is built, but on examination this was found not to have been the case. The tower rested on a foundation that had a base sixteen feet and six inches deep, built of twelve courses of different kinds of stone laid on a platform of two layers of oak beams crossed and resting on a bed of clay, into which piles of white poplar had been closely and deeply driven. The collapse evidently was not due to any failure of the foundation. The bungling manner in which, in making the repairs to the roof of the Logetta, the workmen reopened the old fissure, which dated from 1513 and had never been scientifically repaired, was doubtless the immediate cause of the disaster, which had been imminent, as the architect predicted, for years before it occurred. The indifference of the authorities, when their attention was called to the impending disaster, is astounding. Some workmen had reared a ladder against the wall of the tower on the morning of its fall, and when climbing it noticed the crack and the rapidity with which it was spreading; they had barely time to scramble down to a place of safety before the tower collapsed. That no one was killed or injured was due in no wise to precautions taken by the officials, but to the fact that so few people were about, and that those who were in the neighborhood saw the unmistakable signs of the approaching disaster and got out of the way.

The destruction of this structure was not only an irreparable archaeological loss to the city of Venice and the world at large, but the absence of the tower left a vacancy in the architectural effect of the group of buildings surrounding St. Mark's Square that destroyed the scenic beauty of the whole. This the authorities fully realized, and to fill the void they have now erected a new campanile, on the site of the old one, using its foundations, strengthened and extended according to the requirements of modern engineering science, and following as closely as possible the lines of the old bell tower. The accompanying illustrations will give a fair idea of the measure of success that has rewarded their efforts, and, while the building will not be the old campanile, that for so many years looked over the stirring events that marked the rise and progress of the Venetian republic, it is certainly a handsome and imposing edifice, which entirely restores, with its cloud-piercing altitude, the harmonious equilibrium of this most attractive portion of the picturesque city. Doubtless, too, it is free from the faults or defects, of whatever their nature, in the choice of material and method

of erection of the old tower, that led to its disastrous failure, at an age when so many much older buildings are standing, firm and solid as the everlasting hills.

The dust had hardly settled after the fall of the old tower, a little over eight years ago, when its early replacement was suggested, it being realized that the general effect of the square was seriously marred by its absence. In removing the debris, which was shortly commenced, every fragment of the metal work or stone carvings, of the elaborate Logetta de Sansovino especially, was preserved with conscientious care, with a view to the restoration of both tower and logetta in their original form. The foundation, when laid bare, was subjected to the most rigorous examination by engineering experts, and it was finally decided to widen it to a very considerable extent, the new work being of massive masonry, resting on innumerable piles, driven into the underlying clay. On this greatly strengthened base, the new campanile was reared, with the utmost care; the bricks, of which more than a million have been used, being specially made from clay twice mixed, to insure uniformity of texture, and each brick being twelve inches long, six inches wide and three inches deep. As Signor Edoardo Dr. Piacentini, the chief superintendent, informs the writer, it was found, shortly after the work was commenced, that owing to the presence of certain salts in the clay, there was likely to be an efflorescence that would greatly disfigure the tower. These salts, it was subsequently discovered, could be extracted by prolonged steeping and thorough washing of the bricks, and not only was this done afterward, but all the work already done with the objectionable bricks was torn down and the bricks subjected to the same treatment. Huge pans are provided in which this is effected. The main shaft, which is quadrangular, and tapers imperceptibly toward the summit, was finished in December, 1910, and consists of an inner and an outer shaft, the walls of the latter being six feet in thickness. Between the inner and outer shafts, the inclined plane, which serves in place of a staircase to reach the belfry, is disposed, its construction, of reinforced concrete, being shown in one of the accompanying illustrations. The reinforcement binds the inner and outer shafts together, the pilasters, at the angles of the inner shaft, being of similar construction, and entering into the system. This makes the huge tower practically an immense monolith, and should it ever decide to fall again, it will have to come down as a solid mass, in place of

crumbling to pieces as formerly. Light is furnished by thirty-six windows to the inclined plane.

The tower was built, from the ground up, without scaffolding, an ingenious sliding platform, that was contrived to rise as the structure progressed upward, being used by the masons, until the belfry platform was reached. The lantern and belfry, with the dado of the spire and the spire itself, required a separate scaffold. A heavy wire netting under the platform prevented the fall of anything to the ground.

The reconstruction of the tower had progressed, by June 22nd, 1910, far enough to permit of the replacement of the bells in the belfry. The smallest bell, the Trotteria, was first raised into position by means of the electric hoisting apparatus. This bell weighs but ten hundredweight, and rings daily for half an hour after noon. All, including the great bell weighing thirty-six hundredweight, were successfully raised and are now ready for ringing.

The work of reconstructing the beautiful Logetta de Sansovino has also made excellent progress. With greatest care the fragments of delicately carved stone have been reunited, some idea of the labor this involved being realized when it is stated that of three marble columns, forming part of the façade fronting St. Mark's Cathedral, one was reconstructed from thirteen and another from thirty-two pieces, while the third had to be replaced, suitable marble being brought from an ancient villa near Rome for this purpose. The care displayed in the reconstruction is further revealed in the manner in which the angel is supported on the summit of the tower. The pedestal on which it rests is kept in place by a pendulum that swings free in the spire, so that it will yield without unduly straining the structure.

While the authorities may fairly be criticised for allowing the old tower to lapse into the condition that resulted in its collapse in July, 1902, they are certainly entitled to no small credit for the expedition with which the great building has been replaced, the artistic character of the new structure, and the enduring manner in which the work has been carried out. Apart from the interest attaching to the antiquity of the old tower, it is indeed a question whether Venice has not profited by the disaster of eight years ago and the tardiness in protecting or reinforcing the old tower—if, indeed, this was possible, in the light of investigations as to the cause of its fall—will be overlooked when the bells peal from the new tower.

The Principles of Original Research

Prof. Sedgwick Minot's Views

SINCE pure science has been pre-eminent in the past not only in furnishing useful knowledge, but also as a chief foundation of human progress, and is likely long to continue equally pre-eminent, it is well worth while to study the general principles by which original research is guided. An analysis of the situation forms one of the topics discussed by Prof. Sedgwick Minot in his recent address before the American Association for the Advancement of Science. We quote him in his own words:

"No previous definite study of these principles is known to me, although I have searched not a little to find one. All that I have been able to discover are treatises on logic, the reading of which, most active investigators would, I fear, find tedious and unprofitable rather than helpful and inspiring. We have too many real difficulties to quite enjoy wading through the artificial morass of pedantries, in which logicians by profession imbed their significant truths. The stricture is severe, but not too severe even for so sound and valuable a work as Jevons's 'Principles of Science.' It must be doubted very seriously whether the study of logic is really essential for the right training of an investigator. While it goes without saying that logical thinking is indispensable in science, neither may it be overlooked that thinking is a complicated physiological function, which is brought to efficiency by practice, and that training by actual use is the one indispensable means of disciplining and developing the function. Playing the violin is a complicated physiological function, but it is not thought necessary that the violinist should study the anatomy of the muscles and nerves of the hand and arm. He perfects himself by practice. Anatomical knowledge might enable him to understand why he can make certain motions and can not make others. Our analogy limps, perhaps, but is a real analogy, for practice in right thinking creates the necessary habit of being logical, and ability to describe the mental processes in the language of logicians is an accomplishment which few even of the greater scientific discoverers possess.

"It is my belief that the logical work of scientific men is usually well done, and is the part of their work which is least faulty. The difficulties and the majority of failures are due, it seems to me, to two chief causes, the first, inadequate determination of the premises, the second, exaggerated confidence in the conclusions. If I am right, the method of science is the result of the effort to get rid of these two causes of error.

"We must recognize in starting that the expression, 'the method of science,' means more than 'logic,' being far more comprehensive when rightly defined. We can not alter the fundamental conditions of knowledge, for we are still unable to add new senses or improve the brain—although eugenics dreams of a future with such possibilities—nor can we change the nature of the phenomena. The same fundamental resources are available for daily life and for science. We must be clear in our minds on this point, in order to comprehend that the fundamental distinction of the scientific mind is its accuracy. As I have said on another occasion, 'there is nothing to distinguish the scientific method from the methods of every-day life except its precision. It is not a difference in kind or quality, but a quantitative difference, which marks the work of the true scientist and gives it its validity.' Such being the case, a broad examination of the method of science reduces itself to the study of the general principles of securing accuracy.

"If you will examine frankly your own opinions and those of your acquaintance you will, it may be presumed, quickly acknowledge that many, perhaps most, of the opinions are not of scientific accuracy. On the contrary, they are, to a large extent, mental habits and the result of the summation and averaging of impressions. I, for example, know a generous man, but can give very little of the evidence on which my opinion is based. I know a seacoast on which a fog occurs in summer very frequently, yet I cannot state how often the fog occurs nor just when I have observed it. At sundry times I have received an impression, in one case of the man's generosity, in the

other of fog. The exact data cannot be recalled, but the impression on my mind has been fixed by repetition. The evidence is lost, but the conclusions persist and are accepted by me as correct. For my practical needs they are sufficient. We get along in ordinary life satisfactorily enough with opinions thus formed by summation. Most human opinions, even when they are merely imitative, originate in this way, and are correspondingly unreliable. If we seek to explain the fallibility of ordinary opinions and testimony, must we not attribute it to the absence of the detailed evidence and the consequent impossibility of verifying the testimony?

"We are thus led to recognize the preservation of the evidence as the fundamental characteristic of scientific work, by which it differs radically from the practice of ordinary life. I venture accordingly to define the method of science as *the art of making durable trustworthy records of natural phenomena*. The definition may seem at first narrow and insufficient, but I hope to convince you that it is so comprehensive as to be not only adequate, but also almost complete.

"All science is constructed out of the personal knowledge of individual men. Science is merely the collated record of what single individuals have discovered. Accordingly, we must consider the way in which the individual knowledges are recorded and collated. The process begins, of course, with the publication of the special scientific memoir in which the investigator records his original observations and makes known his conclusions. It is interesting to note that our present standards for original memoirs have developed gradually. In Harvey's essay on the circulation of the blood, published in 1628, there are no precise data as to his observations. The author does not think it necessary to specify how he has laid bare the heart or how often he has repeated his observations. His descriptions of the beating heart are vividly realistic. He writes with conviction and authority. The reader is compelled to believe him. Harvey, however, does not provide information.

facilitate repetition of his work—he offers little aid toward the verification of his results. Francesca Redi, the founder of experimental biology, published his 'Generation of Insects' in 1660. His experiments proved that insects are not spontaneously generated in putrefying meat. His conclusion is sound, but he does not give more than a general account of the actual experiments. A century later Spallanzani established the modern standard, and in his works we find the details as to his evidence put down with scrupulous care, for example, in his paper on the circulation (1773) the individual experiments are exactly described. But Spallanzani in this, as in other respects, was far in advance of his time.

"In a contemporary article we expect a presentation of all the data necessary to render subsequent verification by other observers possible. We further expect clear information as to the amount of material on which the observations were made, or the number of experiments on which the work is based. In other words, a modern investigator will hardly receive consideration for his researches unless he furnishes every aid he can to facilitate criticising and testing his results. This severe standard has been only gradually evolved, but is now stringently enforced in all departments of science, and is the response in our practice to our need of eliminating the purely personal factor.

It would be advantageous if scientific authors generally viewed the obligation of providing for verification as an even more serious duty than it is esteemed at present. It might, indeed, be a wholesome practice to demand that every scientific article should contain a special section or paragraph on the means of verifying the result, for verification by *Fachgenossen* is second in importance only to discovery in the progress of science.

"The conditions of scientific progress have changed greatly though very gradually. Two hundred years ago the number of active investigators was small. This year there are at least ten thousand men of substantial ability carrying on original researches, consequently each theme is being worked at by several men, and the final outcome is the consequence of collaboration, which is none the less actual and effectual because it is unorganized, and is usually not formally designated as collaboration. For example, our present knowledge of the complex and very varied processes of cell-division has been constructed not merely by successive accumulations, but also by incessant debate and repeated mutual criticism. Within a generation the modern science of bacteriology has been created. Within a few years radiology, the wonders of which still thrill us, has suddenly come into existence. Both great achievements are the results of both the orig-

inal observations and also the constant mutual discussions of a number of scientific men.

"These conditions have rendered great men somewhat less important than formerly. Science grows by the accretion of ideas. Now, a great man has, let us say, twelve new ideas, where a man of ability has one. If science gets twelve new ideas it matters little whether they come from one man or from twelve. To a certain extent numbers make a substitute for genius—but nothing probably will ever replace that type of great genius to which we owe most, the man who has a great thought, which no one has ever conceived before.

"We recognize in the present methods of recording and collating scientific discoveries many adaptations which are due, it seems to me, essentially to the mere increase in the number of workers. But though the methods are modified the essential steps are the same: First, the record of the individual personal knowledge; second, the conversion of the personal knowledge by verification and collation into valid impersonal knowledge; third, the systematic co-ordination and condensation of the conclusions.

"Many definitions of science have been given, and did time permit it might be profitable to quote some of them; but is it not sufficient to define science as *knowledge which has acquired impersonal validity?*"

An Important Report on Sewage Disposal Investigations

The Studies of the Philadelphia Bureau of Surveys

A VALUABLE contribution to the literature of sewage purification has been made by the Bureau of Surveys of the Department of Public Works, Philadelphia, Pa., in its partial report upon the comprehensive plan for the collection, purification and disposal of the sewage of the entire city. The information, which has just been made available for publication, is based upon such extensive and careful research work that it will serve as a much needed and welcome addition to the existing data upon the treatment of sewage of American cities, which are admittedly far too meager in proportion to the growing importance of the subject in this country.

Philadelphia is required by statute to submit to the State Department of Health on or before January 1st, 1912, a comprehensive plan for the collection and disposal of sewage of the various drainage districts of the city. A plan of such magnitude demanded very complete preliminary investigations to determine upon the method of purification best suited to local conditions and on July 20th, 1907, the necessary authorization for conducting experimental work, with which the present report deals, was granted. During the following year Mr. George R. Stearns, director of the Department of Public Works, and Mr. George S. Webster, chief engineer of the Bureau of Surveys, visited the sewage disposal works of the principal cities of Europe and also inspected a large number of plants in this country. Upon their return Mr. Rudolph Hering was engaged in an advisory capacity, and a division of the Bureau of Surveys, known as the Sewage Disposal Division, was organized under the supervision of Mr. George E. Datesman, principal assistant engineer. A sewage testing station was established near the Spring Garden pumping station of the Bureau of Water, and experimental work was begun on March 23rd, 1909, under the immediate direction of Mr. W. L. Stevenson, assistant engineer in charge, and continued until May 15th, 1910.

The scope of the experimental work at the testing station was wide and included investigations of fine-mesh screenings, sedimentation in horizontal-flow tanks and in a vertical-flow Imhoff tank, slate contact beds of the Hibbin type, double contact beds, sprinkling filters, Hamburg and intermittent sand filters, disinfection, dilution and sludge. The report contains 204 printed pages in addition to a great many drawings, diagrams and curves, and no attempt will be made at this writing to give anything but an outline of the general conclusions which were reached. The report is intended as a progress report; some of its conclusions are summarized in the following paragraphs.

Fine screening, through metal cloth containing 35 meshes per inch, removed one-third of the suspended matter in the crude sewage as applied, prevented the formation of scum in subsequent sedimentation tanks and prevented the clogging of the nozzle orifices on the sprinkling filter beds.

Experiments on horizontal flow sedimentation showed that three and one-half hours' nominal flow through a baffled tank removed two-thirds of the suspended solids in the crude sewage and that increased storage did not produce a proportionate improvement in the efficiency of the tank. Between periods of three and one-half to six hours' flow the influent was

not deoxidized nor rendered offensive when sprayed upon sprinkling filters. To prevent septic action the tanks required sludging and washing out every six weeks.

In the studies of vertical-flow sedimentation the Imhoff tank was used, and by the substantial separation of the sewage flow from the digesting sludge it was found possible to keep the sewage fresh and eliminate offensive odors either in the effluent, the sludge or the gas developed.

In operating the slate contact bed it was found that the best results were accomplished when the bed was filled twice a day or at a rate of 2,000,000 gallons per acre daily. Crude sewage applied deposited three-fourths of the suspended solids. The conclusion was reached that where slates are not a waste product the construction of beds of this material would be costly.

The sprinkling filters were found to produce the best results with fixed sprinkler nozzles when the film of sewage was made to travel constantly back and forth over the media without a resting period. The superiority of a uniform over an irregular rate of operation was established. The maximum rate obtained with exposed filters was 2,500,000 gallons per acre per day, but in winter the stability of the effluent deteriorated. With a filter protected from the weather and receiving fine screened and settled sewage uniformly distributed over its surface the maximum rate was 3,100,000,000 gallons per acre per day. The effluent was found to be stable practically all of the time.

In studying various kinds of filtering media it was found that trap and gravel maintained their initial size, while limestone and slag disintegrated to a slight extent. The smooth surface of the gravel stone was not as well adapted to the formation of a bacterial jelly as rougher media and the extreme roughness of slag caused it to retain the deposited solid, so that clogging soon ruined the bed. In the uncovered filters, operating at 2,500,000 gallons per acre daily, the best results were obtained with trap media from 1 to 3 inches in size. Under the more favorable conditions of fine screens and settled sewage distributed at a rate of 3,100,000 gallons per acre per day media $\frac{3}{4}$ to $1\frac{1}{2}$ -inch size produced an excellent effluent.

Filters of less depth than 6 feet were not satisfactory, but with depths greater than 6 feet a satisfactory effluent was obtained, operating at rates between 2,500,000 and 3,000,000 gallons per acre daily. Additional depth over $6\frac{1}{2}$ feet did not seem to be economical.

At rates between 2,500,000 and 3,000,000 gallons per acre per day media composed of stones uniform in size completely unloaded the solids stored in the interstices, whereas stones of great diversity in size became badly clogged, but did not unload. Ice caused no trouble in operation.

Fungus growths on the filter surface were completely removed by an application of calcium hypochlorite dissolved in water without interfering with the biological action of the bed.

It was found impossible to operate the Hamburg and the intermittent sand filters at rates high enough to be economical for the conditions in Philadelphia.

Crude sewage, passed through a fine-mesh screen or satisfactorily settled to remove solids larger than about $1/25$ inch and disinfected with calcium hypochlorite to yield six parts per million of available chlorine was added to river water in proportions up to one to ten, and its purification accomplished without offense to sight or smell, or without depleting the dissolved oxygen of the river water below fifty per cent saturation.

In the studies of sludge it was found that horizontal flow in sedimentation tanks produced sludge, 88 per cent moisture, at an average rate of 5 cubic yards per 1,000,000 gallons. An Emscher tank with $4\frac{1}{2}$ -foot vertical flow produced sludge, 82.6 per cent moisture, at an average rate of 0.9 cubic yard per 1,000,000 gallons of sewage. The placing of sludge from a sedimentation tank in a water-tight uncovered tank for digestion did not prove successful. In the sludge bed tests fine sand or sawdust over a coarse drainage floor proved more efficient for reducing moisture in the sludge than a plain earth lagoon. Wet sludge from a sedimentation tank applied 6 inches deep in winter weather under cover dried to a consistency fit to remove in six days, and under the same conditions but not under cover in twelve days. Based upon small size tests in winter weather Imhoff tank sludge, 12 inches deep upon a sand bed, dried to a consistency fit to remove in twelve days during freezing weather. When equal weights of rice coal and wet sludge were mixed and placed on sludge beds the mixture was fit to remove in one day and was successfully burned.—*Engineering Record.*

Tool Hardening by Gas

THE use of the gas furnace for forging, tempering and hardening steel is spreading among the workshops where cutlery and tools are made. The old "hearths" are disappearing, replaced by small, clean gas furnaces, which are not only economical in space and cost of running, and comparatively clean and neat, but furnish a uniform temperature of any desired degree, thus avoiding damage to the steel through "burning," or irregularity of temperature. The working of the furnace is economical, because the gas can be cut off the moment the operation is finished.

English Lithographic Pencils

MELT, in a metal vessel, 30 parts of wax, 25 parts of talcum, 20 parts of soap, 15 parts of shellac and 6 parts of lamp black, mixing thoroughly by stirring. The melted mass is then quickly heated so intensely that it ignites. It is allowed to burn for a time, then take a sample in a spoon, and cover the vessel with a tight-fitting lid, so that the fire is immediately extinguished. From the sample, a pencil is formed, which when tested on the stone must display the characteristics of a good lithographic pencil. In case the mass is not sufficiently elastic, it must be again ignited and allowed to burn, for a time. When the mass has at length attained the desired consistency it is poured out on a marble slab, and rolled into sticks of about $2\frac{1}{4}$ to 3 inches long and of the thickness of a thin pocket book lead pencil.