along the bevelled edge are parallel to each other, their distances apart being one-third of the distances travelled by the arrow along the scale.

Compasses usually take the form of a pair of legs movable about a joint, so that their extremities, which are of steel, finely pointed, may be set at any required distance apart ; the legs may be knee- jointed, and one is usually adapted to hold either a pencil, a ruling pen, or a steel pointer, as may be desired. A beam compass is em­ployed when long lengths are laid off ; it consists of a light tubular metal bar, or a rectangular deal rod, fitted with a pair of boxes, which slide along it and carry either pen, pencil, or pointer, and may be set and clamped at any desired distance apart.

Proportional compasses consist of two parts so exactly similar that when held in contact throughout they appear as one ; each is pointed at both ends, flat and grooved through one-half its length, and tapering to a point in the other half. The two are coupled together by a pair of similar sliders, one for each groove, turning on a common axle which carries a disk at one end and a clamping screw at the other ; by shifting the position of the sliders in the grooves the distances between the points at the opposite ends can be brought into any desired proportion. The settings for different proportions are effected by bringing a line on the slider opposite the lines of a fractional scale engraved on one side of the groove.

Protractors are of two forms circular (or semicircular) and rect­angular ; the circumferences of the former are divided into 360° or 180°; the latter are divided on three sides of their periphery by lines drawn from the centre of the fourth side to the degree points on the circumference of a semicircle of which that side is the diameter. The protractor being set with its centre on a given point and its zero line on a given line passing through the point, any angle with this line at the point can be readily laid off. Pro­tractors for plotting traverses are commonly annular, that they may be centred over the station of origin with the zero diameter on the initial meridian ; their bearings at any other station may be laid off without moving the protractor by drawing lines parallel to the same bearings at the origin. Rectangular protractors some­times have parallel lines engraved on their faces at equal distances, for setting over paper ruled with parallel lines at unequal distances, and their backs engraved with scales of rhumbs, sines, secants, and tangents and common scales of equal parts.

The station pointer enables the position of any station at which angles between three fixed points have been measured to be plotted on paper. It consists of three arms : the centre arm carries a graduated circle fixed over an axis at one end ; the other two are movable round this axis, and each cames a vernier for reading the circle. Each arm has a straight edge bevelled as a ruler, and the lines on the prolongations of these edges meet in the centre of the axis, where there is a small opening through which a point may be pricked on the paper. The arms having been set to the observed angles, the instrument is moved about until each edge is over one of the fixed points on the paper, when its centre will be exactly over the position of the station if none of the angles are very acute. The instrument is much used in nautical surveying, for laying down the position of a vessel at sea by angles measured to fixed objects on shore.

The triangular compass is serviceable in reproducing plans to full scale ; it is formed by jointing a third leg to the centre pin of the joint of an ordinary pair of compasses, so as to be movable in any direction.

The pantagraph is employed in reproducing a map on a different —generally a smaller—scale. It consists of two long arms, *AB* and *AC,* jointed together at *A,*

and two short arms, *FD* and *FE,* jointed together at *F* and with the long arms at *D* and *E* ; *FD* is made exactly equal to *AE* and *FE* to *AD,* so that *ADFE* is a true parallelogram whatever the angle at *A.* The instrument is supported parallel to the paper on ivory castors, on which it moves freely. A tube is usually fixed vertically at *c,* near the extremity of the long arm *AC,* and similar tubes are mounted on plates which slide along the short arms *BD* and *FD* ; they are intended to hold either the axle pin on a weighted fulcrum round which the instrument turns, or a steel pointer, or a pencil, interchangeably. When the centres of the tubes are exactly in a straight line, as on the dotted line *bfc,* the small triangle *bfD* will always be similar to the large triangle *bcA ;* and then, if the fulcrum is placed under *b,* the pencil at *f*, and the pointer at c, when the instrument is moved round the fulcrum as a pivot, the pencil and the pointer will move parallel to each other through distances which will be respectively in the propor­tion of *bf* to *be* ; thus the pencil at *f* draws a reduced copy of the map under the pointer at *c* ; if the pencil and the pointer were interchanged an enlarged copy would be drawn ; if the fulcrum and pencil were interchanged, and the sliders set for *f* to bisect *bc,*

the map would be copied exactly. Lines are engraved on the arms *BD* and *FD,* to indicate the positions to which the sliders must be set for the ratios 1/2, 1/3,. . ., which are commonly required.

The square pantagraph of Adrian Gavard consists of two graduated arms which are pivoted on a plain bar and connected by a graduated bar sliding between them throughout their entire length, to be set at any required distance from the plain bar ; a sliding plate carrying a vertical tube, to hold either the axle of the fulcrum, the pencil, or the pointer, is mounted on one of the arms and on a prolongation of the plain bar beyond the other arm, and also on the graduated con­necting bar ; and an additional arm is provided by means of which reductions below or enlargements above the scales given on the instrument can be readily effected.

The eidograph is designed to supersede the pantagraph, which is somewhat unsteady, having several supports and joints. It is composed of three graduated bars, one of which is held over a ful­crum and carries the others, which are lighter, one at each extremity. The three bars are movable from end to end in box-sockets, each having an index and a vernier in contact with the graduated scale. The box-socket of the principal bar turns round the vertical axle of the fulcrum ; that of each side bar is attached to a vertical axle, which also carries a grooved wheel of large diameter and turns in a collar at either end of the principal bar. The two wheels are of exactly the same diameter and are connected by a steel band fitting tightly into the grooves, so that they always turn together through identical arcs ; thus the side bars over which they are respectively mounted, when once set parallel, turn with them and always remain parallel. A pointer is held at the end of one of the side bars and a pencil at the diagonally opposite end of the other. The bars may be readily set by their graduated scales to positions in which the distances of the pencil and the pointer from the fulcrum will always be in the ratio of the given and the required map scales.

The opisometer is intended to measure the lengths of roads, rivers, and other lines on a map. It consists simply of a milled wheel mounted in a forked handle on a steel screw with a very fine thread. The wheel, being turned up to one end of the screw, is put down on the map with the handle held vertically over the point at which the measurement is to commence, and is run over the road or line until the point is reached at which the measurement is to stop ; it is then lifted off the paper, placed on the scale of the map, and run backwards to the initial end of the screw, over a length of the scale which corresponds to the length run over on the map.

The polar planimeter was invented by Professor Amsler of Schaffhausen for the measurement of areas on maps and plans. It consists essentially of two arms jointed together and a roller, car­ried at right angles to one of the arms and moving in touch with the paper, which by its revolutions records the area of a figure whose perimeter is traced by a point on that arm, while the instrument is turned bodily on a

point on the other arm as a fixed centre. There are two forms of the instrument : in one the position of the roller is fixed and the arms are jointed on a common pinion ; in the other the roller and a pinion, to which the holding arm is attached, are both carried by a slider, which is movable along the tracing arm and can be set at any required distance from the tracing point. The first form gives areas in a single unit of measure only, the second in various units. The annexed figure represents the first form, showing the joint *A,* the tracing point *P,* the fixed point *O,* and the roller with its graduated dial and vernier, for indicating the lengths of line rolled over while the tracer moves round the peri­meter of the area under measurement.

The following ex­planation of the theory of the instrument is due to Professor Green- hill. Let *OA, AP* be the two arms jointed at *A,* with the fixed point at *O* and the tracer at *P,* and suppose the wheel to be fixed at *R* on the prolongation of the arm *PA.* Let *OA=a,*

*AP=b, AR= c,* and the radius of the roller = ?·; and let the direction of a positive rotation of the roller, as marked by the graduations, be that of rotation on a right-handed screw on the axle of *R* which would give motion in the direction *AR.* Drop the perpendicular