the polished surface. The binocular has a long working distance and therefore a large field of vision, which permits two and sometimes three reactions to be observed simultaneously. This feature considerably reduces the time required for determination. The long working distance also allows greater freedom of movement between the objectives and the specimen and permits speedier determination.

The portion of the specimen covered by the reagents is clearly visible, in contrast to the obscured vision under the microscope, for with oblique daylight illumination the rays approach from all angles instead of one direction as in vertical illumination. The formation of a tarnish is more readily noted in oblique than in vertical illumination. Effervescence along cracks and fractures is more clearly observed because the reagent drop does not obscure the points of effervescence.

The binocular magnifier is well made, sturdy and compact. It fits rigidly in its case and is portable. The cost of such an outfit is from $100 to $125 as compared with $350 to $400 for a petrographic microscope. Aside from its use with opaque minerals, the binocular is exceedingly valuable for field study of fossils and rocks.

The chief disadvantages in the uses of the binocular are the inability to use magnifications greater than 45x and the absence of polarizing attachments.

In conclusion, the use of the binocular magnifier eliminates many of the objectionable features of the petrographic microscope for field study, beside increasing the speed and accuracy of many of the observations.

The writer has not had the opportunity of using one of the Leitz pocket microscopes, but is of the opinion that it could serve in place of the more expensive binocular magnifier. In this case, it is recommended that oblique daylight be used for illumination, following the system outlined for the binocular magnifier.

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THE USE OF PLASTICINE MODELS IN TEACHING MITOSIS

During the past few years we have used the following method of teaching mitosis to students of elementary botany. Instead of making the customary series of drawings from prepared slides, the modeling wax is substituted for the pencil. Upon small cards about three by four inches, with a slightly roughened surface, outline drawings are made by the student of the cell wall, nuclear membrane, spindle fibers, etc., according to the stage being studied. On this diagram the chromatin granules, nucleoli or chromosomes, modeled from the wax, are placed. A little pressure is sufficient to make the wax adhere to the card.

Our students take great interest in making these models. They grasp the idea more vividly than when only drawings are made and are quick to shift the cards in their proper sequence. Less time is required in making a series of models than in making complete drawings. The models will stand ordinary handling and may be made somewhat permanent by coating with shellac.

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SPECIAL ARTICLES

THE RING METHOD FOR THE DETERMINATION OF SURFACE TENSION

The methods most often used for the determination of surface tension are known as the drop weight and the ring method, respectively. Of these the former is at present much the more exact, and by careful manipulation and the use of the proper functional relation may be made to give correct results to within 0.1 per cent. New technique recently developed in this laboratory makes this method even more precise.

While an approximate theory of the ring method has been developed by Cantor,[1] Tichanowsky,[2] MacDougall,[3] and others, the theory holds well only for rings of dimensions which are usually not employed in practice, so that the uncertainty which remains in the results amounts to 12 per cent. or even more. On account of the incompleteness of the theory most workers adopt as the basis of their calculations an equation entirely analogous to that used with the capillary height method, or they consider that the total pull on the ring (P) is represented by

$$P = Mg = 4\pi Rp = 4\pi R\gamma \qquad (1)$$

The significance of the symbols is represented below:

γ = surface tension in dynes per centimeter.
a = square root of the capillary constant.
M = weight in grams used in balancing the maximum pull of the film.
P = total maximum pull on the ring in dynes.
p = P divided by $4\pi R$.
R = radius of the ring measured to the center of the circular wire.
r = radius of the circular cross-section of the wire.

1 Cantor, *Wied. Ann.* 47, 399–423 (1892).
2 Tichanowsky, *Physikal. Z.* Various papers, 1923–25.
3 MacDougall, Science, n. s., 62, 290 (Sept. 25, 1925).

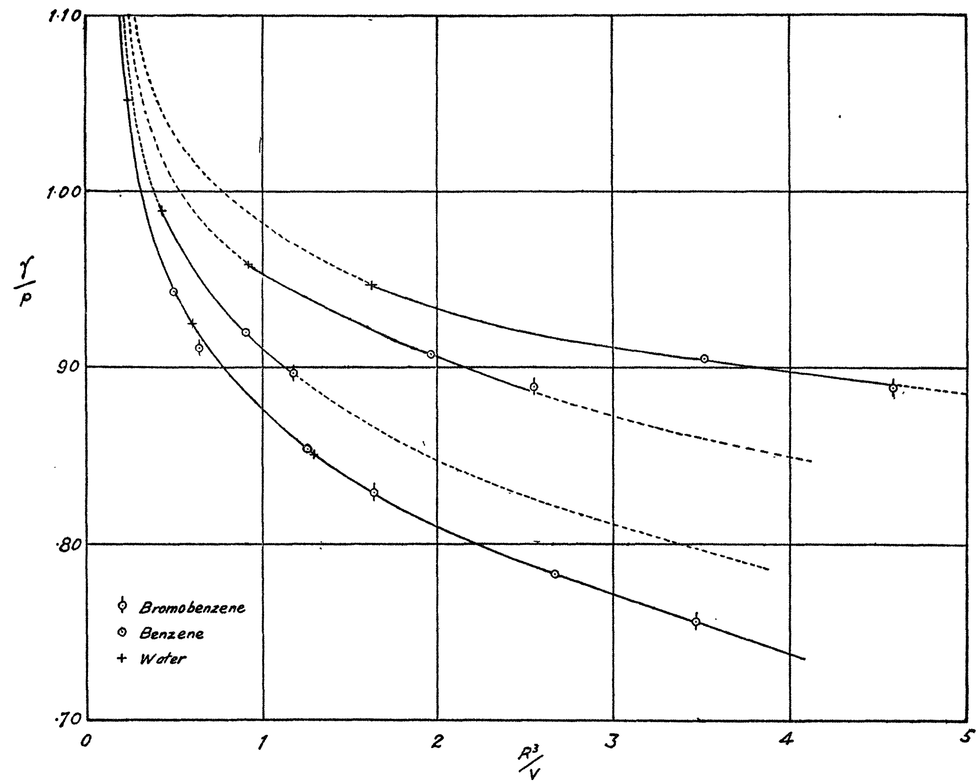

FIG. 1

The values of $\frac{R}{r}$ for the curves in this figure beginning with the bottom curve, are : 29.5, 40.2, 59.1 and 78.5.

D = density of the liquid.

V = volume of liquid upheld by the pull of the ring $= \frac{M}{D}$

g = gravitational constant in dynes per gram.

h = the height above the bottom of the drop at which the pressure in the column of liquid equals that in the vapor at the bottom of the drop ("pressure height").

It will be seen later that the surface tension as calculated by the use of this equation may vary by 25 per cent. or even more from the correct value, which is given by the simple equation

$$\gamma = \frac{Mg}{4\pi R} \cdot F = \frac{PF}{4\pi R} \qquad (2)$$

Here F is a correction factor which may be determined simply by experiment, and might be found by the use of theory if the differential equations of the surface could be integrated in the general case.

The simple equation of Cantor and MacDougall

$$\gamma = p - r\sqrt{2pDg} + \left(\frac{\pi + 3}{4}\right) r^2 Dg$$

gives results with water which are 12 per cent. low if R = .47 and r = .03 cm, but if R is raised to 1.26 the deviation is reduced to 2.5 per cent. Thus, as those who derived the equation indicate, it is more accurate for rings in which R is large. It is apparent that F may be found experimentally, since

$$F = \frac{\gamma}{p} \qquad (3)$$

The writers have obtained preliminary values of this correction factor (F) to within ± 1 per cent. by comparing the surface tensions (γ) of various liquids as determined by the capillary height and drop weight methods with the values of the maximum pull on different rings as determined both by the tensiometer of du Noüy[4] in its latest form, and by a chainomatic balance. Of these the former is the more convenient, while the latter is obviously somewhat more accurate and allows the use of large rings without adjustment of the system.

Cantor, Tichanowski, MacDougall, Johlin[5] and others have pointed out that the value of p varies considerably both with the radius of the ring and that of the wire. The present paper exhibits the nature of these variations.

Fig. 1 shows that the correction factor (F) is most simply represented as a function of $\frac{R}{a}$ and of $\frac{R}{r}$. To obtain the lowest curve in the figure three

[4] *Journal of Gen. Physiology, 1,* 521 (1918–19).

[5] Johlin, SCIENCE, 64, 93 (July 23, 1926).

rings of radii (R) 0.47, 0.77 and 1.18 cm were used, but the ratio of the radius of the ring to that of the wire was kept constant $\left(\frac{R}{r} = 29.5\right)$.

Thus, while the values of the correction factor are represented by a surface this gives a line if $\frac{R}{r}$ is kept constant. This is the most important relation discovered in the present work. With any specific liquid p increases with R (rapidly if $\frac{R}{a}$ is small) provided r is kept constant, and p also increases with r provided R is kept constant. If $\frac{R}{r}$ is kept constant p increases with $\frac{R}{a}$ or $\frac{R^3}{V}$. According to the principle of similitude the shape of a meniscus depends upon $\frac{R}{a}\left(\text{or } \frac{R^3}{V}\right)$ alone and not at all upon its size. The shape of a drop hanging from a sharp tip with circular horizontal face is also the same and independent of the size, provided $\frac{R}{a}$ and $\frac{R}{h}$, where h is the "pressure height," are kept constant. By the proper manipulation the value of $\frac{R}{h}$ is very simply regulated by the experimenter so that the shape of the drop just before detachment depends on $\frac{R}{a}\left(\text{or } \frac{R^3}{V}\right)$ entirely and not at all on its size. According to the principle of similitude the shape of the surface of maximum pull should depend on $\frac{R}{a}$ and $\frac{R}{r}$ alone. Thus if $\frac{R}{a}$ is kept constant the shape of the surface remains the same if the radius of the ring is increased, provided the radius of the wire is increased in the same ratio.

To obtain an unknown surface tension the maximum pull (M) in grams on the ring is obtained experimentally. From this the value of p is obtained from

$$p = \frac{Mg}{4\pi R}$$

The volume of liquid (V) held above the plane surface of the liquid, which corresponds with the maximum pull is

$$V = \frac{M}{D}$$

so

$$\frac{R^3}{V} = \frac{R^3 D}{M}$$

The correction factor (F) for this value of $\frac{R^3}{V}$ and the proper value of $\frac{R}{r}$ is found on the graph (Fig. 1), and the surface tension is obtained from the equation

$$\gamma = p.\frac{V}{p} = p.F$$

Certain experimental precautions are essential if a moderately high degree of precision is desired:

(1) It is important to cover the liquid since evaporation may cool the surface more than the body of the liquid, and in the case of colloidal and other solutions the nature of the surface film may be modified. For this purpose an inverted glass funnel may be used.

(2) The liquid and the vapor above it should be buried beneath the surface of a thermostat. This may be done if a specially designed vessel is used.

(3) In the case of water or of aqueous solutions this special vessel should be designed in such a way that the surface may be renewed or swept by a bar of glass.

(4) The support for this vessel should be entirely independent of that of the thermostat, and during the period of measurement the liquid of the thermostat should not be stirred, since surface waves may be set up in the surface being measured.

(5) The area of the surface should be large, since otherwise corrections for the curvature for the meniscus in the vessel are essential.

It may be well to point out here that certain precautions which have been supposed by some writers to be essential for this method are inherent in the nature of either an ordinary or a torsion balance and have nothing to do with the method of detachment of the ring; thus it is sometimes stated that the force required for detaching the ring from the liquid should be applied on the liquid and not on the ring. Now it is apparent that this is impossible, since the force must be applied on both. What is meant is that the balance must be kept at its zero position. Actually it may be preferable to raise the balance rather than to lower the liquid, since lowering the liquid is apt to set up surface waves. However, raising the balance may transmit momentum to its beam, so what is important is that the mechanism used for its purpose shall operate with extreme smoothness.

An important but simple modification was made in the du Noüy tensiometer, the end of the beam farthest from the torsion wire was lengthened by the insertion of a light, rigid, pointed wire. Opposite this, a fixed (but adjustable) point of the same sharpness was set. A small telescope set a foot distant made it possible to determine the "zero" of the torsion balance with greatly increased ease and precision.

The left hand of the chainomatic balance was replaced by a long weighted wire, which exactly balances the right-hand pan and extends downward below the balance case. A thermostat was not used for the work reported in this preliminary article, but the temperature was determined and corrections were made for variations in temperature. It may be mentioned that if the liquid is to be lowered from the ring, the coarse and fine adjustments of a microscope stand may be employed.

This work is being continued by one of the writers under more exactly controlled conditions, with a greater number of rings and of liquids and it is hoped that an accuracy of ± 0.1 per cent. may be attained, though this may not be possible with ordinary precautions.

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THE CHROMOSOMES OF RODENTS[1]

DURING the present year students working under my direction have made careful studies of the chromosomes of the house mouse, the albino rat and the guinea pig. The purpose of this note is to give the results of these studies briefly. Detailed papers will appear later under the names of the students who have carried out the work.

House mouse (worked out by Elizabeth Cox). A number of investigators have reported the haploid or reduced chromosome number of both male and female mice as twenty, but diploid counts have not been made. Numerous counts made on dividing spermatogonia show that the diploid number for the male is forty chromosomes. Figure 1 is a typical spermatogonial plate. The haploid number is twenty. The sex chromosomes are of the X-Y type, the Y being somewhat larger than the smallest pair of autosomes. In the first maturation division the X and Y appear first as joined (Fig. 2) but they later segregate to opposite poles. As a result the sperm are dimorphic as regards the sex chromosomes.

Albino rat (worked out by Irene Kehoe). The diploid chromosome number for the rat has been given by Allen ('18)[2] as thirty-seven, a number based largely on first spermatocyte counts. It has been found that spermatogonia of albino rats (Wistar stock) show forty-two chromosomes (Fig. 3). This count has been confirmed by a careful study of the somatic (amnion) chromosomes of a number of male and female embryos. The haploid number is twenty-one. Observations on the sex chromosomes have not been completed, but apparently they are of the X-Y type, similar to those found in the mouse (Fig. 2).

Guinea pig (worked out by Bessie League). Stevens ('11)[3] reported that there were approximately fifty-six chromosomes in this form, but recently Harmon and Root ('25) have reported thirty-eight as the diploid number.[4] Counts made at this laboratory indicate that the diploid number is between sixty and sixty-four (Fig. 4) and the haploid number is thirty (Fig. 5). Sex chromosomes have not been identified. The guinea pig has proved of especial interest because in prophases of spermatogonia the chromosome number is lower than in the equatorial plate stages. This suggests that the high number is a late acquisition for this form and has resulted from a breaking up of a smaller number of elements. It seems possible that different strains of guinea pigs may differ in the degree to which this fragmentation occurs and as a result that the chromosome number may vary in well-fixed material.

Four rodents have been carefully studied at this laboratory with chromosome number determinations as follows for males: rabbit forty-four chromosomes, albino rat forty-two chromosomes, house mouse forty chromosomes, and guinea pig about sixty chromosomes.

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1 Contribution No. 203 of the Department of Zoology, University of Texas. These investigations have been aided by grants from the Committee for Research on Sex Problems of the National Research Council under the direction of the writer.

2 Allen, Ezra, 1918, *Journ. Morph.*, Vol. 31.

3 Stevens, N. M., 1911, *Biol. Bull.*, Vol. 21.

4 See Abstracts of Christmas Meetings, Amer. Soc. Zool., at New Haven, 1925. Also Biol. Bull., vol. 51.