distillation at the ordinary atmospheric pressure upon animal and vegetable matter, both separately and mixed, in obtaining three different materials, all of which present in different degrees the properties characteristic of asphalts.[1]

An early worker in the scientific part of this subject was Cyrus More Warren (1824–91), whose original researches on the volatile hydrocarbons and similar bodies resulted in many practical applications in the use of coal-tar and asphalt, especially for roofing and paving purposes. Clifford Richardson (1856–) has in recent years devoted much attention to the study of asphalt and is a recognized authority on its value for commercial purposes.

I cannot claim for the United States the invention of illuminating gas, although as early as 1823 its manufacture was begun in New York City, but the development of the production of a luminous water-gas was largely accomplished in this country. According to excellent authority,[2] Thaddeus S. C. Lowe (1832–) built and successfully conducted gas-works in Phœnixville, Pennsylvania, in 1874, producing a water-gas "far superior to that made from coal." According to Dr. Chandler "there are forty or fifty differing forms of apparatus for manufacturing [water-gas], but they are almost without exception applications of the invention of Thaddeus Lowe."[3]

Those of us whose memories extend back for a quarter of a century may recall Tessie de Motay (1819–80), whose agreeable personality charmed all of those who were so fortunate as to meet him, and to him is due the production of water-gas in the late seventies of the last century by a process of his own invention in New York City.[4]

A much-needed substitute for ivory and horn that could be produced economically was invented in 1869 by John Wesley Hyatt (1837–) and called by him celluloid. It is so seldom that foreign recognition is unqualifiedly given to our American inventors that I am glad of the opportunity to quote Thorpe,[5] who says, concerning celluloid, that it "is an intimate mixture of pyroxylin (guncotton or collodion) with camphor, first made by Hyatt of Newark, U. S., and obtained by adding the pyroxylin to melted camphor . . . and evaporating to dryness." Its many applications in various industries are so well known as to need no further mention here.

It should not be forgotten that saccharin, a coal-tar compound with a sweetening power of about five hundred times that of cane-sugar, although now manufactured chiefly in Germany, was discovered in 1879 in the laboratory of the Johns Hopkins University by Constantin Fahlberg, a student under Ira Remsen (1846–) and the Society of Chemical Industry in 1904 crowned Remsen's work by conferring upon him the medal of the society, recognizing thus for the first time in its history the discoveries of an American chemist.

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[1] *Journal of the Franklin Institute*, September, 1899, p. 205.

[2] See a *Communication on the Lowe Gas Process*, New York (May, 1876), and *A Communication on the Lowe and Strong Gas Processes* of later date (probably 1878), and also *The Chemistry of Gas-Lighting*, by C. F. Chandler (Philadelphia, 1876), a reprint from the *American Chemist* for January and February, 1876. There is also a pamphlet report on the *History and Value of Water-Gas Processes* (New York, 1864), by John Torrey and Carl Schultz, which gives a brief summary of some sixty patents on the subject.

[3] *Journal of the Society of Chemical Industry*, vol. XIX, p. 613, 1900, where also excellent descriptions of both the Lowe and the Motay processes are to be found.

[4] See sketch of Cyprien M. Tessie de Motay by A. J. Rossi in the *Journal of American Chemical Society*, vol. II, p. 305, 1880.

[5] *Dictionary of Applied Chemistry*, vol. I, p. 449, 1891.

In the domain of technical chemistry no American has ever achieved greater results than Hamilton Young Castner (1858–99), and the opportunity of presenting a brief summary of his brilliant inventions is a pleasure that I gladly welcome. His first invention was a continuous process for the manufacture of bone charcoal, but this failed of commercial success, although scientifically of much interest, and he then turned his attention to the study of an improved method for the production of aluminium. To accomplish this it was necessary to produce sodium economically, and this he succeeded in doing by using carbide of iron as a reducing agent. When he began this now historic research the market price of aluminium was $10 a pound, and when his process was completed he was able to manufacture aluminium at about one dollar a pound. "This," says Dr. Chandler, "revolutionized the whole industry and aluminium could be now used for a hundred different purposes." In his retiring address before the British Association in 1890, Sir Frederick A. Abel said: "The success which has culminated in the admirable Castner process constitutes one of the most interesting of recent illustrations of the progress made in technical chemistry."

But there were other uses for which sodium could be employed, and so he invented a process for converting metallic sodium into sodium peroxide. Then came the suggestion that with cheap sodium pure cyanides could be produced, and so he modified his process so as to manufacture pure cyanides, especially the potassium and sodium cyanides, enormous quantities of which were used for the extraction of gold from low-grade ores. His active mind was ever busy with new solutions of chemical problems, and subsequent to the invention of electrolytic processes for the reduction of aluminium, Castner concentrated his attention on the original methods used by Sir Humphry Davy, and overcoming the difficulties encountered by that great chemist he soon devised an electric process of remarkable simplicity for obtaining metallic sodium from caustic soda by electrolysis. His ambition was not yet satisfied and he added to his triumphs a beautiful method for the electrolysis of common salt [1] with the production of caustic soda and bleaching powder. Thus Castner invented "the first process which could be said to be a complete success for accomplishing what French, German, English, and American chemists had been working at for a hundred years." Again to quote Chandler: [2] "He never worked on a chemical process that he did not invent a better one to accomplish the same result."

The silver metal and the white crystals, pure and beautiful, the results of his many hours of study and research, will always preserve in the literature of chemistry the memory of him of whom it is surely not too much to say that he was the most eminent of American inventors in chemical technology in recent times.

While Castner was studying the problem of preparing aluminium by chemical methods Charles Martin Hall (1863–), a student in Oberlin College, conceived the plan of extracting aluminium by electrolysis and he found that a melted bath of the double fluorides of aluminium and metals more electro-positive than aluminium, such as sodium or calcium, was a perfect solvent for aluminia, and from such a solution he was able to separate the aluminium by means of the electric current. It is by this process that all of the aluminium of commerce is produced to-day.

Moissan, whose extended researches with the electric furnace have made his name justly famous, writes: "The discovery of crystalline carbon silicide belongs

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[1] Charles J. Parsons (*Journal of the American Chemical Society*, vol. xx, p. 868, 1898) gives Ernest A. Le Sueur credit for "the distinction of having invented the first electrolytic process for the commercial decomposition of sodium chloride, which became a regular contributor to the markets of the world."

[2] See the *Unveiling of a Bronze Tablet in Havemeyer Hall to the Memory of Hamilton Young Castner*, December 16, 1902, *School of Mines Quarterly*, vol. xxv, p. 204, January, 1904.

to Acheson."[1] This remarkable abrasive, prepared by heating a mixture of silica, coke, aluminia, and sodium chloride in an electric furnace, was invented in 1890 by Edward Goodrich Acheson (1856–) while experimenting for the artificial production of diamonds, and is one of the many beautiful products obtained at Niagara Falls, where quite a number of chemical manufacturers have established their plants in order to take advantage of the power obtained from the great waterfall. Mr. Acheson has also succeeded in preparing artificial graphite as a by-product in the manufacture of the carborundum, and he claims that it is the result of the decomposition of the carbide formed in that process.[2]

Although the existence of calcium carbide has been recognized ever since its original production in 1857 by Edmund Davy, Wöhler, and Berthelot, it was not until May, 1892, that its commercial production became known in consequence of its chance discovery by Thomas Leopold Willson (1860–) while experimenting in Spray, North Carolina. He obtained it by the fusion and reduction in an electric furnace of a mixture of finely powdered and intimately mixed lime and coke. When it comes in contact with water, decomposition ensues, with the production of acetylene gas, an illuminant of remarkable power. This valuable compound is also manufactured at Niagara Falls.

Another valuable application of the high temperatures obtained by the electric furnace to substances from which the extraction of the metal was formerly considered impossible is the method patented in November, 1903, by Frank Jerome Tone (1868–), of Niagara Falls, New York, for obtaining metallic silicon by reducing silica with carbon in an electric furnace of his own construction.

Of great value is the elaborate bulletin[3] on *Chemicals and Allied Products* prepared for the Twelfth Census by Charles Edward Munroe, already mentioned, and Thomas Marean Chatard (1848–). The industries discussed are grouped into nineteen classes and with each the discussion is introduced by a history of the development of the manufacture in the United States, and at the close is a brief bibliography. The volume includes a digest of United States patents relating to the chemical industries.

Worthy of the most distinguished consideration is the career of Charles Frederick Chandler (1836–). This eminent chemist has since 1864 taught the technical chemistry in the Schools of Science in Columbia University and no record of the development of chemistry applied to the arts in the United States would be complete without mention of his work. It is true that no great invention bears his name, but he has achieved results greater than inventions, for he has educated chemists, and yet even more than that as we shall see. Go where you will and you will find busy workers in science who have learned from Chandler something of that splendid power of applying chemical methods to the subject at hand which has long since gained for him the reputation of being the foremost authority on technical chemistry in the United States. Wherever gold or silver is determined, the little assay ton weights — their conception was a stroke of genius — claim him as their inventor. The brilliant series of articles on technical chemistry — the

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[1] *The Electric Furnace* (Easton, 1904), p. 273.

[2] *Journal of the Society of Chemical Industry*, vol. XIX, p. 609, 1900.

[3] *Census Bulletin*, no. 210, 4to, 306 pp. Washington, June 25, 1902.

Much credit is due to H. M. Pierce for the process originally invented by him in 1876 and since greatly improved for the recovery of by-products from the smoke of charcoal kilns. See Munroe, *Census Bulletin*, no. 210, and *The Economical Production of Charcoal for Blast-Furnace Purposes*, by O. N. Landreth, *Proceedings* of the American Association for the Advancement of Science, vol. XXVII, pp. 145–151, 1888.

According to Munroe (*Census Bulletin*, no. 210, p. 26) the Pennsylvania Salt Manufacturing Company of Natrona, Pennsylvania, "were the first to manufacture porous alum."

best in the English language — that appeared in Johnson's Cyclopedia were written by him. The first museum of applied chemistry in the United States where the crude material may be studied in its course of development to a finished product was established by him. Masterly, indeed, were the practical contributions to chemistry which marked the years during which he had charge of the public health in New York City. They resulted in enormous benefits to the community, and in 1883 it was well said: "There is no other city in the world which has so complete a sanitary organization as New York;" for all of which credit is due to Chandler.[1] In 1889 he was chosen president of the Society of Chemical Industry, the first American upon whom that honor was conferred, and a year later, on June 18, 1900, in the lecture theatre of the Royal Institution founded by Count Rumford, to whom reference has already been made, he delivered his presidential address on "Chemistry in America," in the course of which he elaborated most fully the achievements of those who have distinguished themselves in that branch of science in the United States.[2]

It is worth while, I think, to mention very briefly three branches of our national government that have had much to do with the development of chemical technology in this country. The first of these and also the oldest, for it celebrated its centenary in 1891, is the patent office,[3] where inventors receive the protection of the government for their discoveries. By thus recognizing worthy inventions a valuable stimulus is given to invention which has not been without value to the community. Of exceptional interest to chemists is the system of indexing chemical literature now in use in the classification division of the patent office.[4]

I will also call your attention to the excellent work done in the Division of Mineral Resources in the U. S. Geological Survey, where under the efficient direction of David Talbot Day (1859–) valuable information and statistics are gathered concerning native minerals and ores from which are obtained the products of so many of the leading chemical processes.[5]

Finally the bureau of chemistry of the Department of Agriculture has been a potent factor in the development of chemical industries. It was that bureau that first called the attention of the public to the possibility of establishing the beet sugar industry in the United States. As a result of the investigations carried on by chemists in this branch of the government service the average yield of cane-sugar to the ton in the state of Louisiana has been increased from 130 pounds to 170 pounds. In the examination of road materials important contributions to technical chemistry have been made by this bureau. The valuable studies on the dietetic value of foods and on their adulterations, conducted under the direction of Dr. Harvey Washington Wiley (1847–), have not only done much towards creating a demand for the enactment of national legislation for pure food, but they have also been praiseworthy contributions to the application of chemistry to sanitation. This bureau also should receive recognition for its fostering influence over the Association of Official Agricultural Chemists, an organization which has done so much to secure uniform methods of analysis of fertilizers and of foods.

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[1] See the sketch of Charles Frederick Chandler by the present writer in the *Scientific American*, vol. LXVII, July 16, 1887, p. 39, and *President Chandler and the New York City Health Department*, 1866–1883, in the *Sanitary Engineer*, May 17, 1883.

[2] *Journal of Society of Chemical Industry*, vol. XIX, p. 591, 1900.

[3] *Patent Centennial Celebration*, 1891: *Proceedings and Addresses*, 554 pp. (Washington, 1892).

[4] See *On a System of Indexing Chemical Literature; Adopted by the Classification Division of the United States Patent Office*, by E. C. Hill, *Journal of the American Chemical Society*, vol. XXII, pp. 478–498, 1900; also *Scientific American*, vol. LXXXVI, June 14, 1902, p. 411.

[5] Beginning with the year 1882, annual volumes of the Mineral Resources of the United States have been published.

To Henry Carrington Bolton (1843–1903) is due the credit for the series of bibliographies of the literature of the chemical elements that have been published by the Smithsonian Institution. His own memory will always be worthily preserved by the splendid *Bibliography of Chemistry* in four octavo volumes, an important section of each of which is devoted to technical chemistry.

The records of the past give abundant hope for the future.

VIRGIL, HORACE AND VARIUS AT THE HOUSE OF MAECENAS

Photogravure from the Painting by Charles F. Jalabert.

Maecenas, who was Chancellor of the Roman Empire during the reign of Augustus, was the possessor of great wealth, and, being both epicurean and a scholar, kept an open table for men of genius. Virgil, in the scene depicted here, is giving a private first reading of the *Georgics*, with Horace and Varius as attentive listeners. The original of this famous painting is in the Gallery of the Luxembourg.

SECTION F — AGRICULTURE

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(*Hall* 10, *September* 24, 3 *p. m.*)

CHAIRMAN: PROFESSOR H. J. WHEELER, Rhode Island Agricultural College.
SPEAKERS: PRESIDENT CHARLES W. DABNEY, University of Cincinnati.
PROFESSOR LIBERTY H. BAILEY, Cornell University.
SECRETARY: PROFESSOR WILLIAM HILL, University of Chicago.

THE RELATIONS OF AGRICULTURE TO OTHER SCIENCES

BY CHARLES WILLIAM DABNEY

[**Charles William Dabney**, President, University of Cincinnati. **b.** June 19, 1855, Hampden Sidney, Virginia. A.B. Hampden Sidney College, 1873; Ph.D. Göttingen; LL.D. Yale and Johns Hopkins, 1901; Post-graduate, University of Virginia, Berlin, and Göttingen. State Chemist and Director of Experiment Station, North Carolina; Professor of Agricultural Chemistry and Director of Experiment Station, University of Tennessee, 1887–90; President, University of Tennessee, 1887–1904; Assistant Secretary of Agriculture, 1894–97; President Summer School of South. Member of Washington Academy of Science; Southern Education Board; American Institute of Social Science; Fellow of American Association for the Advancement of Science, etc. Author of scientific and educational papers in periodicals and pamphlets and addresses on educational subjects.]

THE subject assigned me is Agriculture in Relation to Science. For this subject, almost cosmical in its vastness, I offer no apology, but ask your indulgence while I attempt to point out a few of the achievements of the new agriculture and to show their relation to the advancement of civilization. While the progress has consisted partly in opening up such lands as are not highly cultivated to people who can cultivate them, its chief progress has been in the improvement of man's methods of cultivating the soil and of using plants and animals to support his ever-increasing numbers. Since population is increasing rapidly and more food is required each year to support the life of the people born into the world, unless the production of food becomes greater in proportion to the unit man and the unit acre, starvation awaits the race. In 1899 Sir William Crookes argued seriously, before a meeting of the British Association, that the world's wheat-supply is already threatened by the failing fertility of the available soil. As the low average of less than thirteen bushels per acre means starvation for the rapidly increasing population of wheat-eaters, when he found the limit of available wheat-lands nearly reached, he saw no hope for the race except by increasing the fertility of the soil.

Man has, however, shown a wonderful ability to utilize the different food-materials and to produce increased supplies from a limited area when he has been compelled to do so. The Harlemer polders support nearly two and a half persons to the acre, and in portions of China and Japan five or six persons often get their living from this extent of soil. These lands, however, are exceptionally fertile. But even on an average acre of land, where the ordinary farmer would make only five dollars' worth of produce, gardeners can easily make five hundred dollars' worth. For these and many other reasons we cannot be very much alarmed about mere food for the race.

It is a narrow view of agriculture, however, which regards this great art only as a means of providing men with the simplest means of existence. We are interested in the progress of agriculture not only as the means of supplying the food necessary for the increasing peoples of the earth, but as the art which chiefly supports man's advancement along all lines, intellectual, moral, and spiritual, as well as physical. "Man shall not live by bread alone." It is a condition of civilization that man is not satisfied with a mere subsistence, but that his wants increase with his development. The modern man is not satisfied with the simplest food or the plainest raiment, or the barest shelter. He wants attractive and delightful food, because such food promotes health, happiness, and the development of his finer nature. Hence there have been developed the various special branches of agriculture and horticulture and the many arts of milling, manufacture, preparing, and preserving the products of the soil so as to make food-substances tempting and delicious, as well as convenient for use. The American people, for example, owe much of their success as purveyors to the clever methods of preparing food-materials of all kinds, and to their skill and taste in presenting them to the public. It is not enough that quantity alone should be considered, for, in these days, quality plays an increasingly important part in food-production. Hence the arts of producing choice meats, "hygienic milk," cereals of greater food-value, etc., which arts may properly be termed the "higher agriculture;" hence also the arts of pomology, viticulture, etc., with the resultant practical arts of wine-making, canning, and preserving, which may be properly considered as a "higher horticulture." These arts, with the important domestic art of cooking, have all been developed in response to man's demand for more refined and delicious food, a demand which is certain to grow more exacting with the progress of civilization. The same law of progress characterizes our demand for raiment and for shelter. With the development of the esthetic sense and the growth of truer ideas of hygiene and comfort, the demand for more beautiful clothing and more sanitary houses will grow steadily.

But this is not all that can be said about the higher results of the new agriculture. Progress in agriculture contributes largely to the intellectual, moral, and spiritual development of a people, as well as to their physical evolution. Perhaps the most encouraging characteristic of the times is the improvement in farm-life in respect to the means of culture. Formerly the isolation and loneliness of country life was the chief cause of that exodus from country to city which until recently continued to depopulate our rural communities. It is a sad fact that the majority of the inmates of our insane asylums in these states are women, a large per cent of them farmers' wives, sent to the hospitals as a result of melancholy induced by the narrowness and monotony of their lives. But now all these conditions are improving. The consolidated school and free transportation of pupils is fast converting the little "red schoolhouse" into a centre of vital community life. The rural free delivery of mails takes not only the letters of friends, but the daily papers and illustrated magazines, into all the farm-homes; the telephone makes visiting easy for lonesome women; and the traveling library stimulates many to improve their minds, who would otherwise live in stupid ignorance. Many of the features which formerly made farm-life so distasteful and narrowing, even maddening at times, are thus being removed; and many of the advantages, which heretofore could be had only in the city, are being put within the reach of those who spend their lives on the farm.

Every one concedes in a general way that the prosperity of one class diffuses itself throughout the whole community; but good harvests are far more valuable and important to the people than prosperity anywhere else. Agriculture not only provides food and raw material for those engaged in manufacture and commerce, but good harvests increase the purchasing power of the largest and most intelligent body of our citizenship, scattered throughout the whole land. The relation of the farmer to the merchant, the miner, and the manufacturer, is indeed a reciprocal one. Each consumes what the other produces. In the circle of trade, whatever produces a demand at any one point accelerates the amount and velocity of exchange in all directions. Good crops, by supplying the manufacturer, merchant, and miner with food or raw materials, are, the world over, the chief factor in profitable exchange.

But abundant harvests signify even more than this. Every series of exchanges must have a beginning, and the first step in starting the movement of products must be taken by those who supply the elementary and vital wants of the race. The miner will dig no ore, the manufacturer make no machinery, the merchant store no goods, until he knows or thinks he knows that somebody wants these things; but the farmer, being very sure that everybody wants food at all times, is sure to plant and to reap, whether there is an expressed demand for his produce or not. The nature of the demand, it is true, will decide for him which seed he should sow and whether on one or two acres;

but sow he will, as surely as the spring comes; and when he sows, he is almost certain to reap. As nature does more work for the farmer than for any other producer, he finds it easier to turn out an almost regular supply of his products. The sun himself is the commander-in-chief of the agricultural army. The changing seasons order the farmer's plowing, sowing, and reaping, and fundamentally every series of human exchanges starts with the farmer.

Good crops are always and everywhere makers of good times. While this is true for all peoples and all lands, it is particularly true of America, which from natural causes is the greatest agricultural country in the world. In this country agricultural prosperity touches, and for a long time to come will continue to touch, the lives and interests of a larger proportion of the people than in any other land. It causes immediately an advance in the standards of living and a broadening in the scope of the demands of the largest number of intelligent, progressive people; and it produces a home market of such tremendous proportions as to furnish independently of foreign nations a sufficient motive for the development of gigantic manufactures and enormous trade. Further the American farmer is a man of so much intelligence and such large wants that his standards of living increase very rapidly with the improvement of his financial condition. He is liberal to his family, ambitious for his children, and he desires above everything else to raise their standard of living and to increase their advantages in all ways beyond those which he himself enjoyed in his youth.

Another cause of the great economic influence of the American farmer is found in the fact that as a rule he owns his own land. In addition to the profit upon his labors he receives the rent on his land. This not only puts a larger sum at his disposal, but it also creates a motive for additional expenditure for improvements and equipments upon that land. The American farmer, moreover, seldom hoards his money, but promptly expends his surplus for improvements, or else puts it in the bank, where others can use it. He is, all things considered, the wisest and safest investor among us, and his prosperity is therefore the greatest blessing that can possibly come to the nation. Our conclusion is thus that the progress of agriculture is the greatest practical concern of civilized man, and especially of the American.

We have found that the problem of agriculture is to produce more and better supplies for the support of human life under conditions that will enable the farmer and his family, and with them the people of the whole country, to live the happiest and most complete life possible, a life which, as the decades and centuries pass, shall be constantly expanding, strengthening, and growing deeper and richer. The question, then, is "How shall agriculture do this?" What prospect is there that this art shall be able to supply these ever-increasing demands, not merely for food to keep the body alive, but for all the resources needed to support a life growing ever more true and beautiful? What encouragement, then, can we find in recent progress, for believing that this world-old art will improve with the years and the demands of the race?

The improvement of agriculture depends, of course, upon the soil, including location as to latitude, longitude, climate, etc., upon the plants and animals used; but most of all, after these things are provided, upon the farmer and his methods. The most we can do here is to give a few illustrations of the advances made in recent years in improving the soil and increasing its fertility, in developing plants, and in training the farmer himself and improving his methods. We hope in this way to give some idea of what we may expect to accomplish in the future for the advancement of agriculture.

Agriculture, the oldest of the arts, was the very latest to apply the discoveries of science. This is due to two causes. In the first place, agriculture is the most difficult of the arts, and involves, one way and another, directly and indirectly, the application of all the sciences. Secondly, its workers have in the past been less trained in scientific methods than those in other callings. Until recently agriculture has been almost wholly an empirical art and only in very recent times has the farmer received any special training for his profession. Always intensely conservative he has learned new methods very slowly. Many breaches have, however, been made in the wall of empiricism which has surrounded him for centuries and the farmer who formerly derided book-farming has now opened his mind to the lessons of science.

Since the farmer commenced to use the teachings of science, the progress of agriculture has been extremely rapid; and as we may expect that agriculture will make gigantic strides in the next decade, the new agriculture, which is based on science rather than empiricism and which is just now being introduced, is destined to advance all the other industries and give the race a new forward impulse. This we must believe from the progress already made. Consider, for example, the progress made since the time of Liebig in the study of soils. Liebig based all his proposals for the conservation of fertility and the improvement of the soil upon chemical composition, and his teachings did much to improve our agricultural methods. According to his theory the soil was composed of dead, inert matter, and the question was how to provide the so-called mineral food of plants in sufficient quantity and available form. For fifty years all methods of soil improvement and culture were based upon this idea. The soil was supposed to be devoid of all vitality until the crop appeared, and the chief business of the farmer was to destroy every other form of life. The question of nitrogen-supply had come to be looked upon as lying at the very foundation of agriculture and demanding the most careful consideration because the conditions of life in the civilized quarters of the globe were thought to cause a constant loss of nitrogen. Every collection of animals, brute and human, was destroying the combined nitrogen-supply; every town and city was dissipating enormous quantities of it through its sewers and into the atmosphere. Tons of this valuable element were being burned in explosives, and nitrates enough to grow bread for a whole city were being destroyed in single battles. At one time there were many who, like Sir William Crookes, predicted a nitrogen famine in the soil which in time would lead to a bread famine throughout the world.

One does not have to read far in the agricultural literature of to-day before finding that all these ideas have been entirely changed. The soil is now known to be filled so completely with living things as to entitle it to be considered a vital mass itself, and even those elements in it not endowed with life now have the highest significance as the necessary environment of the living organisms which they help to nourish. We know that there are countless organisms in the soil, rendering many different kinds of service in preparing it to be the home of the plants, and, what is more important, in preparing the food for the plants themselves. Some of these organisms dissolve the mineral matter of the soils, others exert their activity on the organic nitrogen in the humus of the soil; others develop parasitically or symbiotically with growing plants, like the legumes, herding in colonies upon their roots and securing by their vitality, in a way we do not fully understand, the oxidation of the free nitrogen of the atmosphere. Still others have the ability, independently, apparently without the aid of plant vitality, either to secure the oxidation of atmospheric nitrogen or to produce ammonia. Investigations along these lines, which have now led to the systematic distribution of nitrogen-fixing bacteria for inoculating the soil, have, for a time at least, dispelled all dreams of early famines, and have given the world an assurance of a sufficiency of bread for at least an indefinite period. The refined scientific investigations of Nobbe in Germany have now been made practically effective in fixing nitrogen in the soil. Soil or seed can now be inoculated with the nitrogen-fixing bacteria just as dough is inoculated with yeast.

Mention might also be made in this connection of the proposals to combine the nitrogen and oxygen of the atmosphere by the electric spark, as is now being actually attempted at Niagara. Definite reports of results are not yet obtainable, but if this can be done on a large scale, we shall be able to utilize the great water-powers to make this valuable food for plants from the inexhaustible stores of the atmosphere.

Great progress has also been made in this country in the study of the physics of the soil, with the result that vast new areas, like the alkali soils, are being reclaimed; and crops have been found for many other soils which were supposed to be useless. The proper comprehension of the relation of the soil to moisture has expelled many of the empirical methods of culture, and has given us a new conception of the meaning of tillage. The same may be said of the relation of the soil to heat.

The main object in all farming being the production of larger yields and better quality of crops, scientific men have given a large share of their energy in recent years to investigations having these objects directly in view. This work has included the testing of field-crops, fruits, and vegetables, for the purpose of finding those best suited to given regions and conditions; the improvement of methods of culture, the production of improved varieties by selection and breeding, and the better utilization of the product. Burbank's marvelous work in new flowers and fruits, trees and plants of all kinds, has at last received the popular recognition it has long deserved. The possibilities in this direction now appear almost limitless.

The staple crops of the country, such as wheat and maize, or Indian corn, have been the subjects of much investigation, covering every phase of their improvement by selection, breeding, tillage, fertilization, harvesting, curing, preparation, and utilization. The results have been of vast practical value. Those in the cases of wheat and corn will illustrate the progress made.

Not only has it been shown that the quality of wheat for special purposes can be materially changed at will to suit necessary conditions or special wants, but the productivity of races or types of the grain can be fixed by systematic seed-selection. For plants can be bred just like animals. Burbank's wonderful work is so well known now that we need not describe it. At the Minnesota Experiment Station new varieties of wheat have been produced by breeding and selection, which, we are told, will increase the yield in the hard-wheat region of the Northwest by from three to five bushels per acre. Reduced to a practical basis, this means an increase in the wealth of the three states, Minnesota, and North and South Dakota, of from $20,000,000 to $40,000,000 annually. The yield and quality of wheats in that region has already shown a marked improvement as a result of the distribution of seed of two or three improved varieties. As varieties suitable for other sections will undoubtedly be originated in due time, the results that will accrue when these methods have been extended to all the wheat-producing areas of the United States can hardly be imagined. The wheat crop of this country for the year 1902 was 675,000,000 bushels, valued at $425,000,000. The average yield of wheat is only a little over thirteen bushels per acre, considerably smaller than that of England where it is twenty-six, and that of Germany where it is thirty-one. If, by the introduction of these improved varieties and of better methods of tillage, the average yield of this country can be increased no more than two bushels per acre, the total increase for the entire country will be 100,000,000 bushels per year, worth about $100,000,000. This would seem to be entirely practicable. If the excellent prospect of increasing the nitrogen-supply in the soil for cereals does not allay all anxiety regarding starvation, the results in breeding new varieties of wheat and other food-plants should certainly put that fear to sleep for a long time to come.

No less interesting and instructive is the recent work in corn-breeding conducted at the Illinois and Kansas stations. Although corn, which is this year yielding probably two and three-fourths billions of bushels, worth approximately one and a half billions of dollars, heads the list of cereals in value, until the valuable work of these experiment stations was announced there had been no material improvement in the production of this crop in twenty years. The Illinois station has shown that if the methods of selection practiced by it, which are quite feasible and within the reach of every farmer, were followed throughout that single state, the increase in production in one year would amount approximately to $20,000,000.

Methods have also been found for changing the composition of the grain itself to meet special requirements: such as an increased yield of oil or of protein. Since the manufacture of oil from corn has become an industry, the amount of this constituent is a matter of considerable consequence. By selection the oil-content has been doubled in some varieties.

The most important question, however, connected with the improvement of corn is that which relates to its value as a well-balanced food. Its relative deficiency in protein has probably been the chief reason this grain has not been more extensively used as a human food in continental countries. It has, therefore, long been a question how to increase the protein in a grain of corn at the expense of the starch and fats. As the nitrogen, like the other constituents in the grain, varies in the different varieties, the way is thus opened for the control of the variations in this important element. The Illinois and Kansas stations have been engaged for some time upon this problem. By the selection of varieties containing a high percentage of protein, it has been found possible to develop strains containing an increased amount of this desirable substance. The protein-content of some varieties of corn, now apparently well fixed, has been increased fully 2.5 per cent, that is, from about 10 to about 12.50 per cent, which makes corn equal to the average wheat in this respect. In special cases it has been increased to even as much as 17 per cent. Should wheat then fail us, Indian corn will be ready to take its place with an equal amount of protein.

The development of the rice industry in Louisiana and Texas furnishes a good example of the building-up of a new industry by the introduction of a new type of seed and of improved methods of cultivation and harvesting. Rice was one of the earliest introductions into this country and was grown for nearly two hundred years in South Carolina and the adjacent states with little improvement of method. It was thought that these states were the only ones that possessed the requisite irrigable lands. It has recently been discovered, however, that the prairie lands of southern Louisiana and Texas will produce large crops of rice, if provided with the requisite water, which is now obtained from bayous or artesian wells. The water is drained off in time to permit the ground to dry and the crop is then harvested with machinery similar to that used with wheat. As a result of these improved methods, the total rice-production of this country has increased in five years from about 100,000,000 pounds to about 400,000,000 pounds. The two states mentioned produce over 90 per cent of this. As the American people import some 40,000,000 pounds of rice annually, there is still room for the development of this industry. It is estimated that there are available in these two states alone 3,000,000 acres of land suitable for rice-growing. This is perhaps the best single illustration of the introduction of new races of seed and the use of improved methods of cultivation in their production.

I wish next to suggest another place where scientific investigations of a similar character are greatly needed. Cotton-culture needs precisely the same sort of attention from scientific men and expert agriculturists as has been given to wheat, corn, and rice. Considering the immense importance of this crop, it is remarkable that it has not received more systematic study.

A group of states in the southern portion of America, constituting less than one fourth of the total area of the United States, grows from 60 to 70 per cent of the cotton consumed in the world. The total value of the annual crop is exceeded, among the cultivated crops of the United States, only by Indian corn and occasionally by wheat, both of which are grown in almost every state. Since it is fair to assume that all the fibers have been pretty well tested as to their capabilities and uses, we may conclude that cotton, now the preferred fiber, is destined to grow steadily in favor with civilized man, and will continue to be used by him in increasing amounts. We are constantly finding new uses for it, and may safely predict that the demand for cotton will increase rather than diminish. It has been estimated that to meet the world's demand, when its standard of consumption has been raised to that of the civilized nations, will require an annual crop of at least 45,000,000 bales. It is therefore eminently desirable that the Southern States of America should meet this demand. Will they do it?

Present tendencies in the cotton world, at least, seem to answer "No." During the last four years the consumption of cotton seems to be rapidly overtaking the production, with the consequence that many of the mills in the United States, in England, and on the Continent have been running on short time. There are two principal causes which have contributed to this shortage. The most important has been the large increase, amounting now to at least 500,000 bales per annum, in the world's consumption. Of this increase, the greater part was in the Southern States themselves, where the consumption of cotton was doubled within the last ten years. These states are now taking nearly twenty per cent of the cotton produced by them. The second cause of the shortage is the failure of the American cotton-planter to respond to the increased demand, and perhaps a slight falling-off in the yield per acre. In fact there are some reasons to believe that the yield per acre has been slowly but steadily declining for a number of years.

Although in many sections from 500 to 800 pounds of cotton may be obtained by good cultivation, the average yield of cotton in the United States is only about 190 pounds of lint per acre. There is evidently great room for improvement in the methods of cultivation and fertilization, and especially for improvement of the plant itself. Any one who has traveled through the South will acknowledge that the methods of cotton-culture are the poorest and most backward used with any staple crop in our country.

Cotton is limited by climatic conditions to that portion of America south of latitude 37. The essential features of the climate in this section are a long, warm season and a peculiar distribution of the rainfall. Statistics show that the fluctuations in the yield per acre in a given section are less in the case of cotton than in that of almost any other product of the soil. The production of cotton may be due to the greater uniformity of all the climatic conditions obtaining in the cotton-belt, but the chief determining condition as between different sections of our country is the amount of light and heat distributed over the required number of days. For cotton is a sun plant. As a rule a certain amount of sunshine produces, upon a given territory, a certain amount of cotton. The distribution of rainfall is also important, but sunlight is the chief factor The plant requires an abundant supply of moisture during the growing stage, but can stand a good deal of drought after the middle of summer is passed. Now the section of the country providing these conditions measures only about 500,000 square miles, less than one third of the total settled area of the United States. Some 50 per cent of this area is contained in farms, and about 21 per cent is improved; but only about five per cent of the total area, or one tenth of the area in farms and one fourth of the area of the improved lands, is annually cultivated in cotton. If the whole area in farms in this section were cultivated in cotton, it would produce at least 80,000,000 bales. So far, therefore, as soil and climatic conditions are concerned, the Southern States can produce seven or eight times as much cotton as they now do.

But soil and climate are not the only conditions. It requires men and mules to make a cotton crop. It is generally recognized that the labor used in the production of cotton is something over fifty per cent of the total expense of growing the crop. This exceeds the cost of labor in growing corn and wheat, and also in many manufacturing industries. But statistics of population show that there is labor enough available in the South to handle an increase in the cotton crop such as the cotton-belt is capable of producing under favorable conditions. The Negro is well adapted for working in the cotton-fields, and his children are the only successful cotton-pickers known. The great need is that this labor be better trained and organized. Although the supply of mules and horses is inadequate at present for the production of a crop of this size, they might be raised within a few years.

We come thus to the question why the South does not actually produce more cotton to supply the world's increasing demand. It is commonly stated that the low prices which prevailed for a number of years led the planters to diversify their farming and to devote more of their means and energy to the production of general farm-supplies. This is true; but when this has been successfully accomplished, the planters should be in an even better position to produce the crop demanded. Where then is the trouble? Experts seem to agree that the chief difficulties are the impoverishment of the cotton-soils through continued cropping under the renting system, and the running-out of the seed. Observation in the cotton-belt leads us to believe that fully two thirds of the planters use seed taken entirely at random from the public gins, about which they know nothing whatever.

It is safe to estimate that the cotton crop could be doubled on the same acreage by the use of good seed and careful methods of tillage and fertilization. Questions of tillage and fertilization must be left to the farmers chiefly, but the experiment stations should take up the question of improving the seed.

Certain definite things should be kept in mind in the process of cotton-seed development. Among these are an increased yield of fiber and of seed, an increased length of fiber with uniformity, the strength of the fiber, the season of maturity, adaptation to soil and climate, and resistance to diseases. It is probable that cotton having these different qualities will have to be bred to suit the soil and climatic conditions of each section. Here then is a great task, one, however, which offers magnificent rewards. It is firmly believed that the scientist and the cotton-planter will together be fully equal to its solution.

We have sought by these few illustrations to show what science has already contributed to the advancement of agriculture and how it may be expected to do still more for it in the future. No one now doubts that the progress of agriculture in the future depends chiefly upon the discoveries in science and their application to the practical problems of the farmer.

The discoveries of science, however, and the demonstrations of the United States Department of Agriculture through its experiment stations, will be of little value to the American farmer unless he is well enough educated to understand them and skilled enough to apply them. More secondary agricultural schools and schools for the training of horticulturists, dairymen, and other specialists are needed in all our states. The higher agricultural institutions and departments of agriculture in our universities are answering an admirable purpose in training experts and investigators; but so far we have very few secondary agricultural schools. It is believed that the next development will be along this line. Certainly the greatest need of American agriculture is farmers trained to habits of observation and skilled in the application of science to their business. What the new agriculture will do for the advancement of the race when even a majority of farmers have learned its methods confounds the imagination. This greatest of productive industries will lay a new foundation, deep and broad, upon which man will build a new life, growing ever nobler and truer "unto the perfect day."

SOME PRESENT PROBLEMS IN AGRICULTURE

BY LIBERTY HYDE BAILEY

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AGRICULTURE is now in a transitional stage. It is passing from the old to the new. It is pupating. The problems are great, and they all have a forward look.

Most of these problems are incapable of solution quickly. They must ripen and mature. They are many; this paper proposes only to state a few of them that appeal most to me, leaving the discussion of them to others.

The problems of agriculture are of pressing importance, both to agriculture itself and to the public welfare. They are of two kinds: (1) the technical problems of the business, (2) the problems of adjustment to the affairs of our growing civilization.

The problems of adjustment are of the greatest public concern because agriculture is our greatest occupation and is necessary to civilization. Of all occupations, it employs most men, most capital, and is followed in the most places. It probably must always employ from one fifth to one fourth of the people of any self-sustaining nation. There are supernumerary, eleemosynary, and parasitic occupations; but agriculture is basic.

Other occupations have had their day in the public appreciation. All of them have been born out of agriculture. Tubal-Cain was the descendant of Adam. The greatest of public problems are to come with the rise of the agricultural peoples. Just because it is basic, agriculture has been conservative and patient. Fundamental strata are likely to be azoic; but in great world-movements they are also likely to rise permanently to the top.

The farmer is a wealth-producer. Therefore his importance in the body politic is primary. He deals with elemental forces. As a wealth-producer, he will come to have a larger voice in the expenditure and waste of wealth in maintaining armaments of war. All his instincts are of peace.

The public problems of agriculture have been slow to gain recognition. The agricultural questions that we customarily discuss are those of the individual farmer. The burden of our teaching has been that the farmer must be a better farmer. Only in recent years has it come to be fully recognized that agricultural problems are of the greatest national and governmental significance. Consider how recent is the Land Grant Act, the secretaryship of agriculture in the President's cabinet, the Experiment Station Act, the origin of a definite farmers' institute movement, the development at public expense of fertilizer and feed controls and other policing policies, the making of liberal grants of public money for specific agricultural uses.

Governmental fiscal policies have been shaped primarily for other occupations, as, for example, the tariff for protection. This is primarily a manufacturer's policy. It matured with the rise of concentrated manufacturing. One of the stock arguments of the protectionist when addressing farmers is that any policy that aids manufacturing interests must indirectly aid them. I am not here to discuss or to criticise tariff legislation, but it is apparent that such legislation is only secondarily of benefit to agriculture. It has been the history of institutions that special and organized interests receive attention before care is given to the common people and the masses.

We have really not endeavored, as a people, to solve our technical agricultural problems until within the present generation. We have escaped the problems by moving on to the west. Thereby we have fallen into the habit of treating symptoms rather than causes, as the policeman does when he orders an offender to "move on," and leaves the real difficulty for some one else to solve. Even yet, farmers are moving on to find land that is not depleted and regions free of blights and of pests. The real development of agriculture lies in developing the old areas, not in discovering new ones. When virgin land can no longer be had, scientific agriculture will come. An isolated island develops something like a perfected agriculture, as one may see in Bermuda or Jersey. The earth is an island: in time it will be developed.

As agriculture comprises a multitude of different businesses, everywhere touching many sciences and having contact with many public questions, so it is impossible for one person adequately to state even its present and pressing questions. I have been in the habit of inquiring of farmers, students, and colleagues what they consider the agricultural problems to be. Many of the problems that they have stated to me are temporary, local, or incidental. Others are common to many occupations, having to do with the general constitution of society and the general trend of economic events. In this paper I have tried to assemble statements of such questions as appear to me best to illustrate the complex nature of the subject before us. I wish I could give credit to the sources of all the suggestions, but this is impracticable, even though in some cases I have followed very closely the ideas and the language of my informants. I shall be obliged to assume full responsibility for the statements.[1]

The Technical Agricultural Problems

In America the so-called problems of agriculture have been largely those of the mere conquest of land. They are the result of migration and of the phenomenal development of sister industries. They have resulted from a growing, developing country. They have been largely physical, mechanical, transportational, extraneous — the problems of the engineer and inventor rather than of the farmer. The problem has not been to make two blades of grass grow where only one grew before, but how economically to harvest and transport the one blade that has grown almost without effort.

During the past hundred years there has been an area of development on the western border of the country, and this border has been able to compete at an economical advantage with the older area farther east. The price of land has fallen in the East, while it has risen in the West. From 1870 to 1900 we practically doubled our population and doubled our agricultural area. Aside from the geometrical increase in the population, this development has been due largely to a fertile, level, practically treeless prairie. Hitherto the axeman had hewn his way tree by tree. The development of the area west of the Mississippi River is probably the most remarkable in the history of the world. A second cause for this development is the consolidation of railroads into transcontinental lines; and another is the improvement of labor-saving machinery, of which the self-binding harvester is the most conspicuous example, a machine that first attracted wide attention at the Centennial Exposition in 1876.

To this day the American is a cheap-land farmer. A few minutes on the train from a European city brings one into a highly tilled agricultural country. The other day I took an express train from New York City. It was three quarters of an hour before I saw what I could call a farm, and a full hour before I reached a farming country.

As early as one hundred years ago, a distinct movement for the betterment of agriculture had set in. This movement was largely educational. It was an effort to improve the farmer quite as much as to improve the farm. Washington was vitally interested in the problem. He wished to have a central board or clearing-house for agricultural information. The full fruition of his hopes came with the establishment of a secretaryship of agriculture in the President's cabinet, in Benjamin Harrison's administration. In 1799 a concrete

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[1] I am under special obligations to my colleagues, Professors Hunt and Lanman, and to one of my students, Mr. Charles Aronovici.

proposition for the establishment of an agricultural college in Pennsylvania came to an untimely end. In 1821 instruction was given in agriculture in the lyceum at Gardiner, Maine. In 1824 a school of agriculture was opened at Derby, Connecticut. A number of other similar attempts were made previous to the passage of the Land Grant Act of 1862, but of these only two or three persist. The gist of the whole movement was to adapt education to men's lives. The culmination was the Land Grant Act, the purpose of which is "to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life." So far as agriculture was concerned, the Land Grant Act was somewhat premature. The developing and organizing mechanical and engineering trades were the first to profit by it. Agriculture will now have its turn.

The tide to the limitless west rose and fell, and we came to a pause. The technical problems of the farmer called for study. His personal difficulties pressed for solution directly on the farm. These problems are of two categories: (1) to remove the special disabilities (insects, fungi, weeds, animal diseases), (2) to augment production (fertilizers, soil studies, tillage, improving plants and animals). Then was born the experiment station (in 1887): the idea is to improve the farm; it is investigational, not educational.

How special the purpose of the Experiment Station Act is may be seen at once from the purposes that it definitely mentions:

"That it shall be the object and duty of said experiment stations to conduct original researches or verify experiments on the physiology of plants and animals; the diseases to which they are severally subject, with the remedies for the same; the chemical composition of useful plants at their different stages of growth; the comparative advantages of rotative cropping as pursued under a varying series of crops; the capacity of new plants or trees for acclimation; the analysis of soils and water; the chemical composition of manures, natural or artificial, with experiments designed to test their comparative effects on crops of different kinds; the adaptation and value of grasses and forage-plants; the composition and digestibility of the different kinds of food for domestic animals; the scientific and economic questions involved in the production of butter and cheese; and such other researches or experiments bearing directly on the agricultural industry of the United States as may in each case be deemed advisable, having due regard to the varying conditions and needs of the respective states or territories."

The experiment stations are holding to these special fields with great faithfulness. In a lot of three hundred and fourteen bulletins that came to my attention bearing the date of 1903, the following rough classification of subjects was made:

Bulletins, 1903

Insects, diseases of plants	63 or 20%
Feeding and grazing	52
Fertilizers	37
Farm crops	33
Fruits, orchards	28
Dairy (milk and cheese)	23
Diseases of animals	16
Meteorology	15
Garden vegetables	12
Sugar	7
Natural resources, irrigation	7
Poultry	4
Weeds	4
Ornamental plants	4
Seed germination	3
Educational	3
Forestry	2
General advice, bees, exhibitions, plant-breeding, etc.	1
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Some epochs are now passing — as the fertilizer epoch based on agricultural chemistry. The larger question of self-sustaining farm management is now pressing. Three categories of technical farm subjects are just now beginning to demand much thought: (1) problems of feeding to increase efficiency of farm animals; (2) problems of breeding of animals and plants for the same purpose; (3) problems of the business organization of the farm, or development of a farm-plan. We are beginning to apply research to large fundamental questions. The earlier subjects of investigation in the agricultural experiment stations were mostly the smaller and incidental ones. A good many of them were vest-pocket questions. Now the fundamental or backbone crops and products are being investigated in their entirety — the corn crop, the cotton crop, the grass crop, the milk product, the beef product. The experiment stations are originating a kind of constructive investigational method, and the really great questions are ahead of us. Large problems come last.

We are now just coming to the large question of adaptation of special areas to special purposes. In the future one of the problems will be the more perfect adaptation of the kind of farming to soil and climate. As an illustration, the production of domestic animals for meat and for wool has been most extensive on the western border of the developing country for economic reasons, and not because the area is naturally best adapted to this enterprise. The central Mississippi Valley is primarily adapted to the production of cereals and not so well adapted as the North Atlantic States to the production of grass either as pasture or hay. These Atlantic States are particularly adapted to growing all kinds of trees and of grass. In the course of time, therefore, we may expect that the production of live-stock will become more important in the East. Out of this grow some immediate problems. At present, live-stock husbandry in the East can be carried on economically only when large tracts of land can be purchased at low price. It is possible to purchase small tracts of land at comparatively low price, but not possible to purchase large areas. More of the live-stock will be raised on small farms within the more densely populated districts, with comparatively few animals to a place. This will lead to the question of maintaining the improvement in domestic animals. It will mean the gradual substitution of soiling systems for pasturing systems, and this will lead to remoter economic and social changes.

New industries are to be developed. This calls for special governmental recognition. The national Department of Agriculture aids such new enterprises by giving counsel and investigating the special technical difficulties; but is this kind of aid sufficient? If the government helps new manufacturing industries by giving them special privileges, why not aid new agricultural industries by bounties? If a bounty system were to become a recognized public policy (following perhaps the experience with sugar bounties), would it result in undesirable social and economic changes? The money grants to agriculture are only a fair offset to special privileges given to other industries.

The Social and Economic Problems

We are now returning to the farmer, although still holding to the farm. There is a distinct recrudescence of the educational point of view. The new emphasis is to be placed on the man rather than on his crops. The farmer is a citizen as well as a farmer; he is an important factor in public affairs.

The new education must reach the farmer in terms of the whole man — his particular business, his home and its ideals, his relation to good roads, good schools, the church, to social forces, to all that makes up a broad and satisfying country life. We must give attention to the ideals of living as well as to the ideals of farming. The sanitation of the farm-home, the architecture of the buildings (what silent and effective teachers buildings are!), the reading, the character of the farmyard, the questions associated with the bringing-up of children, the social and commercial organizations — these are the kinds of subjects that the rising educational impulse must attack.

All this enforces the economic and social questions relating to agriculture. The greatest problems of American agriculture are not the narrower technical ones, but the relations of the industry to economic and social life in general. Agriculture has not as yet been able to call to its aid in any marked degree those forces and tendencies which have culminated and been of such economic value in the general business world, in the great productive and distributive aggregations. The complete solution of the economic ills of American agriculture may not be in coöperation, and yet in both the productive and distributive phases this is perhaps the most apparent remedy. Coöperation in distribution has made a beginning, but coöperation in production is still almost unknown. Are Kropotkin's ideals attainable?

The problem of the supply of capital in agriculture has never been solved in this country other than in the most expensive way. Capital must return to the land. Two factors enter into the problem: (1) to demonstrate that capital can be made remunerative in farmed land, (2) to insure that land will not bear an unjust burden of taxation.

Closely associated with the economic side is the sociological phase. In the days when all were interested in agriculture, both school and church flourished, but in these later days both have lost their molding influence in the country, though the former shows signs of renewed activity vital to the community.

The specific economic and social questions that even now press for study are so numerous that they cannot be catalogued in an address of this character. Is there still an active exodus from the country? If so, is the movement caused by purely economic conditions, or is it in part the social attractiveness of the city? In other words, does the education of the farmer fit him for the appreciation of the esthetical and philosophical values of his environment? In what relations do the labor-saving devices stand to the rural exodus? Can it in any way be due to super-population of the rural communities? Are the final rewards of labor greater in the city than in the country? Is the arrested development of country church and school in any way responsible?

What are the tendencies as to size of farms? Is the American, starting with small individual ownership, tending towards consolidation into larger units? Is the European, starting with large landlorded ownership, tending towards small individual units? Are the small farms decreasing in number? In what way does the development of the railroads and electric roads affect the size of farm properties? In what way do the labor-saving devices influence the size of farms? Could coöperation of farmers remedy any tendency towards large farms? Or, are larger farm units to be desired?

What can coöperation do for the farmer? Must it be economic, social, political, or to increase production? What are the moral and psychological effects of coöperation? What relation can coöperation have to the isolation of the farmer? To his hygienic conditions? Is it possible or desirable by means of coöperation to save small individual ownership of farms?

Is it true that the country promotes health better than the city? What are the diseases of the country? Are there mental diseases of isolation? Are most of the farmer's diseases due to his work, environment, or poor intellectual preparation to meet the requirements of his condition? What could the state do for the farmer from a hygienic standpoint? What are the relations of farm water-supplies to the prevalence of typhoid fever and other diseases?

How is isolation to be overcome? By a hamlet system? Or by a distributive system of communication — as by better roads, trolley-lines, auto-vehicles, rural mail delivery, telephones, traveling libraries, coöperative reading-courses? Is the social life of the small village as vital and wholesome as that of the separated farm-home?

These are only the merest suggestions of a very few apparent present problems. They are not to be solved by any *a priori* reasoning, nor by using the stock statistics and opinions of economists and sociologists. The field must be newly studied. New data must be collected. New means of attack must be developed. With much painstaking, actual facts in detail must be secured. What is the actual social and economic status of every farmer in a township? a county? a state? Who knows? History must be studied from a new point of view. The very foundation of historical development is public opinion of the common people; and until within the past century the common man was the farmer. Agriculture is the basis of history. The best data of the actual conditions of the people antecedent to the French Revolution are said to be found in Arthur Young's minute description of the agriculture of France. The historian of agriculture is yet to be born.

As an example of the inadequacy of our information on important economic problems, let me cite the most pressing problem just now confronting the American farmer — the question of farm-labor. Farm-labor is scarce; it is dear; it is inefficient; it is unreliable. Yet we read of the armies of the unemployed asking for bread. Why? Who can answer? Who has the data? There seems to be not one authority to whom we can turn. It is apparent that these serious pressing problems — scarcity, expensiveness, inefficiency of farm-labor — are only symptoms of some deep-seated maladjustment.

A large proportion of the labor on farms is done by the farmer himself or his growing family. The inability to find steady employment for laborers is a very difficult problem. Ordinarily, men desire to work all the time and to use their energy to the best advantage.

A farmer's family arrives at the productive age when the parent is between forty-five and sixty. The farm does not offer opportunity for the sons because the father still desires to maintain his activity. The farmer does not take the boy into his business to the same extent that other business-men do. The result is that the sons must find employment elsewhere, and in the nature of the case they most conveniently find employment on salary. By the time the father is sixty-five to seventy years of age and feels the necessity of giving up the farm, the sons are engaged in other lines of effort which it is not practicable for them to leave. The result is that the farm declines with the declining years of the father and on his death is sold or becomes a rented farm. Occasionally a parent solves the difficulty; and herein a distinct public responsibility rests on the individual farmer.

Is the farm-labor difficulty a too low wage-rate? Is farm-labor inefficient merely because it is cheap? If so, how must the farm be made to be able to pay a rate in competition with other labor? Has the tariff contributed to the inequality? Is social poverty of the country districts a cause? Is the lack of continuity or unsteadiness of farm-labor responsible? Has the decrease in the size of the farmer's family been responsible for part of the trouble? And if so, why has his family decreased? Must the farmer of the future raise his own labor? Must machinery still further come to his aid? If so, what effect will this have on systems of agriculture? Will the urbanization of the country tend to establish a regularity of farm-labor? Will cheap railway rates from cities for laborers aid in maintaining the supply of labor for those living on the land, making it possible for the laborers to find work during winter in some neighboring community (it is said to have helped in some parts of Europe)? Can we develop a competent share-working system, in which the owner of the land still retains directive control? And if so, will social stratification result? Must there come a profit-sharing system? Or must the greater number of farmers themselves become employees of men of great executive ability who will amalgamate and syndicate agricultural industries as they have consolidated other industries? Is the agriculture of the future to be a business of fewer and larger economic units? If so, how will this affect the centres of population and the social fabric? Will the lack of farm-labor force us more and more into "nature farming" — the hay and pasturage systems? What, in short, is the farm-labor problem?

The country as well as the city must be made attractive and habitable. It must express and satisfy the highest human ideals, else it will not attract the best men and women. In area and population, the country is the larger part of the national domain: the improving of the ideals of the persons that live therein is one of our greatest public questions. The farmer is the conservative, not the dynamic element of society. We live in a dynamic social age.

The farmer always will be relatively conservative. His business is rooted in the earth. In a thoroughly well-developed agriculture, the farmer does not move his business rapidly from place to place. He remains while others move on. Therefore is it especially necessary that we extend to him all the essential benefits of our civilization. (I hope he will not care for the unessential benefits.) He has the rural free delivery of mails — although this was thought to be impossible a few years ago. Shall he not have a parcels post? Each year the good roads movement, originating in the cities, is extending itself farther into the real country. Trolley-lines are extending countryward; soon they will come actually to serve the farmer's needs. The telephone, as a separate rural enterprise, is extending itself. Extensional educational enterprises are reaching farther and farther into the open farming districts. Coöperation and organization movements are at the same time extending and concreting themselves.

Farming stands for individualism as distinguished from collectivism. Farming enterprises will be more and more consolidated and capitalized, but they can never be syndicated and monopolized to the same extent as many other enterprises. How best to preserve and direct this democratic individualism of the open country is one of the greatest questions now confronting us.

The art impulse will soon take hold of the country, as it has already laid hold on the city. We have lived all these centuries on the assumption that work of art is associated with buildings and "collections." As nature is the source of all our art, so the time is coming when we shall allow nature herself to express her full beauty and power. We shall go to nature oftener than to art galleries. We shall first remove objectionable features from the landscape — features for which man is responsible — such as all untidiness and blemishes, all advertising signs, all unharmonious buildings. Then we shall begin to work out our enlarging aspirations with the natural material before us — make pictures with sward and trees and streams and hills, write our ideals in the sweep of the landscape and the color of the flowers. Our "art" societies still confine themselves to imitation art. The great art societies will be those that give first attention to nature as it is, and to human ideals expressed in nature, not only as it is represented to be in plastic materials and in paints.

Of all the forces that shall revitalize and recrystallize the country, the school is the chief. The schools make the opinions of the nation. The city school has been developed, but the country school has been relatively stationary; yet every farm family is interested in the school. The farmer believes in schooling, just as completely as the city man does; but he may not be convinced that the schools are really touching the problems of life. Persons make more sacrifices for their children than for any other cause. Probably more persons leave the farm to educate their children than for any other cause.

An ideal condition would be the total abolition of rural schools as such. The custom of setting apart towns and villages into special school-districts in order separately to tax the town or village for school purposes has been a misfortune to the rural schools. The whole school-system of any state should be organized on a broad enough basis so that every boy and girl, whatever the occupation of the parents, shall have the opportunity of securing the same, or at least equally efficient, education. The country mill has gone. The old-time country school is a passing institution. A one-teacher school may be as inefficient as a one-man mill. Schools will be consolidated into larger or at least into stronger units. The first pedagogical result will be the differentiation of the work of teachers — perhaps one of these teachers can give special attention to nature-study and country-life subjects.

The school must connect with real life. It will be one of the strong constructive and dynamic influences in our social organization. At present its influence is receptive and passive, rather than creative. The particular subjects that shall be taught are of less importance than the point of view. Many questions of detail are to be discussed, often with much travail; but the final solution must be to allow every subject in which men engage to find its proper pedagogic place in a wider and freer educational system than the world has yet seen, and to place agricultural subjects with the others and not exclusively in institutions by themselves.

Whatever our doubts and misgivings, the American farmer is bound to be educated. He will demand it. Having education and being endowed with a free chance, he will not be a peasant. Some persons have made the serious mistake of confounding peasantry with comparative poverty. Peasanthood is a social stratum. It is a surviving product of social conditions.

If the open country is to be made attractive to the best minds, it must have an attractive literature. There must be a technical literature of the farm, and also a general artistic literature portraying the life and the ideals of the persons in the country. The farm literature of a generation ago was largely wooden and spiritless, or else untrue to actual rural conditions. The new literature is vivid and alive. The new, however, is yet mostly special and technical, with the exception of the growing nature-literature. Artistic literature of the farm and rural affairs is yet scarcely known. Where is the high-class fiction that portrays the farmer as he is, without caricaturing him? Where is the collection of really good farm poems? Who has developed the story interest in the farm? Who has adequately pictured rural institutions? Who has carefully studied the history of the special farm literature that we already have? Who has written the biological evolution progress that attaches to every domestic animal and every cultivated plant? We need short and sharp pictures of the man at his work and the woman in her home — such quick and vivid pictures in words as an artist would stroke on his canvas. There is nobility, genuineness, and majesty in a man at useful work — much more than there is in a prince, or a general, or a society leader, whose rôle it is to pose for the multitude. The man holding the plow, digging a ditch, picking fruit, the woman sweeping or making bread — what stronger pictures of human interest can there be than these? If I could have the choice of the mite that I should contribute to the developing and the nationalizing of agricultural sentiment, I should choose its literature.

WORKS OF REFERENCE FOR THE DEPARTMENT OF TECHNOLOGY

(Prepared through courtesy of Chancellor W. S. Chaplin, Washington University)

CIVIL ENGINEERING

Allen, Railroad Curves and Earthwork.
Baker, Roads and Pavements.
  Masonry Construction.
Baumeister, Sewerage of Cities.
Bovey, Hydraulics.
Burr, Materials in Engineering.
Church, Mechanics of Engineering.
Comstock, Field Astronomy.
Doolittle, Practical Astronomy.
Foster, Electrical Engineer's Pocket Book.
Freitag, Architectural Engineering.
  Fireproofing of Steel Buildings.
Frizzell, Water Power.
Folwell, Water Supply.
  Sewerage.
Gerhard, Sanitary Engineering.
Harcourt, Harbors, Rivers and Canals.
Hayford, Geodetic Astronomy.
Hazen, Filtration of Public Water Supplies.
Johnson, Surveying.
  Framed Structures
  Engineering Contracts and Specifications.
Kent, Mechanical Engineer's Pocket Book.
Lanza, Applied Mechanics and Strength of Materials.
Marsh, Reinforced Concrete.
Mead, Irrigation Institutions.
Merriman, Hydraulics.
Merriman and Jacobi, Roofs and Bridges.
Patton, Foundations.
Rankine, Applied Mechanics.
Raymond, Plane Surveying.
Searles, Field Engineering.
Sedgewick, Sanitary Science.
Thomas and Watts, Improvement of Rivers.
Tilson, Street Pavements.
Trautwine, Civil Engineer's Pocket Book.
Turneaure and Russell, Public Water Supplies.
Waddell, De Pontibus.
Wait, Law of Contracts
  Law of Operations.
Wellington, Economic Theory of Railroad Location.
Wheeler, Sea Coast.
Wilson, Irrigation Engineering.

MECHANICAL ENGINEERING

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Proceedings of the Institute of Mechanical Engineers.

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WORKS OF REFERENCE RELATING TO THE SECTION OF AGRICULTURE

(*Prepared through courtesy of Professor Liberty H. Bailey, Cornell University*)

(The literature related to technical farm operations and to the scientific phases of agricultural production is now very voluminous. It is comprised in a considerable part of books and also in a great number of Experiment Station publications as well as in the current discussions in the agricultural press. In the field of rural economics and rural sociology there is yet very little specific literature. In this direction the following publications may be consulted for their bearing on the general subject.)

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Dodge, J. R., Farm and Factory: Aids to Agriculture from Other Industries.
Elliott, J. R., American Farms.
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György, Andrew, The State and Agriculture in Hungary.
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Myrick, Herbert, How to Coöperate.
Pratt, E. A., The Organization of Agriculture.
Simons, A. M., The American Farmer.
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Ireland, Industrial and Agricultural (Published by Dept. of Agriculture and Technical Education, Dublin).
Vols. x and xi of the Report of the Industrial Commission, Washington, 1901.
Vols. v and vi of the 12th United States Census.
Division of Statistics, U. S. Department of Agriculture.

ADDENDA PAGES

FOR LECTURE NOTES AND MEMORANDA OF COLLATERAL READING