increase in the activity of such solutions. Outside of the living cell, therefore, these substances do not seem to be able to grow or to reproduce.

In this connection it has occurred to the writer that the enzymes sustain about the same relation to the living cell as do the non-nucleated cell fragments. It has been proved as the result of numerous observations that, if a unicellular organism be subdivided by mechanical means, each fragment thereof will still manifest vital activity. To the biologist, all these fragments are alive and yet their ultimate fate may be very different. Those that are nucleated have been found to have the power of completely repairing their injuries and ultimately develop into complete cells again and reproduce by cell-division. On the other hand, while the non-nucleated fragments frequently retain their vitality for days, for example, non-nucleated fragments of the amœba have been known to live for fourteen days, they ultimately perish. In some cases the non-nucleated fragments may even heal their wounds and engulf food particles; the latter, however, remain undigested and the fragment ultimately dies without reproduction. In this connection Verworn has pointed out that a nuclear fragment entirely devoid of cytoplasm can no more regenerate the entire cell than can the non-nucleated cytoplasm alone. He is, therefore, of the opinion that the formative energy of the cell cannot derive from either the nucleus or cytoplasm alone, but from both. To him the cell itself, and not merely the nucleus, is the vital unit, the activities of which are contributed to, in part at least, by both the nucleus and the cytoplasm, and that numerous exchanges of material actually go on between them is supported by the most trustworthy histological evidence of the present day. We see thus that in the formation of a new cell, whether by the natural repair of a cell fragment or by the usual process of reproduction, both the cell nucleus and the cytoplasm are concerned. It has also been shown, however, that both the nucleus and the cytoplasm are concerned in the production of the zymogens and ultimately of the ferments. It would seem, therefore, that the enzyme and non-nucleated cell fragments stand in essentially the same relation to the living cell. Both originate in much the same manner, both lack the power of growth and reproduction, and yet both exhibit certain vital activities. Would it be far from the truth, therefore, to look upon the enzyme as the chemical basis of life?

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THE PROGRESS MADE IN ENGINEERING DURING THE NINETEENTH CENTURY. *

THE progress made in engineering during the nineteenth century, on the one hand, furnishes in itself a reminder of its ultimate dependence upon mathematics and the sciences, and, on the other hand, it attests the fact that its great and growing inspiration has been the welfare of all the civilized world. A hundred years ago but little of engineering worth or prominence was in existence; so little, comparatively, that a glance at contrasting conditions then and now will reveal striking differences.

A century ago traveling in its highest development was limited on land to the horse and coach, covering perhaps a wearisome fifty miles in a day; now a day's travel is eight hundred miles. Then, a trip from New York City to Philadelphia consumed as much time and occasioned more fatigue than one from New York to St. Louis now; or a journey then from New York to St. Louis consumed the greater

* Read before the Academy of Science of St. Louis on February 18, 1901.

part of a month at best and was considered a greater hardship than a journey to India or China now. Then, the wind furnished the sole motive power for the ships of the ocean, and a voyage took as many weeks as now it does days. A hundred years ago the great canals were not built (one making the route to India as short as was formerly the distance to the half-way point—the Cape of Good Hope); nor monolithic lighthouses erected along the coasts for the safety of ocean voyagers. Then a building three stories in height was unusual; now a sixteen-story building is not uncommon. The century has seen the chaise give place to the horse-car and this to the cable, and finally the electric car with its speedy service brings the office within easy reach of the suburban residence.

The military engineer, while still trained and ready to engage in the fiercest shock of battle, has also developed plans of hasty works to accelerate transportation and the march, to make practicable the temporary entrenchments of the battlefield or the more permanent works of encampment and the siege; and he has perfected to a high degree the many stupendous works of permanent fortification and defense. While in the preceding century architecture was considered a branch of engineering,* yet in the century just closed they have been definitely divorced.

The mine engineer has developed methods and perfected details, until the total yield of mineral wealth now each year exceeds a thousand millions of dollars, while a hundred years ago it was but a modicum. Copper has been needed for electric purposes and the arts, and he has driven adits and shafts, drifts and tunnels, until some regions are honeycombed in the search for the metal to depths exceeding a mile. The same watchful enterprise characterizes the search for other metals. But by far the most important products of the mine are coal, devoting over seven hundred million tons a year to the countless uses of commercial and industrial life, and more than seventy million tons per annum of iron and steel, whose services in the century's developments are preeminent.

The marine engineer has developed not only the speed of ocean vessels as noted, but their safety and size as well, developing a marvel of steel construction that will contain the lading of a score of barks of a hundred years ago and carry a small city of people across the seas with a safety all but perfect. Less than a hundred years ago the first successful steamboat was built, of 4 H. P. and steaming at a rate of seven miles per hour; now the tonnage of our great steamships reaches 16,000, with a H. P. of 37,000, a length of more than seven hundred feet and a speed of twenty-seven miles per hour, while some military steamboats attain an hourly speed exceeding forty miles. A century ago the tonnage of steamships was naught; now this yearly addition to the commerce of the world is more than two million tons. Since the days of the *Clermont* and the *Savannah*, the marine engineer has been applying new discoveries and evolving improvements, slowly at first and then with increasing success, until the perfected steel giants of to-day cost about four million dollars each, instead of twelve thousand dollars for the sailing vessel of a century ago. And now there are more than fourteen thousand steamships in the world aggregating nearly twenty million tons register—a great world's fleet that, steaming abreast, would cover a width of a hundred miles.

The electrical engineer, within the latter portion of the century, has developed a field felt in all phases of practical progress, ranging from the inauguration of the telegraph of the mid-century and the submarine cable

* *Vide* 'Science des ingenieurs,' Belidor, Paris, 1729.

of about forty years ago to the enormous electric stations, furnishing power for our expanding industries, turning night into day in our cities and making practicable the great development in electric traffic in urban districts, electric elevators in our stores and electric apparatus of infinite variety everywhere to minister to our needs and comforts. Through the electric transmission of power has a vast field of industry been opened. Through all the ages had great water power been useless because of its remoteness, until the development of electric machinery, suited to the purpose, made practicable the transmission of power, twenty, thirty, forty miles, with much greater distances in prospect. As indications of the inevitable result, witness the busy life in the new cotton mills of the Piedmont regions of the Southern States, or the quickened industries of the Pacific Coast.

The mechanical engineer had invented the steam engine before the beginning of the century just closed, but its development was crude, as shown by the winding and pumping engines, the sun and planet, and beam engines placed in South Kensington Museum to illustrate the practice of that day, engines which were then considered unusual if they developed one two-hundredth part of the power of engines of to-day; while the total for the world is now not far from seventy million horse-power, which is greater than the aggregate physical power of the total population of the world, even were it possible to exert this power without cessation. And the engine is only one instance of the unparalleled advance; we should also mention such inventions and developments as the cotton-gin and cotton-bailing machinery, the gas and oil engines, the harvester, the sewing machine, the hydraulic press and other hydraulic machinery, the steam-hammer, and countless other labor-saving, epoch-marking machines of wide import and far-reaching significance, like the printing press, capable now of printing, folding and counting 1,600 eight-page newspapers per minute, where the hand-press a century ago could make not more than four or five impressions in the same length of time.

The metallurgical engineer has added his full share to the increased productive capacity of the world. A hundred years ago only a pitiful modicum of iron and steel was produced, and this with great expense and almost infinite pains. The blast furnaces then were about one-half their present diameter and one-third the height, producing perhaps five thousand tons per annum, where furnaces now will produce thirty to forty times that amount. Wrought iron was produced by the Bloomery, Catalan or other crude direct processes, or by the direct open-hearth fineries of Sweden or Wales; and steel by the Catalan, cementation or crucible steel processes, likewise very expensive and slow. At the present day we have, for the production of pig iron, blast furnaces a hundred feet high, costing seven hundred thousand dollars each; and for the finished product we have the puddling furnace (first introduced by Cort, close to the end of the eighteenth century), producing malleable iron, and the Siemens open-hearth and the Bessemer processes (developments of the last half-century) for the production of steel. These last two inventions mark the greatest advance ever made in metallurgical processes, and have made possible the wide range in construction in steel in all the various branches of engineering. Figures are wanting to give the quantity of steel produced a century ago. It could not have exceeded a hundred thousand tons, for fifty years ago Sheffield, then the great steel-producing city of the world, manufactured about fifty thousand tons per year; and the cost of crucible steel, made from Swedish iron, worth seventy dollars, was two hundred and fifty dollars per ton. Now steel is produced at less than thirty dollars; single steel firms produce millions of tons each year, and the annual product of the world is nearly thirty million tons. To show the great growth of this interest, Sir Henry Bessemer illustrated the total production of Bessemer steel of the world by saying that if the product of a single month were made into a solid shaft of one hundred feet diameter it would reach 557 feet high. This illustration of the world's production eight years ago is now equally applicable to the United States alone, nor does it include the production of open-hearth steel, or wrought or pig iron, the total for the world approaching eighty million tons annually. There is hardly any personal, municipal or corporate life, or hardly an enterprise of war or peace, that has not more or less closely connected with its development the use of this remarkable engineering material.

In the domain of the civil engineer progress is none the less marked. Within a score of years there has been developed the tall office and other buildings of the steel skeleton type, where the engineer has had to so design the steel frame that it will support sixteen, eighteen or twenty stories, crowded with busy life and industry, as well as to bear the weight of the walls and the great wind pressures that such high buildings sometimes must sustain; and not only this, but he has so considered and controlled methods and materials in the design and in protecting this all-important steel skeleton from fire that the occupants are safer in them than in the older style of building. Steel bridges have had a longer reign, though less than forty years ago it was considered a very remarkable feat to build an iron bridge whose length of span was 320 feet. Thirty years ago the magnificent steel-arch bridge of our own city, consisting of three spans, with the central one 520 feet in length, was erected by Captain Eads. Twenty years ago the Brooklyn suspension bridge, of 1,600 feet length of span, was being constructed. Ten years ago the great cantilever bridge across the Firth of Fourth was built, containing two spans of 1,710 feet each. And now there are plans, perfectly practicable, for a suspension span of 3,200 feet, to carry eight railway tracks across New York harbor and to weigh between sixty and seventy thousand tons. In railway affairs the engineer has perfected the problems of transportation as we have seen, until the total mileage of the century is great enough to girdle the world fourteen times. In questions of water supply and sewage all our cities provide systems as a necessity, where a hundred years ago they were the luxuries of the very few, and woefully inadequate at that; and the engineer and the biologist have been colaborers in developing successful methods of preventing danger of contagion from these public utilities. Harbors and docks have been constructed and improved consonant to the spirit of the age. Foundations for great bridges and towering buildings are carried to depths requiring methods and inventions of particular resourcefulness, including the famous pneumatic processes. The development of hydraulic principles has made possible a varied series of achievements of far-reaching significance. Irrigation enterprise, which had been dead for centuries in its ancient home and was dormant even in India, has spread over the arid regions of the globe and is making oases of the waste places of the earth. In only two-thirds of the year one of the small canals of the century transports merchandise of a greater value than have the imports of China, for which the great world powers are so strenuously alert. The construction of the proposed canal from ocean to ocean across Central America will be a stupendous undertaking; humanity has never ceased to marvel because of the great pyramids, and they have always been considered one of the wonders of the world; but, reckoned at the present cost of masonry, a dozen such pyramids could be built for the expense in-involved in the Nicaragua Canal. And when it shall be built the engineer may well improve the great waterways of the interior and build fleets of steel barges that can withstand the sea, so that our products can be sent without transhipment from our inland cities to the western coasts of the Americas. Another product of the century of significant import is Portland cement. With the aid of the chemist this material has been so improved and made accessible that now the artificial stone made from it is most widely used and is superior to most natural ones. Furthermore there is the unequivocal indication that, in combination with the all-important steel, many classes of structures of superior characteristics will be designed. Already there have been built many steel and concrete bridges which are a hundred feet in span and more, and for the Memorial Bridge at Washington, maximum spans of this construction are planned to be 192 feet each in length; while the engineer who designed it considered perfectly practicable an alternative plan of similar arches 283 feet in length. Arches of such majestic span are among the imminent constructions of the engineer.

A half-century ago Macaulay said, "Those projects which abridge distance have done most for the civilization and happiness of our species." And yet, since then, transportation facilities have increased many-fold, the first ocean cable had not been laid, nor was the telephone in use, nor other distance-annihilating inventions made. The attainment of results both definite and valuable has been in constantly accelerating ratios through all the broad field of endeavor which marks the domain of the engineer, viz., the 'direction of the great sources of power' and the development of the boundless resources of materials in nature to the use and convenience of mankind. The effect and value of this art pervade all lines of human interest and of contact, whether following Macaulay's idea of potentially bringing peoples nearer together or in the way (largely developed since his day) of rendering it possible to make life more thorough and intense by the concentration of power and of effort in great centers of activity, which is made possible by engineering structures and developments such as the towering office and industrial buildings of the last score of years; the tremendous concentrated power in steam and electric machinery of the present; the penetrating circulation of life-bringing, waste-removing water, ministering to our cities as does the blood to the body; and other examples of almost infinite variety which would cause amazement were they not so common now.

The glory and the power of the civilization of to-day result from the concentration of forces, both human and material, commanding the resourcefulness of mankind, applying the principles and discoveries of pure science, and developing the resources of nature for this purpose; and such is the degree of successful adaptation already reached, that the span of life of man potentially surpasses the millennial existences of legendary times. 'Better fifty years of Europe than a cycle of Cathay.' And the crowning glory of the measure of achievement thus far reached is that its inspiration is the welfare of the race.

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MONAURAL LOCALIZATION OF SOUND.

IN the *Psychological Review* for May, 1901, occurs a detailed account of an investiga-