SCIENCE

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MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Prof. J. McKeen Cattell, Garrison-on-Hudson, N. Y.

ON TWO FORMS OF AUTOMATIC MICROTOMES.

IT is proposed to describe two microtomes, one of which has already been widely used; the other, on the contrary, has been put on the market very recently. The older instrument may be known as the 'automatic wheel microtome;' the new one has been named the 'precision microtome,' and is also planned to work automatically.

A microtome is an instrument of precision, which implies that it must be treated with extreme delicacy and kept most scrupulously clean. It will be found usually, when complaint is made against a microtome, that the complaint is misdirected and ought to be, not against the machine, but against the owner. A modern microtome necessarily has several adjustments, every one of which must be exact and secure. If any one of them is imperfect and insecure; if any of the movable parts are allowed to become corroded, or gummed up with oil, or loose, or clogged with dust or dirt of any kind, the microtome will not and can not work as an instrument of precision.

The knife used for cutting ought to be regarded as an integral part of the microtome, and as its most delicate and easily injured part. In accordance with this view, there has been added a description of a new form of knife, which offers certain substantial advantages.

I. THE AUTOMATIC WHEEL MICROTOME

This instrument was designed in 1886 and was first made by G. Baltzer, the trusted instrument-maker of Professor Carl Ludwig. Baltzer, who died recently, continued for many years to furnish apparatus for the Physiological Laboratory in Leipzig, and had, therefore, unusual experience in the practical construction of new instruments. The first automatic microtome made by him is still in active service in my laboratory. Experience suggested various minor improvements, which have contributed to render the microtome more accurate and more convenient. Besides the changes which I have introduced, there have been several proposed by Professor Wilhelm His and by Dr. Spalteholz, which have proved especially valuable. It is remarkable that very few available suggestions have been made by the mechanics who have manufactured the machines hitherto. The most important change, I consider, to have been the increase in the heaviness of the construction, for it secures greater rigidity, a quality of great importance when very thin sections are desired.

Mr. Francis Blake, of Weston, Massachusetts, is engaged in improving the mechanical construction of the instrument. The changes proposed by him will prove, I think, of great value.

The automatic microtome is now made in Boston, by the Franklin Educational Company; Leipzig, by E Zimmerman; Paris, by E. Cogit; Cambridge, England, by the Cambridge Instrument Company.

Over two thousand are now in use. I believe that the instruments are in all cases well made. I have not, however, had an opportunity of testing myself those made in England. The first instruments made in America were not wholly satisfactory, but I believe them now to be made in this country fully as well as elsewhere, and there are certain details in the American design, as at present followed, which render it, in my judgment, preferable to the European models. The illustrations give two views of the American microtome, as now made. The general principle of the instrument is to keep the knife fixed, and to move the object to be cut in a vertical direction, supplying it to the knife by an automatic feed. The knife is carried by two upright standards, united by two cross bars; in the American microtome these are all a single casting; in the German they are four separate pieces screwed together, and, therefore, less securely rigid. The two uprights can be adjusted as to their distance from the object to be cut. The object, imbedded in paraffine, is attached to a brass plate, which can be securely clamped at any desired angle in the machine. The motion of the apparatus is imparted by a wheel, which may be turned by hand, or by a water or electromotor, but the hand-power is the most satisfactory. The wheel is made considerably heavier and is better balanced in the American model than in the others, so that the machine works more smoothly and evenly to the sensible improvement of the cutting. The wheel turns the axle to which it is attached, and at the opposite end of the axle is a crank working a slide, which raises and lowers the vertical carriage. This carriage is held by adjustable gibs against the vertical ways; it carries on the side toward the knife the object-holder, with its adjustments to fix the plane of the sections; it also carries the horizontal microtome screw. The head of the micrometer screw is a tooth-wheel, each tooth corresponding to a feed of $\frac{1}{300}$ mm. The screw is turned by a pawl, which acts upon the toothed-wheel; the pawl is worked, as may be readily seen in Fig. 2, by the vertical motion of the carriage, and the number of teeth caught at each rise of the carriage may be varied mechanically from one to six. The American form of pawl is simpler,

more certain and accurate, and less liable to get out of order than the foreign form.

The Zimmerman microtomes are of a very high grade of workmanship, and I can recommend them with confidence, having thoroughly tested them. The Cogit microtome also appeared to me thoroughly good, but I have had no opportunity to test one by prolonged use. Zimmerman has added to the microtome, as made by him, an attachment to give a feed of 0.001 mm., but it seems to me that the addition is of slight value, since the accuracy of the instrument cannot be carried so far, because with vertical ways the precision of movement cannot be made so great. No doubt such sections (of 0.001 mm.) can be made with the machine, but if the object offers any difficulty from its size or its hardness the machine will fail. For very fine work another type of microtome is called for.

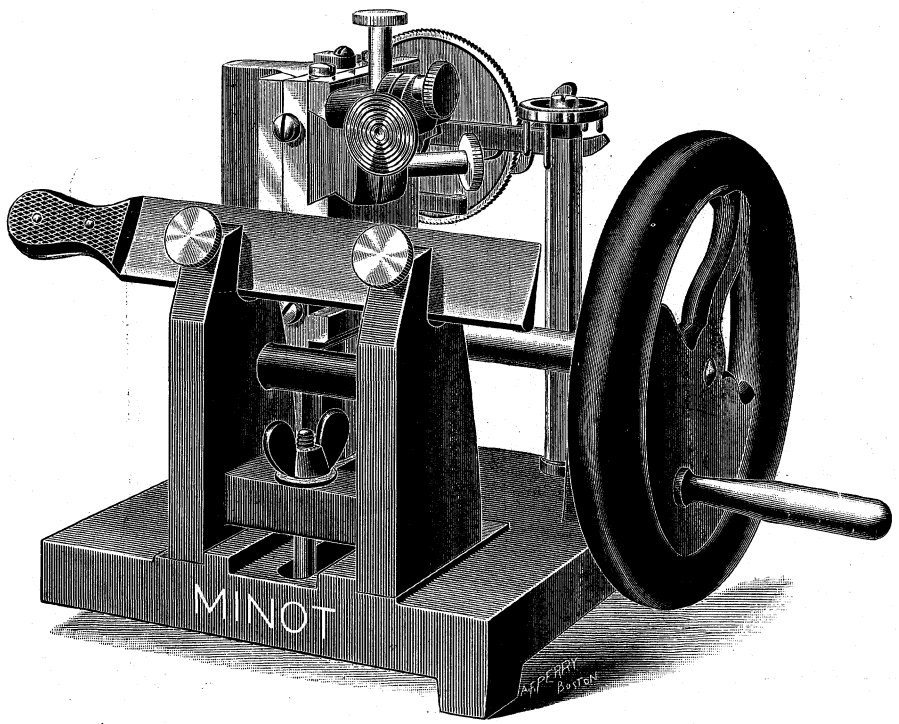

FIG. 1.

The automatic wheel microtome will cause only vexation and disappointment if it does not receive the utmost care. I will, therefore, mention the most necessary precautions. The following are of the first importance:

1. *Keep the microtome perfectly clean* To accomplish this, not only must all dust be removed, but also no oil which has become thick or gummy must be allowed to remain. A special risk comes from the paraffine, small bits of which are very apt to fall upon the instrument, and if they are permitted to lodge on any of the movable parts they may easily cause serious injury and will certainly prevent even section-cutting. Extreme cleanliness is indispensable, and to better secure it the microtome should always be covered when not in actual use.

2. *Keep the microtome perfectly oiled.* All the movable parts must be well lubricated

with clean, fresh oil. The micrometer screw should be oiled with porpoise oil, which will last for months. For the other parts a light paraffine oil may be used. I have found that which is known to the trade as No. 40 suitable.

3. *All the permanent adjustments must be perfectly set.* Of the permanent adjustments there are two which require more or less constant attention: *First*, the movable gib, by which the carriage is held against the vertical way; that gib should fit as tightly against the way as is compatible with the free running of the apparatus. If this is not done no satisfactory sections can be obtained, because the action will be irregular. *Second*, the split-ring around the neck of micrometer screw must be tightened sufficiently to prevent any back-lash, but not enough to make the screw hard to turn.

4. *All the changeable adjustments must be absolutely firm.* In order to attach the paraffine plate to the movable carriage there is a triple clamp, so constructed as to allow independent movements in three directions. The three screws of the clamp must all be tightened, and novices must remember that a metal screw cannot be tightened with the first turn, but that after a minute or so it can be tightened a little more. The knife is held by two screws, which must also be doubly tightened to ensure the knife being firmly held. In my experience with students, it seems to me that about nine-tenths of the failures to get satisfactory sections are owing to the neglect of the proper clamping either of the knife or the object-holder, or both.

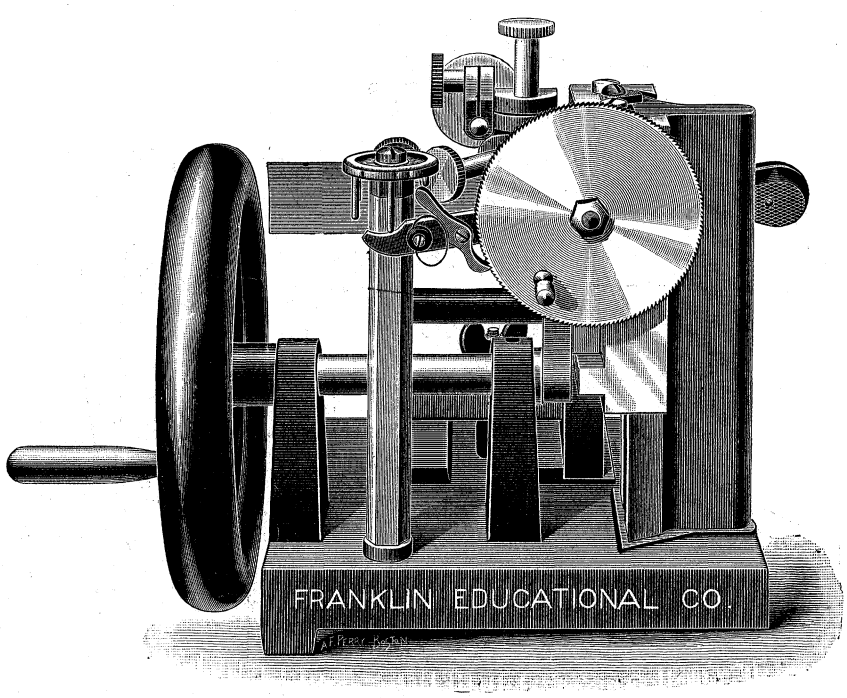

FIG. 2.

5. *Avoid cutting on days when the sections become highly electrified.* Everyone who has done much section cutting of objects imbedded in paraffine has encountered the difficulty of handling sections which have been electrified during the cutting, for the

sections will then jump at any neighboring object, especially of metal, and adhere to it obstinately. Sometimes the force is sufficient to break a ribbon of sections, which will then snap at the microtome and in an instant be clinging to it in a hopeless snarl. The amount of electrification varies from day to day, and there are fortunately days during which the phenomenon is absent. Usually damp days are the best. The cutting of any valuable object should be reserved for one of the favorable days. By laying an inclined plane, some ten inches long, of wood or cardboard, with its upper edge under the knife and its lower edge resting on the table, it will be found that the ribbon of sections, even if electrified, can be handled with comparative safety, for, even if the sections are drawn down by the electrical attraction, they will lodge upon the plane and usually will become either twisted or entangled.

II. THE PRECISION MICROTOME.*

The first object of a microtome is to make sections of even and known thickness; the second object is to make a sections in large numbers of uniform thickness; the third object is to make sections rapidly. Finally, in recent years, there has been a growing and justified demand for microtomes to make good sections of extreme thinness, if possible not over one five-hundredth of a millimeter or two microns (0.002 mm.). Sections of such tenuity and even possibly of less thickness have been made hitherto with the microtomes now in use, and I have not infrequently encountered the statement that the requisite precision was already secured by one or another pattern of microtome. In looking at such sections I have observed in a number of cases that they were much thicker than they were stated to be, and have learned upon inquiry that the scale of the microtome was unknown to the operator. In other cases the sections appeared to be really as thin as stated, but such as I have seen were invariably of minute objects, which offered no real difficulty to fine sectioning. I do not think any form of microtome hitherto constructed can be relied upon to yield sections 0.002 mm. thick of objects that are of even moderate size or that offer much resistance.

The first step was to gain a more definite notion of the practical hints of admissible error. Now, upon trial it was found that sections which vary more than one-tenth from their supposed thickness can, in the case of stained animal (vertebrate) tissues, be readily recognized by the naked eye as uneven. Hence, it is obvious that the thinner the section the less must be the amount of absolute error in the cutting. For example, an error of 0.0002 mm. is the maximum admissible for sections of 0.002 mm. (500 to a millimeter), though a much greater error would not be noticeable in sections of 0.02 mm. Applied to the microtome this means that a roughly made instrument is sufficient for thick sections, but the most perfect construction is necessary to secure a microtome for fine cutting. Besides, for greater mechanical perfection, a new microtome should also strive to be so constructed as to be suitable for both dry (paraffne) and wet (celloidine) cutting.

It seemed to me that progress might be made on the basis of the following principles:

First: The object should be supported directly under the knife, and upon a carriage with a broad base.

Second: The carriage should move upon a horizontal way below the knife.

Third: The object should be fed to the knife by a vertical micrometer screw, which should be arranged to work automatically.

Fourth: The knife should be firmly

*This instrument has been shown at Paris, Liverpool and before the Society of Morphologists at Boston. See Comptes Rendus Soc. Biologie, Paris, 1896, Juin, p. Report British Assoc. Adv. Sci., Liverpool, 1897, p. 979. SCIENCE, N. S., Vol. V., p. 106.

clamped at both ends upon a rigid frame, the frame to be made square so as to allow the knife to be placed in any desired position or at any desired angle.

Fifth: A cup, with a drainage tube, to be placed under the object-holder to collect alcohol and prevent its falling, while the apparatus was in use for wet-cutting, upon the gears or ways beneath.

About two years ago I consulted with Mr. Edward Bausch in regard to the projected microtome, and we have worked in collaboration to solve the many problems involved in the practical application of the five principles enumerated. It is a pleasure to state that Mr. Bausch has contributed in many and in essential ways to the plan of the microtome, and its successful production is largely due to his zealous interest. He has certainly spared neither time nor pains to secure a good result.

In designing the new microtome precision was made the prime object. The usual sources of error are: (1) in the bending of the knife; (2) the yielding of the object to be cut, chiefly because it is at the end of an arm which acts as a lever; (3) the 'jumping' of the sliding gear. All these defects are at their maximum in the Rivet type of microtome, of which the best known form is the Heidelberg or Thoma-Jung. It is believed that in the new microtome these three sources of error are materially diminished.

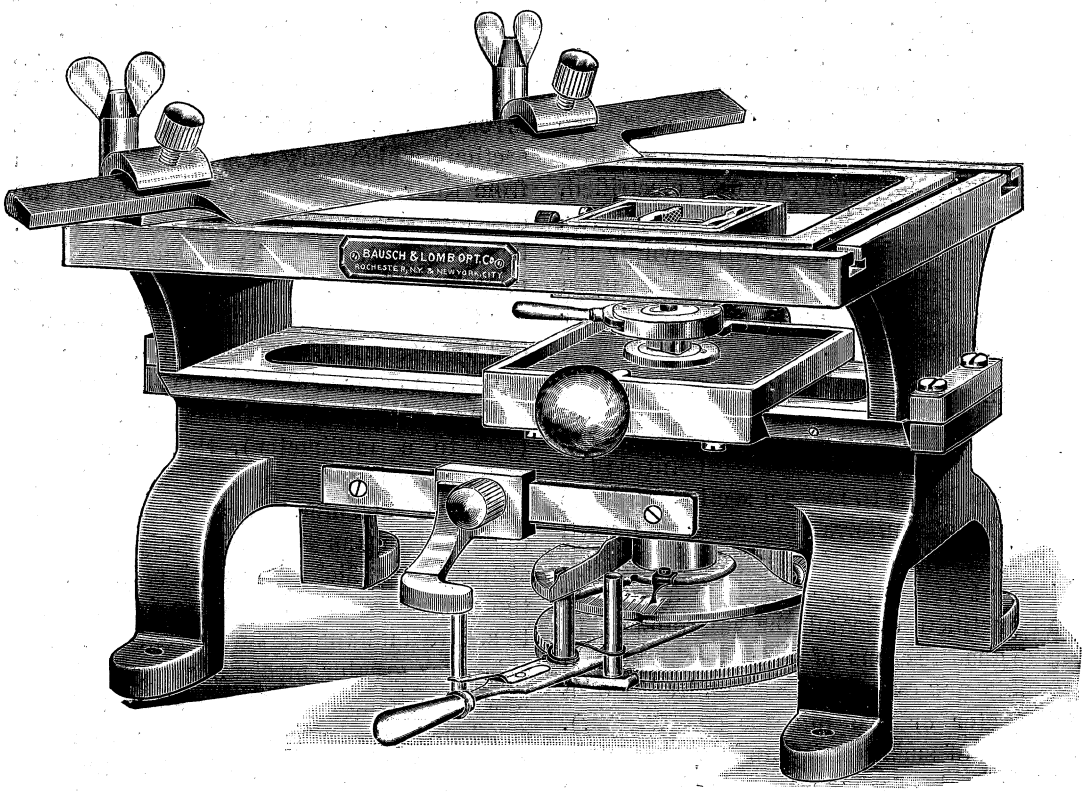

Fig. 3.

The accompanying illustration, Fig. 3, affords a general view of the Precision Microtome. The uppermost part of the microtome is a square frame heavily made

of cast iron. The knife is held by two clamps, which can be fastened at any point in the slots upon the upper part of the square frame, so that the knife may be either at right angles or at any desired inclination to the direction of the draw in cutting. As the knife blade is thick and strong, and is clamped at both ends, the cutting edge is rendered almost immovable. Underneath the knife-bearing frame are the two horizontal ways, upon which runs the sliding carriage. It will be noticed that the general construction of the whole machine resembles in principle a lathe-bank. The carriage itself is a broad platform with a raised rim; by its size the danger of tilting in any direction is rendered small; between the two horizontal ways. At the bottom of the screw there is a large toothed-wheel, which is utilized to feed the screw automatically. The toothed-wheel is turned either to the right or left, as desired, by means of the lever, the long handle of which is seen projecting at the bottom of the figure. The figure also shows the lever resting against a vertical bar. When the carriage is moved the micrometer attachment and the lever are moved along with it, and when the lever strikes against the vertical bar it is forced to turn the toothed-wheel and so work the feed of the apparatus. It will be noticed that the vertical bar is borne upon an arm, which can be slid to and fro upon the body of the microtome

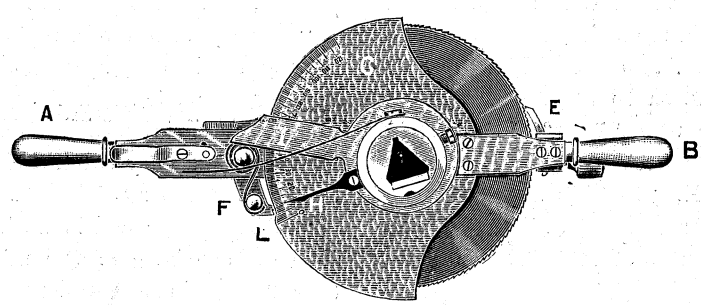

FIG. 4.

the raised rim serves to retain the alcohol, which drips from the specimen above and prevents its falling upon any of the working gear; from the surface of the carriage the alcohol is drained off by a tube, which, being upon the further side of the instrument, is not shown in the engraving. The object-holder is a square box, and is so devised that it can be readily lowered or raised, and renders it easy to adjust the plane of the section after the object has been clamped in. As the object-holder is supported firmly immediately under its own center, the possible leverage is minimized. The object is raised by a micrometer screw, which works with a vertical tube which descends from the middle of the carriage and clamped at any point as wished. By these means the lever can be set in action at any desired point of the excursion of the movable carriage.

The arrangement for the automatic feed is similar to that employed in de Groote's microtome. As modified for the needs of the 'Precision Microtome,' the device seems to me to leave little to be desired on the score of either convenience or accuracy. Figure 4 gives the plan of the arrangement. The following description of the feed was drawn up by Mr. Bausch:

"The feed arrangement consists of a micrometer screw, having pitch of 0.5 mm., which elevates the object-holder.

"The motion of the screw is transmitted

to the object-holder through a triangular bar, moving smoothly but firmly in a triangular channel, all lateral motion being eliminated by means of a wedge.

"The construction of this part is exactly the same as that used in the fine adjustment of the microscope. (The triangular bar, wedge and bearing are shown in section in the figure.)

"The micrometer screw is provided at its lower extremity with two metal discs in contact, each having one hundred serrations, the acute angles of the upper disc pointing to the right, and those of the lower to the left. The discs are revolved by means of the lever A, which is pivoted loosely on the axis of the micrometer screw, and which is provided with a pawl, F. F is actuated by the small lever shown on the upper surface of A, so that when the actuating lever is thown to the left, F engaged the teeth of the upper disc, and motion of A to the right elevates the object. The spring rachet, E, prevents any backward motion of the screw head and may be disengaged by means of the thumb screw shown.

"After the screw has been fed up to its greatest extent it is quickly returned by moving the actuating lever to the right, when a small pawl, not shown in the figure because beneath the lever, engages the teeth of the lower disc, and motion of A to the left depresses the object carrier. The *amount* of elevation of the object is concontrolled in an entirely automatic manner.

"The stop I is a rigid attachment and is provided with an index, H. C is a graduated disc pivoted around the axis of the feed and movable by means of the lever, B. Two graduations on C correspond to one of the notches on the disc of the micrometer screw.

"Beginning at zero of the scale, the circumference of C has an inclined plane for the following purpose:

"The disc C being set so that the number indicating the desired thickness of section is opposite the index, the stop post of A is held against the stationary stop, I, by the long spring; F engages a tooth of the upper disc. If now the lever A is moved to the right, F will continue to engage the tooth of the disc until the guide post, L, comes in contact with the inclined plane on the margin of C, which disengages the pawl, F, from the tooth of the disc exactly at the zero point of the scale. It will thus be seen that no matter how far A may be moved, F will act only through a certain prescribed distance, governed by the position of the disc C, and that the amount of elevation of the object is definitely indicated by the position of H on the scale.

"The operation of the feed arrangement may be made either automatically or by a separate movement of A by the hand; the former for serial and ordinary sectioning; the latter for very thick sections or for sections of irregular thickness.

"If automatic feed is desired, the sliding stop on the base of the microtome frame (see figure) is adjusted to act as a stop for A, carrying it through the required arc, when the sliding carriage is moved forward and backward for cutting the section.

"When the hand feed is used, the adjustable stop may be slid back out of the way, or removed from the instrument altogether.

"The advantages of this feed may be summed up, as follows:

"Simplicity.

"Great accuracy.

"Short feed (distance object is elevated by movement of one tooth of the disc, being 2 microns).

"The feed entirely independent of amount of motion given to feed lever, A.

"Convenience of setting for any desired thickness.

"Automatic or hand feed at will.

"Object elevated when object carrier is

being returned to position to begin cutting and after the object has passed under the knife.

"Ease with which feed screw may be returned when fed up to its full limit."

III. A NEW FORM OF MICROTOME KNIFE.

To satisfactorily sharpen a knife for fine section-cutting is a diffiulty, which we all have learned to estimate as serious. The valuable article by Moll on sharpening in the *Zeitschrift für Wissenschaftliche Mikroskopie* in 1892 (Bd. IX, p. 455) called my attention to various possibilities, and at my request Dr. F. S. DeLue tested a number of methods. These tests resulted in the adoption of plate glass and diamontine powder mixed with water as the best means of securing a satisfactory cutting edge. Plate glass seems to have been used from time to time, and is especially recommended by Moll. The use of diamontine powder was suggested by Dr. Lotze (Johns Hopkins Hospital Bull., Dec., 1894).

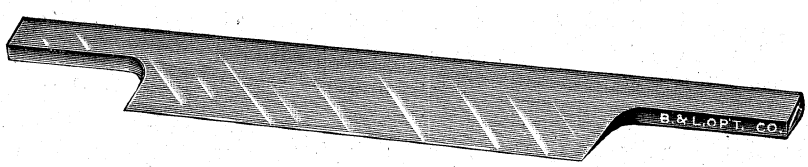

FIG. 5.

Having at command a satisfactory method of sharpening, it soon became evident that the knives should have a form to which that method could be applied conveniently. It was necessary that the knife should be: 1, rigid; 2, slightly hollowed on both sides; 3, of such shape that it could rest its whole length on a plane surface; 4, that there should be no edge to be sharpened, except such as could be used for actual cutting. These four requirements are met by the pattern illustrated in Fig. 5, already made in two sizes, the larger being intended for the '*Precision*,' the smaller for the '*Automatic wheel*' microtome. In both knives the essential features are the same, the proportions only being different. The larger knife is 330 mm. long; its cutting edge is 185 mm. long, and it is 12 mm. thick at the back. The smaller knife is 160 mm. long; its cutting edge 85 mm. long, and it is 10 mm. thick at the back. These knives have the handles of the same cross section as the blade; they are alike on both sides, being slightly concaved. A knife of this pattern can be laid upon a glass plate, upon which a little water with diamontine has been rubbed; the knife rests upon its cutting edge and upon its back edge, and may be perfectly sharpened without any special technical skill by simply passing the blade to and fro, resting alternately first on one side, then on the other, until the entire edge is completely polished.

The knife is then removed, thoroughly cleaned, the glass plate also cleaned and the edge finished by polishing on the glass plate with water only. The glass plate by itself will remove any wire edge which may be left by the diamontine powder.

It often requires considerable time to get the first edge on a new knife, for the knives as furnished by the manufacturers are never quite straight, but after the edge has been once obtained it is easily kept in condition, provided that it is not allowed to become nicked or dented through careless handling.

There is one precaution in the use of this method of sharpening which cannot be taken too conscientiously, namely, to keep the glass plate while in use absolutely free from dust and dirt of every description;

the glass itself must be kept absolutely clean, only *filtered* water to be put upon it, and the diamontine must invariably be protected from the dust.

A knife is sharpened when its edge appears smooth and straight under a magnifying power of 40–50 diameters.

When section cutting began a razor was the sharpest of familiar tools, and so it happened that for years razors were used not only for free-hand cutting, but also for microtomes. When knives began to be made specially for microtomes the razor type of thin blade was followed. We now know that the razor is the worst possible model for a microtome knife and that the chisel pattern is infinitely superior, because a thin blade is elastic, while a thick blade is rigid. With small objects or soft tissues the resistance may be so slight that the razor will cut them satisfactorily. Or, again, if the sections are thick the error of the razor may be unimportant, but for very thin sections, or for cutting difficult objects, the new heavy type of knife may fairly be said to be indispensable.

Charles Sedgwick Minot.

Harvard Medical School.

XII. DEUTSCHER GEOGRAPHENTAG, JENA, 1897.

During the late Easter vacation there were gathered together, in the charming little university town of Jena, a large number of the German Scientists whose work touches more or less closely the field of geography. When one considers the variety of subjects represented he must put the question: What is Geography?—What has it been in the past and to what future fields is the present aspect of the science leading. To consider this theme, at length, is not the intention of the writer in giving a short account of this Congress of German Geographers, but he would like to use this question as a connecting thread in the following lines.

There were nearly 600 members and associates in attendance, making this Geographentag the third largest in numbers of this series of most successful gatherings. Only Berlin and Vienna have had a larger attendance, and so it was said that Jena should be rated as a city with a million inhabitants. All those present were not from Germany, as eleven other nationalities were represented, these justly famous scientific gatherings naturally attracting foreigners. The addresses given are of such merit and given by such men as to induce many to come to hear, but it is not forgotten by the committees in charge that the most important feature of such gatherings is to bring the workers in various fields together, and to give them opportunities for conversation and consultation. The four and a half days were very happily arranged so as to supply a combination of attractions suited to the wants of all.

Under the presidency of Geheimrath Neumayer the members were led to consider the investigation of the region of the South Pole, and were shown that while very little in the way of actual exploration had been done by the commission, which was appointed at the XI Deutschen Geographentag in Bremen, still a large amount of material had been collected, and the way was being prepared for pioneer work in this little mapped region. Outline cartography, or the separation of land from water areas, is one of the early stages of geographic science. It is naturally followed by expeditions over land in the less known portions of the continents. This second phase of the science was represented at Jena by the three following papers: Expedition to Central Brazil, by Dr. Herrmann Meyer, of Leipzig; German Investigations in Asia Minor, by Dr. Heinrich Zimmerer, of München; Journey through Syria and Ana-