will be remembered for a long time. Authors in future will not fail to admire the men of America who, unmoved by the swords or insults of their enemies, devoted their energies to the restoration of letters as well as to the establishment of an independent republic.

Now that the storm is over and we have acquired leisure and liberty, let us remember that a Medical School is the strongest defense against illness, that common ravager of all nations. For it is the function of the medical profession to preserve those who are in health, to strengthen those who are weak, and to restore if possible or at least prolong the lives of the dying.

The address then refers to the various subjects of medicine, described as "anatomy, chemistry, the science of herbs, and the knowledge to be gained from the whole of Nature." The address stresses the modern advances of medicine as follows:

The industry of modern days has discovered many new facts about the composition of the body. Much still is hidden and will probably remain long hidden. None the less who ever wishes to compare the ancient physician with the modern must admit the superiority of the modern, taking into consideration our present-day knowledge of anatomy, chemistry, surgery, botany and physics, remembering the new remedies that have been devised and the old ones discarded.

After discussing the existing fields of medical knowledge, the address strikes another modern note, and points to a new field—the treatment of "mental illness."

What is more human, more worthy of man and Christianity than to help the weak, the diseased and the suffering? It is to be lamented that the field of medicine which treats of mental illness and of cures for the mentally diseased is still so uncultivated and so deserted that it is almost nonexistent. The dignity of the argument commands, the progress of medicine persuades and the love of the human race should compel Harvard University to commence the investigation of means to combat such illness.

The conclusion is as follows:

Sagacious and learned president, generous members of the Corporation and Board of Overseers, I trust that nothing will be nearer to your hearts and dearer to your honor than Harvard College. From its founding, in every wise man's judgment, Harvard has been of extreme usefulness, glory and help to the whole American Republic. May the college, day by day and forever, make signal progress. To you gentlemen, fathers of your country, my friends and benefactors, has been given the privilege of advancing the medical sciences. You deserve great praise for having established a medical institution here.

College of Cambridge, permit me an adopted son to address you as mother. May you ever proceed on your way serenely and like the rising sun diffuse your light even to the extreme recesses of the Republic.

SCIENTIFIC APPARATUS AND LABORATORY METHODS

THE ULTRACENTRIFUGE

THE need of the ultracentrifuge as a research tool in so many different fields of science perhaps makes a brief description of some of our experiments in this journal worth while. The method used to rotate the centrifuge is a modification of one used by Henriot and Huguenard[1] for obtaining high rotational speeds and is essentially the same as that described in detail by two of us previously.[2] However, certain important variations and improvements in design will be described, as they make for greater ease of construction and less expense.

Fig. 1a shows a cross-section of a typical arrangement. Air from a compressor is admitted to the chamber B through flexible rubber pressure tubing. Air jets from the tubes L'L impinge upon the flutings U of the rotor and start it rotating. Automatically the rotor seeks a position of stable equilibrium and rides upon a cushion of air just above the surface of the stator. The air entering through C from the atmosphere greatly improves stability and provides automatic adjustment for different air pressures, speeds and weights of rotor. The cylindrical air chamber B is mounted on a rubber washer R'R' (made of sheet rubber packing) which aids in damping vibrations. The support S is mounted on three screws used for leveling. Because of the great danger of explosion by the rotor by the centrifugal forces, the whole apparatus should always be surrounded by a barricade to insure the safety of the observer. Fig. 1b shows the important part of the stator. Although it is very important to get the holes L'L bored properly if maximum speed is to be obtained, yet there is a considerable variety of angles P and Q and sizes of holes that work successfully.[3] For example, the following dimensions are quite satisfactory: TT = 1⅛ inches, $\beta = 92.5°$, $Q = 46°$, $P = 90°$. The nine holes were bored with a No. 63 twist drill. The angle of the rotor $\alpha = 102°$.

The stator may be made of almost any metal that is easily machined, such as brass, soft steel or duralumin. Although not at all necessary, a hardened steel ring TT makes for longer wear. The rotor

[1] *Comptes Rendus*, 180; 1389, 1925; *Jour. de Phys. et Rad.*, 8: 443, 1927.

[2] See Beams, *Rev. Sci. Inst.*, 1: 667, 1930; Beams and Weed, SCIENCE, 74: 44, 1931.

[3] See above references, Girard and Chukri, *Comptes Rendus*, 196: 327, 1933, and Garman, R.S.I. 4, 450, 1933.

should be made of very strong metal, such as good steel, phosphorbronze or duralumin, because the principal factors that limit the rotational speed are the strength of the rotor and velocity of the air. It might be mentioned that the rotor will run smoothly with the apparatus inverted or sidewise, as well as in the position shown in Fig. 1a.

Fig. 2a shows a cross-section of a rotor used to separate a small amount of the lighter portions of a fluid. The chamber A is filled with the substance to be centrifuged and the rotor spun at an approximately constant speed until separation takes place. A few drops of a heavy fluid that does not mix or react with the substance being centrifuged is then

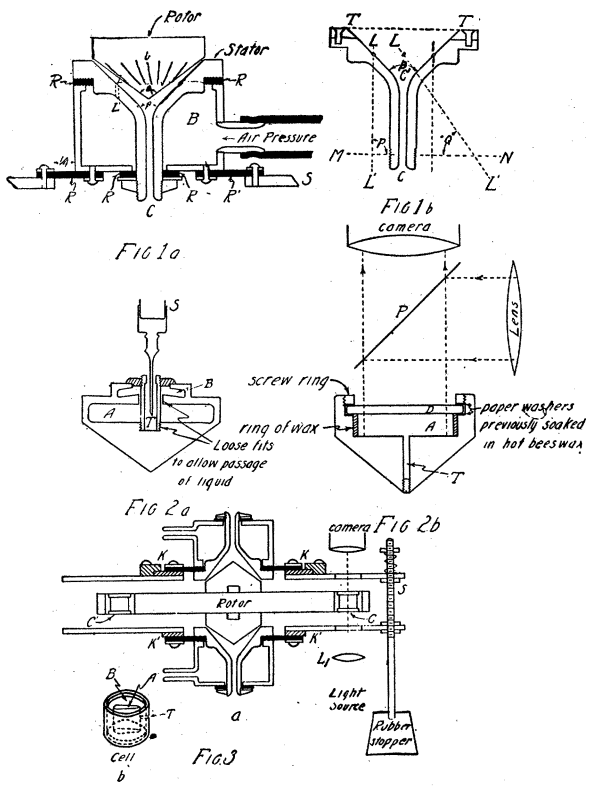

FIG. 1.

"squirted" into the tube T by the syringe S. This immediately enters the chamber A, forcing the lighter fraction into the chamber B, where it is collected after the rotor is stopped. Fig. 2b shows a cross-section of a rotor designed to permit observation of the rate of sedimentation, while the rotor is in motion. Parallel light of a wave-length that is absorbed by either the heavier or lighter (but not both) portions of the substance to be centrifuged is reflected or scattered from the bottom of the chamber A and enters the camera. A photograph is taken first with the rotor turning a few revolutions per second and then at regular intervals with the rotor at high speed. The photographs give a record from which the rate of sedimentation can be found and hence the particle size or micellar weight.[4] Some difficulty was experienced, at first, in getting the glass disk D strong enough to stand the necessary stresses. This was solved by a special heat treatment of the glass. A circular disk cut from ordinary plate glass 3 mm thick was slowly rotated with face vertical in a furnace which was gradually heated until the glass just began to soften. The disk was then quickly removed from the furnace and dropped into compressor oil. After this treatment its strength was increased several times and withstood forces of 2.5×10^5 gravity.[5] The joint between the metal rotor and glass disk was made tight by a ring of special wax made of 25 parts by weight beeswax, 10 lead oxide, 7 rosin, 6 shellac, 3 venice turpentine, 2 paraffin; heated until brown color appears. The wax ring was formed by first heating and then cooling the rotor while it was spun in a lathe. The lower scattering surface of A was made by carefully baking white Duco paint on the steel. This white surface was then covered with a thin film of paraffin. The chamber A was partially filled through the tube T.

Fig. 3a shows another variation in design that we have used to spin comparatively large disk rotors. The rotor is driven by air jets from two stators instead of one, so that more power can be communicated to it. The stators are mounted on three supports S. There are additional adjustments KK′ so that the upper stator can be moved perpendicular to and the lower parallel to the plane of the paper. The other parts are the same as in Fig. 1a. When properly adjusted, the rotor is extremely stable. The process of sedimentation is observed with transmitted light through a cell C with two glass windows. The cell is fastened into the disk-shaped rotor near its periphery and balanced by a dummy cell C′ of exactly the same dimensions and placed diametrically opposite C. With transmitted light the rate of sedimentation may be obtained either by light absorption or index of refraction measurements. The latter is of course best for transparent substances. Fig. 3b shows a top of the cell C. A slit A of 3½ mm average width is machined in the cylindrical cell. The glass disks are then cemented to the surfaces B with hard De Khotinsky. The cell A is filled through the tube T and the cell "squeezed" into a hole bored in the disk-shaped rotor. This type of cell is not very

[4] See Svedberg, "Colloid Chemistry," 2nd ed., Chem. Catalog Company, 1928; or Nichols, "Physics," 1, 254, 1931, for theory.

[5] We are also very grateful to Dr. J. T. Littleton, of the Corning Glass Company, for some very strong glass disks.

satisfactory but will stand up to approximately 10^5 gravity if sufficient care is taken in the construction.

The rotational speeds of the above centrifuges were determined by the stroboscopic method. The maximum rotational speed of course depended upon the diameter of the rotor. The 1⅛ in. all-metal rotor described in Figs. 1 and 2 would rotate up to 3,000 R.P.S. and give centrifugal forces in excess of 4×10^5 gravity. However, the glass disk and seals in Fig. 2b are not as yet practical above 2×10^5 gravity. With a small 1 cm all-metal rotor over 10^6 gravity has been obtained. With the larger 3½ in. rotor shown in Fig. 3a we obtained approximately 10^5 gravity but were apparently limited here by the capacity of our air compressor (we use a garage "Dayton" V-30, but most regular laboratory air compressors should have sufficient capacity). The air pressure of course regulates the speed. We seldom operate above 150 pounds per square inch, 90 pounds per square inch being a convenient working pressure. The temperature of the centrifuge is usually just below room temperature.

In conclusion, we believe that the air-driven type of ultracentrifuge described above offers certain important advantages as follows: First, it is simple and easy to construct; second, the design may be widely varied to suit the need of the experimenter, and still remain extremely stable;[6] third, the cost is very little if air pressure is already available; and fourth, the centrifugal forces developed are as high as any material (as yet tried) of the rotor will safely stand.

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SPECIAL ARTICLES

EXPERIMENTAL MENINGOCOCCAL INFECTION IN MICE

INVESTIGATION of the biology of meningococcus has been retarded by the lack of a satisfactory means of producing experimental infection in laboratory animals. Although guinea-pigs and mice succumb to intraperitoneal inoculation, the dose required of the most virulent strains is very large. Even when a fatal issue has resulted, it is not always possible to recover living organisms from the heart's blood or from the peritoneal cavity itself. Considering the essential toxicity of meningococcus, it seems reasonable to regard such heavy inoculations as overwhelming intoxications rather than true infections. It has been found, in fact, that the minimum lethal dose of meningococci suspended in saline is so close to that of heat-killed organisms that the difference falls within the limits of experimental error. Of particular interest in this connection is the work of Branham and Lillie[1] on experimental meningitis produced in guinea-pigs by intracisternal injection. They report that boiled or filtered suspensions of meningococci produced essentially the same clinical as well as histopathological pictures as did living organisms.

In the course of experiments begun some time ago in the hope of establishing gonococcal infection in some laboratory animal, various menstrua for the organisms were tried out. Since the gonococcus in its natural host gains a foothold in a surface covered by mucous secretion, it was assumed that mucin, the characteristic constituent of mucus, might provide a desirable environment for the initiation of growth under experimental conditions. Of the several preparations tried, the most practicable was found to be mucin prepared commercially from hog's stomach.[2] While this was more satisfactory than other vehicles for the inoculation of gonococci, its value in promoting experimental infection with meningococci was even more striking. It has been possible, in fact, to produce with regularity a fatal infection in mice by the intraperitoneal injection of relatively few organisms. That the mucin is itself non-toxic is demonstrated by the fact that mice seem to suffer no more ill effect from the intraperitoneal injection of 2 cc of mucin than from an equal quantity of salt solution. A report[3] has recently appeared on the enhancement of virulence of pneumococci and hemolytic streptococci for mice by means of mucin, but since this species is naturally susceptible to these organisms, the effect is less pronounced than in the case of meningococci.

The suspension fluid is prepared as follows: hog's gastric mucin is washed for several days in many changes of 70 per cent. alcohol to remove unnecessary ingredients and also to kill the spores of contaminating bacteria. It is then dried between blotting-paper and dissolved in sufficient saline to make a 6 per cent. solution and buffered at pH 7.4 as is ordinary culture media. Solution is facilitated by adding the saline slowly to the mucin as it is being ground vigorously in a mortar. The solution is then tubed and sterilized in an Arnold sterilizer at 100° C. for one hour every

[1] S. E. Branham and R. D. Lillie, *J. Bact.*, 1933, 25, 90.

[6] See Harvey, *Jour. Franklin Inst.*, 214: 1, 1932; or Beams, *Phys. Rev.*, A 39: 858, 1932.

[2] We have used the preparation marketed by The Wilson Laboratories, Chicago.

[3] W. J. Nungester, A. A. Wolf and L. F. Jourdonais, *Proc.* Soc. Exp. Biol. and Med., 1932, 20, 120.