This star has been under observation for nearly twelve months, and some 200 measures obtained. The period adopted is

6d. 10h. 19·6m.,

and the light-curve based on this value is given, with an enlarged diagram of the part near minimum. The curve is almost identical in form with that of S Velorum. Other details are as follows:—

Limits of variation are 9·1 and 10·8 magnitude.
Duration of increasing or decreasing phase = 4h. 15m.
Stationary period at minimum = 8h. 30m.

The system thus apparently consists of two bodies, one of which is *three* times the diameter of the other. The smaller star is nearly twice as bright as the larger one, and the distance between their circumferences is about two-thirds of the radius of the orbit. The density of the system is probably not more than one-sixth that of the sun.

V Puppis.

$$\left.\begin{array}{l}\text{R.A.} = 7\text{h. } 55\text{m. } 22\text{s.}\\ \text{Decl.} = -\ 48^\circ\ 58'{\cdot}4\end{array}\right\}(1900{\cdot}0).$$

This star differs from the preceding one in that it consists of two bodies of about equal size and brightness. The mean period, as deduced from the light variation, is

1d. 10h. 54m. 26·7s.

The light-curve of this star is strikingly similar to that of U Pegasi, showing double and *unequal minima*, and double and *equal maxima*.

Prof. Pickering, however, from spectroscopic determinations, deduces a period of

3d. 2h. 46m.

From the peculiarity of there being no stationary period at either maximum, Dr. Roberts infers that the two component stars revolve around each other *in actual contact*. Under such conditions, both bodies would most probably undergo distortion. The value derived for the density of V Puppis is 0 0? that of the sun, the orbit being circular.

POLISH.[1]

THE lecture commenced with a description of a home-made spectroscope of considerable power. The lens, a plano-convex of 6 inches aperture and 22 feet focus, received the rays from the slit, and finally returned them to a pure spectrum formed in the neighbourhood. The skeleton of the prism was of lead; the faces, inclined at 70°, were of thick plate-glass cemented with glue and treacle. It was charged with bisulphide of carbon, of which the free surface (of small area) was raised above the operative part of the fluid. The prism was traversed twice, and the effective thickness was 5½ inches, so that the resolving power corresponded to 11 inches, or 28 cm., of CS_2. The liquid was stirred by a perforated triangular plate, nearly fitting the prism, which could be actuated by means of a thread within reach of the observer. The reflector was a *flat*, chemically silvered in front.

So far as eye observations were concerned, the performance was satisfactory, falling but little short of theoretical perfection. The stirrer needed to be in almost constant operation, the definition usually beginning to fail within about twenty seconds after stopping the stirrer. But although the stirrer was quite successful in maintaining uniformity of temperature as regards *space*, *i.e.* throughout the dispersing fluid, the temperature was usually somewhat rapidly variable with *time*, so that photographs requiring more than a few seconds of exposure showed inferiority. In this respect a grating is more manageable.

The lens and the faces of the prism were ground and polished (in 1893) upon a machine kindly presented by Dr. Common. The flat surfaces were tested with a spherometer, in which a movement of the central screw through 1/100000 inch could usually be detected by the touch. The external surfaces of the prism faces were the only ones requiring accurate flatness. In polishing, the operation was not carried as far as would be expected of a professional optician. A few residual pittings, although they spoil the appearance of a surface, do not interfere with its performance, at least for many purposes.

In the process of grinding together two glass surfaces, the particles of emery, even the finest, appear to act by *pitting* the glasses, *i.e.* by breaking out small fragments. In order to save time and loss of accuracy in the polishing, it is desirable to carry the grinding process as far as possible, using towards the close only the finest emery. The limit in this direction appears to depend upon the tendency of the glasses (6 inches diameter) to *seize*, when they approach too closely, but with a little care it is easy to attain such a fineness that a candle is seen reflected at an angle of incidence not exceeding 60°, measured as usual from the perpendicular.

The fineness necessary, in order that a surface may reflect and refract regularly without diffusion, viz. in order that it may appear *polished*, depends upon the wave-length of the light and upon the angle of incidence. At a grazing incidence all surfaces behave as if polished, and a surface which reflects red light pretty well may fail signally when tested with blue light at the same angle. If we consider incidences not too far removed from the perpendicular, the theory of gratings teaches that a regularly corrugated surface behaves as if absolutely plane, provided that the *wave-length* of the corrugations is less than the wave-length of the light, and this without regard to the *depth* of the corrugations. Experimental illustrations, drawn from the sister science of acoustics, were given. The source was a bird-call from which issued vibrations having a wave-length of about 1·5 cm., and the percipient was a high-pressure sensitive flame. When the bird-call was turned away, the flame was silent, but it roared vigorously when the vibrations were reflected back upon it from a plate of glass. A second plate, upon which small pebbles had been glued so as to constitute an ideally rough surface, acted nearly as well, and so did a piece of tin plate suitably corrugated. In all these cases the reflection was *regular*, the flame becoming quiet when the plates were turned out of adjustment through a very small angle. In another method of experimenting the incidence was absolutely perpendicular, the flame being exposed to both the incident and the reflected waves. It is known that under these circumstances the flame remains quiescent at the *nodes* and flares most vigorously at the *loops*. As the reflector is drawn slowly back, the flame passes alternately through the nodes and loops, thus executing a cycle of changes as the reflector moves through *half* a wave-length. The effects observed were just the same whether the reflector were smooth or covered with pebbles, or whether the corrugated tin plate were substituted. All surfaces were smooth *enough* in relation to the wave-length of the vibration to give substantially a specular reflection.

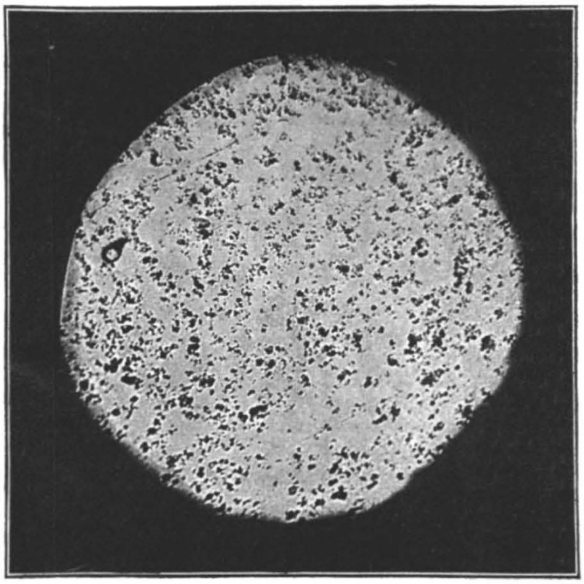

Fig. 1

Finely ground surfaces are still too coarse for perpendicular specular reflection of the longest visible waves of light. Here the material may be metal, or glass silvered chemically on the

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[1] A discourse delivered at the Royal Institution on Friday, March 29, by the Right Hon. Lord Rayleigh, F.R.S.

face subsequently to the grinding. But experiment is not limited by the capabilities of the eye; and it seems certain that a finely ground surface would be smooth enough to reflect without sensible diffusion the longest waves, such as those found by Rubens to be nearly 100 times longer than the waves of red light. An experiment may be tried with radiation from a Leslie cube containing hot water, or from a Welsbach mantle (without a chimney). In the lecture the latter was employed, and it fell first at an angle of about 45° upon a finely ground flat glass silvered in front. By this preliminary reflection, the radiation was purified from waves other than those of considerable wave-length. The second reflection (also at 45°) was alternately from polished and finely ground silvered surfaces of the same size, so mounted as to permit the accurate substitution of the one for the other. The heating-power of the radiation thus twice reflected was tested with a thermopile in the usual manner. Repeated comparisons proved that the reflection from the ground surface was about 0·76 of that from the polished surface, showing that the ground surface reflected the waves falling upon it with comparatively little diffusion. A slight rotation of any of the surfaces from their proper positions at once cut off the effect. It is probable that the device of submitting radiation to preliminary reflections from one or more merely ground surfaces might be found useful in experiments upon the longest waves.

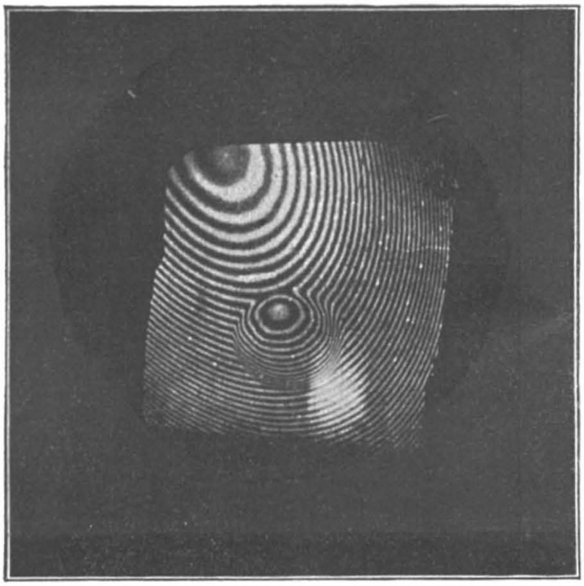

FIG. 2.

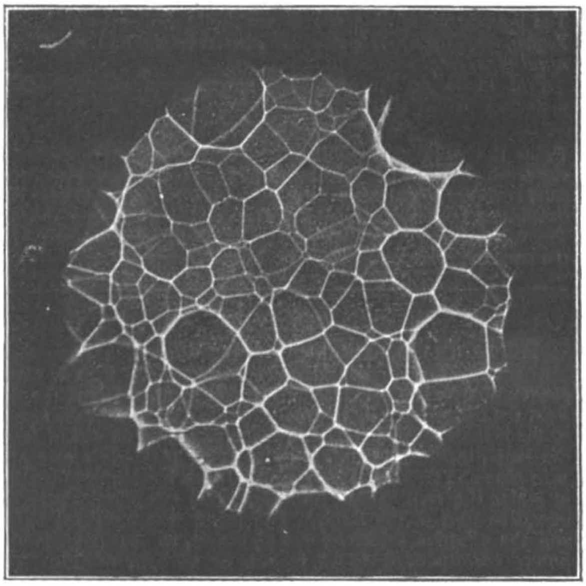

FIG. 3

In view of these phenomena we recognise that it is something of an accident that polishing processes, as distinct from grinding, are needed at all; and we may be tempted to infer that there is no essential difference between the operations. This appears to have been the opinion of Herschel,[1] whom we may regard as one of the first authorities on such a subject. But although, perhaps, no sure conclusion can be demonstrated, the balance of evidence appears to point in the opposite direction. It is true that the same powders may be employed in both cases. In one experiment a glass surface was polished with the same emery as had been used effectively a little earlier in the grinding. The difference is in the character of the backing. In grinding, the emery is backed by a hard surface, *e.g.* of glass, while during the polishing the powder (mostly rouge in these experiments) is imbedded in a comparatively yielding substance, such as pitch. Under these conditions, which preclude more than a moderate pressure, it seems probable that no pits are formed by the breaking out of fragments, but that the material is worn away (at first, of course, on the eminences) almost molecularly.

The progress of the operation is easily watched with a microscope, provided, say, with a ¼-inch object-glass. The first few minutes suffice to effect a very visible change. Under the microscope it is seen that little facets, parallel to the general plane of the surface, have been formed on all the more prominent eminences.[1] The facets, although at this stage but a very small fraction of the whole area, are adequate to give a sensible specular reflection, even at perpendicular incidence. On one occasion five minutes' polishing of a rather finely ground glass surface was enough to qualify it for the formation of interference bands, when brought into juxtaposition with another polished surface, the light being either white or from a soda flame; so that in this way an optical test can be applied almost before the polishing has begun.[2]

As the polishing proceeds, the facets are seen under the microscope to increase both in number and in size, until they occupy much the larger part of the area. Somewhat later the parts as yet untouched by the polisher appear as pits, or spots, upon a surface otherwise invisible. Fig. 1 represents a photograph of a surface at this stage taken with the microscope. The completion of the process consists in rubbing away the whole surface down to the level of the deepest pits. The last part of the operation, while it occupies a great deal of time and entails further risk of losing the "truth" of the surface, adds very little to the effective area or to the intensity of the light regularly reflected or refracted.

Perhaps the most important fact taught by the microscope is that the polish of individual parts of the surface does not improve during the process. As soon as they can be observed at all, the facets appear absolutely structureless. In its subsequent action the polishing tool, bearing only upon the parts already polished, extends the boundary of these parts, but does not enhance their quality. Of course, the mere fact that no structure can be perceived does not of itself prove that pittings may not be taking place of a character too fine to be shown by

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[1] "Enc. Met.," Art. Light, p. 477, 1830: "The intensity and regularity of reflection at the external surface of a medium is found to depend, not merely on the nature of the medium, but very essentially on the degree of smoothness and polish of its surface. But it may reasonably be asked how any regular reflection can take place on a surface polished by art, when we recollect that process of polishing is, in fact, nothing more than grinding down large asperities into smaller ones by the use of hard gritty powders, which, whatever degree of mechanical comminution we may give them, are yet vast masses, in comparison with the ultimate molecules of matter, and their action can only be considered as an irregular tearing up by the roots of every projection that may occur in the surface. So that, in fact, a surface artificially polished must bear somewhat of the same kind of relation to the surface of a liquid, or a crystal, that a ploughed field does to the most delicately polished mirror, the work of human hands."

[1] The interpretation is facilitated by a thin coating of aniline dye which attaches itself mainly to the hollows.

[2] With oblique incidence, as in Talbot's experiments (see *Phil. Mag.*, xxviii. p. 191, 1889), achromatic bands may be observed from a surface absolutely unpolished, but this disposition would not be favourable for testing purposes.

a particular microscope or by any possible microscope. But so much discontinuity, as compared with the grinding action, has to be admitted in any case that one is inevitably led to the conclusion that in all probability the operation is a molecular one, and that no coherent fragments containing a large number of molecules are broken out. If this be so, there would be much less difference than Herschel thought between the surfaces of a polished solid and of a liquid.

Several trials have been made to determine how much material is actually removed during the polishing of glass. In one experiment a piece 6 inches in diameter, very finely ground, was carefully weighed at intervals during the process. Losses of ·070, ·032, ·045, ·026, ·032 gm. were successively registered, amounting in all to ·205 gm. Taking the specific gravity of the glass as 3, this corresponds to a thickness of $3 \cdot 6 \times 10^{-4}$ cm., or to about 6 wave-lengths of mean light, and it expresses the distance between the original *mean* surface and the final plane. But the polish of this glass, though sufficient for most practical purposes, was by no means perfect. Probably the 6 wave-lengths would have needed to be raised to 10 in order to satisfy a critical eye. It may be interesting to note for comparison that, in the grinding, one charge of emery, such as had remained suspended in water for seven or eight minutes, removed a thickness of glass corresponding to 2 wave-lengths.

In other experiments the thickness removed in polishing was determined optically. A very finely ground disc was mounted in the lathe and polished locally in rings. Much care was needed to obtain the desired effect of a ring showing a continuously increasing polish from the edges inwards. To this end it was necessary to keep the polisher (a piece of wood covered with resin and rouge) in constant motion, otherwise a number of narrow grooves developed themselves.

The best ring was about half an inch wide. When brought into contact with a polished flat and examined at perpendicular incidence with light from a soda flame, the depression at its deepest part gave a displacement of three bands, corresponding to a depth of 1½λ. On a casual inspection this central part appeared well polished, but examination under the microscope revealed a fair number of small pits. Further working increased the maximum depth to 2½λ, when but very few pits remained. In this case, then, polish was effected during a lowering of the mean surface through 2 or 3 wave-lengths, but the grinding had been exceptionally fine.

It may be well to emphasise that the observations here recorded relate to a *hard* substance. In the polishing of a soft substance, such as copper, it is possible that material may be loosened from its original position without becoming detached. In such a case pits may be actually filled in, by which the operation would be much quickened. Nothing suggestive of this effect has been observed in experiments upon glass.

Another method of operating upon glass is by means of hydrofluoric acid. Contrary to what is generally supposed, this action is extremely regular, if proper precautions are taken. The acid should be weak, say one part of commercial acid to two hundred of water, and it should be kept in constant motion by a suitable rocking arrangement. The parts of the glass not intended to be eaten into are, as usual, protected with wax. The effect upon a polished flat surface is observed by the formation of Newton's rings with soda light. After perhaps three-quarters of an hour, the depression corresponds to half a band, *i.e.* amounts to ¼λ, and it appears to be uniform over the whole surface exposed. Two pieces of plate glass, 3 inches square, and flat enough to come into fair contact all over, were painted with wax in parallel stripes and submitted to the acid for such a time, previously ascertained, as would ensure an action upon the exposed parts of ¼λ. After removal of the wax, the two plates, crossed and pressed into contact so as to develop the colours, say of the second order, exhibited a chess-board pattern. Where two uncorroded, or where two corroded, parts are in contact, the colours are nearly the same, but where a corroded and an uncorroded surface overlap, a strongly contrasted colour is developed. The combination lends itself to lantern projection, and the pattern upon the screen [shown] is very beautiful, if proper precautions are taken to eliminate the white light reflected from the first and fourth surfaces of the plates.

In illustration of the action of hydrofluoric acid, photographs[1] were shown of interference bands as formed by soda light between glass surfaces, one optically flat and the other ordinary plate, upon which a drop of dilute acid had been allowed to stand (Fig. 2) Truly plane surfaces would give bands straight, parallel and equidistant.

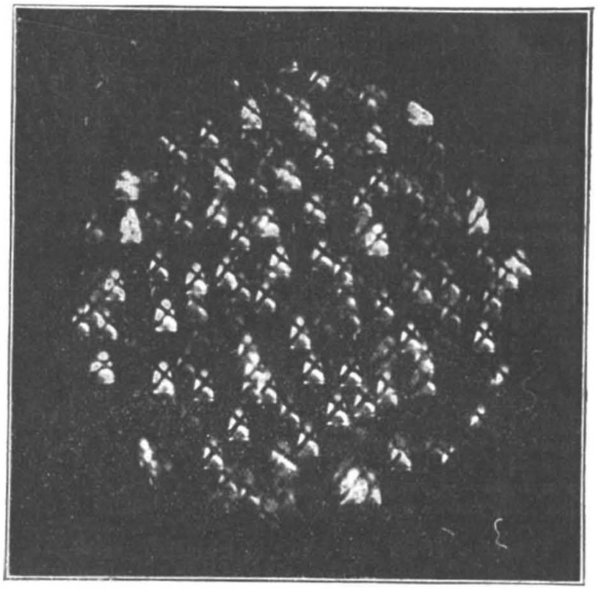
FIG. 4.

Hydrofluoric acid has been employed with some success to correct ascertained errors in optical surfaces. But while improvements in actual optical performance have been effected, the general appearance of a surface so treated is unprepossessing. The development of latent scratches has been described on a former occasion.[2]

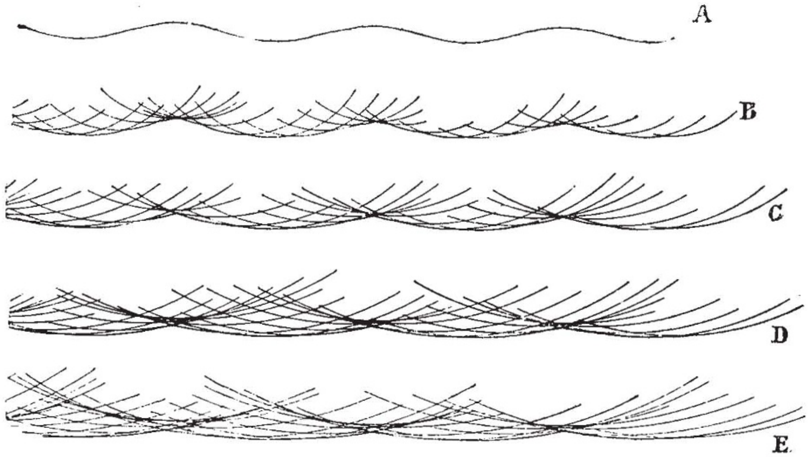

FIG. 5.

A second obvious application of hydrofluoric acid has hitherto been less successful. If a suitable stopping could be

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[1] The plates were sensitised in the laboratory with cyanine.

[2] *Proc.* Roy. Inst., March, 1893.

found by which the deeper pits could be protected from the action, corrosion by acid could be used in substitution for a large part of the usual process of polishing.

In connection with experiments of this sort, trial was made of the action of the acid upon finely ground glass, such, for example, as is used as a backing for stereoscopic transparencies, and very curious results were observed. For this purpose the acid may conveniently be used much stronger, say one part of commercial acid to ten parts of water, and the action may be prolonged for hours or days. The general appearance of the glass after treatment is smoother and more translucent, but it is only under the microscope that the remarkable changes which the surface has undergone become intelligible. Fig. 3 is from a photograph taken in the microscope, the focus being upon the originally ground surface itself. The whole area is seen to be divided into cells. These cells increase as the action progresses, the smaller ones being, as it were, eaten up by the bigger. The division lines between the cells are *ridges*, raised above the general level, and when seen in good focus appear absolutely sharp. The general surface within the cells shows no structure, being as invisible as if highly polished.

That each cell is, in fact, a concave lens, forming a separate image of the source of light, is shown by slightly screwing out the object-glass. Fig. 4 was taken in this way from the same surface, the source of light being the flame of a paraffin lamp, in front of which was placed a cross cut from sheet-metal.

The movement required to pass from the ridge to the image of the source, equal to the focal length (f) of the lens, may be utilised to determine the depth (t) of a cell. In one experiment the necessary movement was ·005 inch. The semi-aperture (y) of the "lens" was 0015 inch, whence by the formula $y^2=ft$, we find $t=\cdot 00045$ inch. This represents the depth of the cell, and it amounts to about 8 wave-lengths of yellow light.

The action of the acid seems to be readily explained if we make the very natural supposition that it eats in everywhere, at a fixed rate, normally to the actual surface. If the amount of the normal corrosion after a proposed time be known, the new surface can be constructed as the "envelope" of spheres having the radius in question and centres distributed over the old surface. Ultimately, the new surface becomes identified with a series of spherical segments having their centres at the deeper pits of the original surface. The construction is easily illustrated in the case of two dimensions. In the figure (Fig. 5) A is supposed to be the original surface; B, C, D, E surfaces formed by corrosion, being constructed by circles having their centres on A. In B the ridges are still somewhat rounded, but they become sharp in D and E. The general tendency is to sharpen elevations and to smooth off depressions.

THE FUNCTIONS OF A UNIVERSITY.[1]

THE word University has borne many significations; and, indeed, its functions are various, and the signification attached to the word has depended on the particular point of view taken at the time. An eminent German, who visited me some years ago, made the remark after seeing University College:—"Aber, lieber Herr College, University College ist eine kleine Universität." So it is; for it fulfils most of the functions of the most successful Universities in the world. And why is this? Because the traditions of University College have always been, that it is not merely a place where known facts and theories should be administered in daily doses to young men and young women, but that the duties of the professors, assistant-professors, teachers and advanced students is to increase knowledge. That is the chief function of a University—to increase knowledge. But it is not the only one.

A University has always been regarded as a training school for the "learned professions," *i.e.* for theology, law and medicine. The terms of our charter have excluded the first of these branches of knowledge. Founded as it was in the '20's, when admission to Oxford or Cambridge involved either belief in the tenets of the Church of England or insincerity, it was not possible to provide courses in theology which should be acceptable to Nonconformists, Jews and others who desired education. On the whole, it appears to me better that a subject about which so much difference of opinion exists should be taught in a separate institution. There are many branches of knowledge which can be adequately discussed without intruding into any sphere of religious controversy; and, indeed, it would be difficult, I imagine, to treat mathematics or chemistry from a sectarian standpoint. I at least have never tried. There are subjects which may be placed on the border-line, for example, philosophy; but such subjects, and they are few in number, might well form part of the curriculum of the theological college, if thought desirable. It is a thousand pities that instead of founding King's College a theological college had not been established in the immediate neighbourhood of University College; it would have strengthened us, and it would have tended, too, to the advantage of the Church of England. However, what is done can't be undone; and let us wish all prosperity to our sister College, and a long and a useful life. We are now friends, and have been friends for many years. May that friendship long continue!

Dismissing the faculty of theology, therefore, as out of our power, as well as beyond our wishes, let us turn to the remaining two learned professions. University College, I believe, was the first place in England where a systematic legal education could be obtained. Our chairs of Roman law, constitutional law and jurisprudence were the first to be established in England, although such chairs had for long been known on the Continent, and in Scotland. "Imitation is the sincerest flattery," and in the fulness of time the Inns of Court started a school of their own. Our classes, which used to be crowded, dwindled, and our law-school is certainly not our strongest feature. I am not sufficiently acquainted with English legal education to pronounce an opinion as to whether methods of training as they at present exist in England are the most effective; I have heard rumours that they are not. That must be left to specialists to decide. But arguing from the experience of another faculty, in which the apprenticeship system once existed, and which has changed that system with a view to reform, and judging, too, from the experience abroad and in Scotland, I venture to think that some improvement in legal education is possible. If that opinion is correct, it is surely not too much to hope that the claims of University College may be considered as having made the first attempt to systematise legal education in England.

The faculty of medicine has existed in a flourishing state since the inception of University College. Not long after the College was built, the Hospital buildings, of which we have the last unsightly remains still before our eyes, were erected. One of my predecessors on a similar occasion to this has given you an entrancing account of the early history of this side of the College, and has discoursed on the eminent men who filled the chairs in the medical faculty. Here young men whose intention it is to enter the medical profession are trained; they now receive five years' instruction in the various branches of knowledge bearing on their important calling. I would point out that this function of a University is professedly a technical one—the training of medical men. True, many researches have been made by the eminent men who have held chairs in this faculty; but that is not the primary duty of such men; their duty is to train others to exercise a profession. If they advance their subject in doing so, so much the better; it increases the fame of the school, it imparts enthusiasm to their students, and in many cases their discoveries have been of unspeakable benefit to the human race. In a certain sense, every medical man is an investigator; the first essential is that he shall be able to make a correct diagnosis; the next, that he shall prescribe correct treatment. But novelty is not essential; few men evolve new surgical operations or introduce new remedies, and though we have in the past had not a few such, they are not essential for a successful medical school, the object of which is to train good practical working physicians and surgeons. The teaching staff of the medical faculty must of necessity be almost all engaged in practice, and, indeed, it would be unfortunate for their students if they were merely theoretical teachers. Let me again recapitulate my point; the medical faculty is essentially a technical faculty; the hospital is its workshop.

In England, of recent years, schools of engineering have been attached to the Universities. Abroad and in America they are separate establishments, and are sometimes attached to large engineering shops, where the pupils pursue their theoretical and practical studies together, taking the former in the morning, the latter in the afternoon. Here again the subject is a professional

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[1] Oration delivered at University College, London, on June 6, by Prof. W. Ramsay, F.R.S.