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THE ABSOLUTE VALUE OF THE ACCELERATION OF GRAVITY DETERMINED BY THE RING-PENDULUM METHOD.

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THE ABSOLUTE VALUE OF THE ACCELERATION OF GRAVITY DETERMINED BY THE RING PENDULUM METHOD.

The use of a ring pendulum for the determination of the absolute value of the acceleration of gravity was first proposed by Dr. T. C. Mendenhall, who in 1898 presented to the National Academy of Sciences a brief report of some preliminary experiments made by Prof. A. S. Kimball at the Worcester Polytechnic Institute. The use of the method as an ordinary laboratory exercise in the physics department of the institute (in charge of Professor Kimball) had shown that even with rather roughly constructed apparatus results were obtained agreeing well with each other and with the approximately known value of the constant at that point. It seemed desirable, therefore, that a careful examination and test of the method should be made, since the importance of a knowledge of the value of this constant is so great and the known methods of determining it are so few that any process which may serve as a check upon these methods can not fail to be of value. Accordingly a grant from the Bache fund of the Academy was made to Dr. Mendenhall by the trustees of this fund to enable him to procure the apparatus necessary for a more exacting test of the method. During the two succeeding years some preliminary work was done under his direction by Dr. Edward Rhoads at the Worcester Polytechnic Institute, consisting mostly of a study of some points relating to the theory of the method and the design of a part of the apparatus. Dr. Mendenhall being at that time unable to give further attention to the investigation, it was placed in my hands; the material turned over to me consisting of the unfinished pendulum case, and some notes by Dr. Rhoads, to which I am glad to acknowledge indebtedness. It is only, however, at intervals during the past two years that the work has been under way, the greater part of this time having been devoted to the completion of the pendulum case and other accessory measuring apparatus, and more especially to the completion of the rings.

Geometrically, the ring pendulum is a figure bounded by two plane parallel surfaces and two concentric cylindric surfaces whose axis is perpendicular to the plane faces, and it is to be vibrated on a knife edge resting on an element of the inner cylindric surface. The relation between the dimensions of the ring, the period, and "g" is quite simple, the most interesting point being the existence of a particular ratio of the inner and outer radii which makes the period depend only on the value of the outer radius; that is, the period is very insensitive to changes in the inner radius. This ratio, $\frac{R}{r}=\sqrt{3}$, is one which gives a very deep, and hence a very rigid, ring. For a convenient coincidence interval of about 6 minutes (with a one-second clock beat)—that is, a period of about $1^s.003$—the external diameter should be about 28.85 cm. and the inner 16.65 cm. The ring can be swung from any internal element and by so doing irregularities of density or figure, not otherwise easily discovered, can be detected and their effects to an extent eliminated. This matter will be discussed more in detail later, but the above considerations are enough to suggest the three points on which the desirability of the ring pendulum method will certainly depend, namely:

I. A definite and easily observable length to measure—the external diameter of the ring.

II. The great rigidity of the pendulum, hence but slight departure from its measured figure when suspended.

III. Detection of, and partial correction for, nonhomogeneity of pendulum.

It is evident, however, that any nonhomogeneity or figure error which is symmetrical with respect to the center of the ring can not be detected by observations on the period; hence the necessity of comparing results with a number of rings. With this in mind, five forgings for rings were obtained, of which one was broken during construction; but on account of the great labor involved in making a finished ring, only two have been completed and used.

What has been said as to the simplicity of the theory is also true of the measurements involved; the difficulty of the problem lies in the construction of the ring. But before taking up this, it will be well for the sake of reference to consider the following:

1. The vibration of a perfect ring, that is, one having no irregularities of figure or density.
2. The effect of "flaws" in general.
3. Special cases of nonhomogeneity, and error in figure:
   (*a*) Nonparallelism of faces.
   (*b*) A particular case of irregular density.
   (*c*) One face conical.
   (*d*) Inner edge conical.
4. Effect of error in adjusting the plane of the ring at right angles to the knife edge.

1. PERFECT RING.

[After Kimball.]

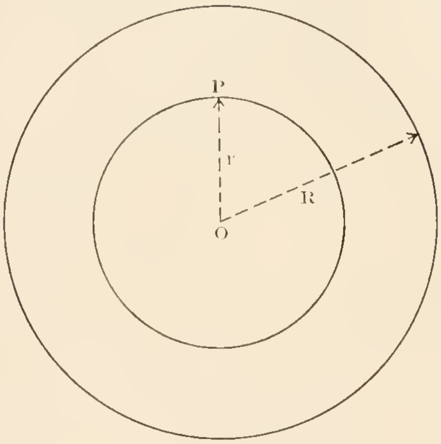


Fig. 1.

Let:

R=external radius.
r=internal radius.
M=mass of ring.
T=period of vibration around P.
ρ, t,=density and thickness of ring, which may be assumed unity.

Then:

$$I_o=\frac{\pi}{2}(R^4-r^4)=\text{moment of inertia around O.}$$

and:

$$I_P=I_o+\pi(R^2-r^2)r^2=\text{moment of inertia around P.}$$

$$=\frac{\pi}{2}(R^2-r^2)\,(R^2+3r^2)$$

$$=\tfrac{1}{2}M\,(R^2+3r^2).$$

$$\therefore\quad T=2\pi\sqrt{\frac{I_P}{Mgr}}=2\pi\sqrt{\frac{R^2+3r^2}{2gr}}$$

Differentiating with respect to r:

$$2\mathrm{T}\frac{d\mathrm{T}}{dr}=4\,\pi^2\left[\frac{3}{2g}-\frac{\mathrm{R}^2}{2gr^2}\right]$$

But if

$$\frac{d\mathrm{T}}{dr}=0$$

the period will be independent of r, which gives the condition—

$$\frac{3}{2g}-\frac{\mathrm{R}^2}{2gr^2}=0$$

or

$$\mathrm{R}^2=3r^2$$

[By noting the effect of putting $r=0$ this condition is seen to be that for a minimum value of T].

Introducing this relation above we find—

$$\mathrm{M}=\tfrac{2}{3}\pi\mathrm{R}^2$$

$$\mathrm{I_P}=\mathrm{MR}^2=3\mathrm{M}r^2$$

$$\mathrm{T}=2\pi\sqrt{\frac{\mathrm{R}\sqrt{3}}{g}}$$

$\mathrm{R}\sqrt{3}$ is evidently the length of the equivalent simple pendulum.

It is also useful to know the radius of the equivalent "simple ring" pendulum—i. e., a *linear* ring concentric with the real ring, and vibrating (by means of a massless support) around the same point of suspension (P) with the same period.

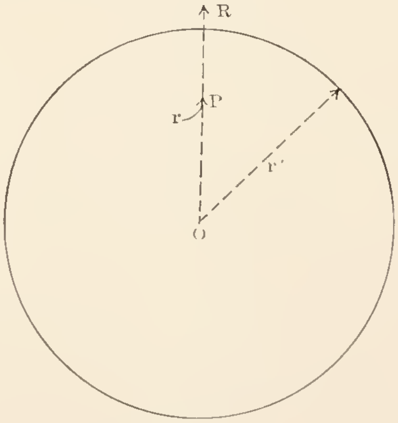


Fig. 2.

In this case:

$$\mathrm{I_P}=2\pi r'^3+2\pi r'\frac{\mathrm{R}^2}{3},$$

and:

$$\mathrm{T}'=2\pi\sqrt{\frac{r'^2+\frac{\mathrm{R}^2}{3}}{\frac{\mathrm{R}}{\sqrt{3}}g}}$$

By hypothesis:

$$\mathrm{T}'=\mathrm{T}.$$

$$\because\quad r'^3+\frac{\mathrm{R}^2}{3}=\mathrm{R}^2$$

or

$$r'=\sqrt{\frac{2}{3}}\mathrm{R}.$$

Such a ring could be added to or taken from the perfect ring without altering the period; hence any symmetrical system of fine lines or graduations could be made on the ring at the distance r' from the center without sensibly altering its period.

The degree to which the period of a perfect ring is independent of r when the relation $R=\sqrt{3}r$ is nearly satisfied is shown by the following computed values of T for a constant R and varying r.

R= 14.413 cm. $g=980.$

r=	$8^{cm}.31$	$8^{cm}.32$	$8^{cm}.33$
T=	$1^{s}.00567$	$1^{s}.005669+$	$1^{s}.005671-$

It is evident from this that it is a very easy matter to satisfy the relation $R=\sqrt{3}r$ with sufficient accuracy.

2. THE EFFECT OF FLAWS, OR SMALL IRREGULARITIES IN DENSITY, ON THE PERIOD OF THE RING.

[Rhoads.]

Suppose a flaw of magnitude $\varDelta m$ located at the point r_1, θ (fig. 3), and let this flaw produce a change $\varDelta$T in the period T of the otherwise perfect ring.

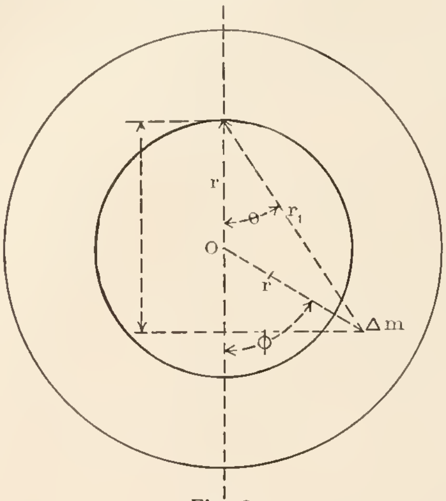


Fig. 3.

Then:

(1) $$T+\varDelta T=2\pi\sqrt{\frac{3mr^2+\varDelta m r_1^2}{g(mr+r_1\cos\theta\varDelta m)}}$$

(2) $$=2\pi\sqrt{\frac{3r^2+\frac{\varDelta m}{m}r_1^2}{g(r+r_1\frac{\varDelta m}{m}\cos\theta)}}$$

(3) $$=2\pi\sqrt{\frac{3r^2(1+\frac{r_1^2}{3r^2}\frac{\varDelta m}{m})}{gr(1+\frac{r_1}{r}\frac{\varDelta m}{m}\cos\theta)}}$$

(4) $$=T\sqrt{1+\frac{r_1}{r}\frac{\varDelta m}{m}\left[\frac{r_1}{3r}-\cos\theta\right]}$$

(5) $$=T\left[1+\frac{1}{2}\frac{r_1}{r}\frac{\Delta m}{m}\left[\frac{r_1}{3r}-\cos\theta\right]\right]$$

(6) $$\therefore\quad \frac{\Delta T}{T}=\frac{1}{2}\frac{r_1}{r}\frac{\Delta m}{m}\left[\frac{r_1}{3r}-\cos\theta\right]$$

This may be written:

(7) $$r_1=\frac{r}{2}\left[3\cos\theta\pm\sqrt{9\cos^2\theta-24\frac{\Delta T}{T}\frac{m}{\Delta m}}\right]$$

which is the equation of a family of circles (or circular cylinders), the variable parameter being $\frac{\Delta T}{T}\frac{m}{\Delta m}$; that is, a given flaw m will produce the same change in period T if located anywhere on one of these circles. The distance of the center of these circles from P is evidently:

$$D=\frac{1}{2}\left[r_{1,\theta=0}+r_{1,\theta=\pi}\right]=\frac{3}{2}r$$

The condition that $\frac{\Delta T}{T}=0$ gives $r_1=3r\cos\theta$ as the equation of the locus of a flaw which will have no effect on the period. This is evidently a circle tangent to the inner circumference at P; if Δm is positive and located *inside* of this circle it will decrease T; if *outside*, it will increase it. A question more to the point is that of the resultant effect of a number of flaws for different positions of the knife-edge.

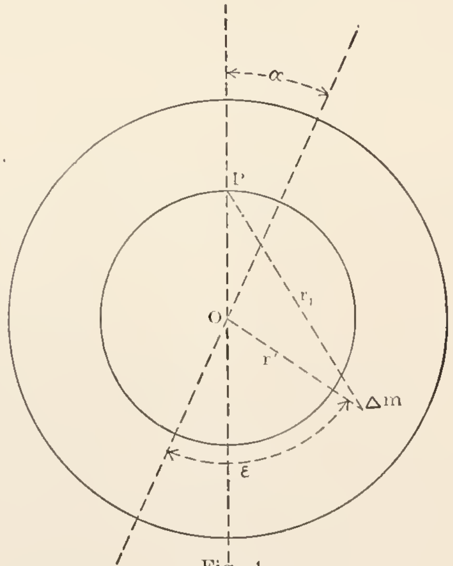


Fig. 4.

It will simplify matters to transfer the origin to the center of the ring, using the variables r' and ϕ, which are determined by:

$$r_1\cos\theta=\quad r+r'\cos\phi$$
$$r_1=\sqrt{r'^2+r^2+2r'\cos\phi}$$

Making this substitution, equation (6) becomes:

$$\frac{\Delta T}{T}=\frac{1}{6}\frac{\Delta m}{m}\left[-2+\left[\frac{r'}{r}\right]^2+\frac{r'}{r}\cos\phi\right]$$

Now let there be a number of flaws Δm_1, Δm_2, Δm_3, ... whose position is determined by the radii r', r'' . . . . . and the angles e_1, e_2, ... which these radii make with a diameter fixed in the ring, which, in turn, makes an angle α with the vertical line through the knife-edge. We should then have, if

$$t = \Sigma \Delta \mathrm{T}$$

is the resultant change in period produced by all the flaws:

$$\frac{t}{\mathrm{T}} = \frac{1}{m}\frac{1}{6}\left[\frac{1}{r^2}(\Delta_1 mr'^2 + \Delta_2 mr''^2 + \ . \ . \ .) - 2(\Delta_1 m + \Delta_2 m + . \ .)\right]$$

$$-\frac{1}{r}\left[\Delta_1 mr' \cos(e_1 - \alpha) + \Delta_2 mr'' \cos(e_2 - \alpha) + . \ . \ .)\right]$$

or, if—

$$\mathrm{A} = \Sigma \Delta_1 mr' \cos e_1$$

$$\mathrm{B} = \Sigma \Delta_1 mr' \sin e_1$$

$$\Gamma = \tan^{-1} \frac{\mathrm{B}}{\mathrm{A}}$$

We have—

$$\frac{t}{\mathrm{T}} = \frac{1}{6m}\left[\frac{1}{r^2}\Sigma \Delta mr'^2 - 2\ \Sigma \Delta m - \frac{1}{r}\ \sqrt{\mathrm{A}^2 + \mathrm{B}^2} \cos(\alpha - \Gamma)\right]$$

The effect of the flaws is then in general to produce a certain change in T which is independent of the position of vibration (i. e., of the angle α) and in addition a change dependent on this position. As is otherwise evident, for any symmetrical distribution of flaws, A=B=O and the change in T will be independent of α. If at the same time—

$$\frac{1}{r^2}\ \Sigma \Delta mr'^2 = 2 \Sigma \Delta m$$

the constant part of the change, t, will also be O; and this determines the radius of the equivalent "simple ring" previously deduced from other considerations.

3. SPECIAL CASES OF NONHOMOGENEITY AND ERRORS OF FIGURE.

In order to the better interpret the behavior of the actual rings, it will be well to consider a few special cases of departure from a perfect ring which, on account of the method of making the ring, are especially to be guarded against. The first of these is the matter of nonparallelism of the side faces, which is equivalent to the addition of a wedge-shaped ring to a perfect ring. Exactly the same effect would be produced by a special case of nonuniform density—i. e., that in which the density varied as the distance from a plane tangent to the outer circumference of the ring. The method of procedure has been to determine the period of the "ring and wedge," for three positions, thick edge up, thick edge down, and one of the symmetrical positions with thick edge to right or left. By comparing these periods with that of the perfect ring, the effect of a given wedge as to both the "constant" and "variable" changes in the period can be determined.

Let—

t = thickness of ring.

Δt = maximum thickness of added wedge.

Δm = mass of added wedge.

ΔI_P = moment of inertia of added wedge about P.

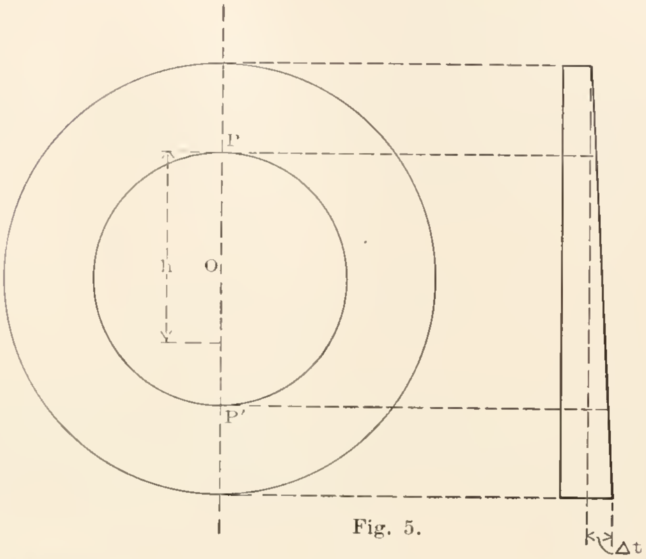


Fig. 5.

Then—

$$\frac{\Delta m}{m} = \frac{1}{2}\frac{\Delta t}{t}$$

$$\Delta I_P = \Delta I_o + \Delta m\left[\left(\frac{R}{3} + r\right)^2 - \left(\frac{R}{3}\right)^2\right]$$

$$= 0.692\ MR^2\frac{\Delta t}{t} \text{ putting } R = \sqrt{3}\,r$$

Similarly—

$$\Delta I_{P'} = 0.307MR^2\frac{\Delta t}{t}$$

Also—

$$T'_P = 2\pi\sqrt{\frac{I + \Delta I_P}{(Mr + \Delta m h)g}}$$

(Where h = distance from P to center of gravity of wedge)

$$= 2\pi\sqrt{\frac{R\sqrt{3}\left(1 + 0.692\frac{\Delta t}{t}\right)}{g\left(1 + 0.788\frac{\Delta t}{t}\right)}}$$

$$= T\sqrt{\frac{1 + 0.692\frac{\Delta t}{t}}{1 + 0.788\frac{\Delta t}{t}}}$$

Similarly—

$$T'_{P'} = T\sqrt{\frac{1 + 0.307\frac{\Delta t}{t}}{1 + 0.230\frac{\Delta t}{t}}}$$

If we assume as a special case $\frac{\Delta t}{t}=0.001$, that is, for the actual ring $\Delta t=15\mu$, approximately, the above expressions become—

$$T'_{P'}=0.999952\ T$$

$$T'_{P'}=1.000039\ T$$

From which

$$T'_{P'}-T'_{P}=0.000086\ T$$

$$\frac{1}{2}(T'_{P'}+P'_{P})=0.999995\ T.$$

Also for either symmetrical position in which the thick edge is to right or left, we have, neglecting terms of second and higher orders in $\frac{\Delta t}{t}$.

$$T_{P''}=2\pi\sqrt{\frac{MR\ (1+\frac{\Delta t}{2t})}{M\frac{R}{\sqrt{3}}(1+\frac{\Delta t}{2t})}}=T.$$

T in all these expressions being the period of a perfect ring having the same outer and inner radii as the imperfect ring under discussion. The above conclusions will be of interest in connection with the experimental results later discussed. They will, of course, apply equally well to the special case of nonuniform density before mentioned, where the increment of density at a point r', θ, is given by

$$\Delta\rho'=\frac{\Delta\rho}{2R}(R-r'\cos\theta)$$

$\Delta\rho$ being the maximum increment in density (at the bottom of the ring in this case); in the final result $\frac{\Delta\rho}{\rho}$ would appear in the place of $\frac{\Delta t}{t}$ above.

Another error of figure which must be especially guarded against is that shown in figure 6, one face being symmetrically conical; here, if Δm is the increment of mass and ΔI the increase in moment of inertia about P due to the added conical ring, we find

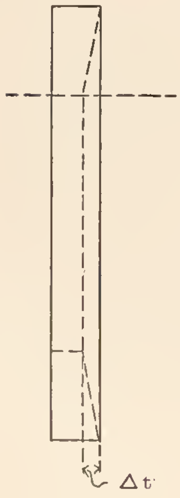


Fig. 6.

$$\frac{\Delta m}{m}=0.54\frac{\Delta t}{t}$$

and

$$\frac{\Delta I}{I}=0.6\frac{\Delta t}{t}$$

from which

$$T'=T\sqrt{\frac{1+0.6\frac{\Delta t}{t}}{1+0.54\frac{\Delta t}{t}}}$$

If

$$\frac{\Delta t}{t}=0.0001 \qquad (\Delta t=1.5\mu)$$

$$T'=1.000006\ T.$$

Even a systematic error in thickness as small as this could be detected and corrected in the course of construction.

Irregularities in the outer radius must be determined in each case and their effect computed. Irregularities in the inner radius are of no importance (except as they affect the amount of contact on the knife edge) unless they result in making the inner surface conical, and hence forcing the ring to swing out of its own plane. In this case if we consider a thin lamina of the ring, it will evidently be equivalent to its elliptical projection upon the vertical plane; and for small values of α (fig. 7), since the external diameter is supposed uniform, all laminæ will be equally affected and it will suffice to consider a plane ring whose—

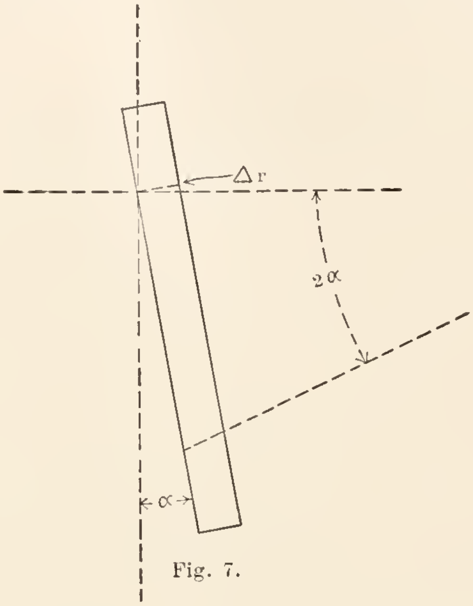


Fig. 7.

external major axis (horizontal) $=2\text{R}$.
external minor axis (vertical) $=2\text{R}\cos\alpha$.
internal major axis (horizontal) $=2\frac{\text{R}}{\sqrt{3}}$.
internal minor axis (vertical) $=2\frac{\text{R}}{\sqrt{3}}\cos\alpha$.

If
$\text{I}'=$ the moment of inertia of this equivalent elliptical ring:
$\text{I}\;=$ the moment of inertia of a corresponding circular ring about a normal axis through P we find

$$\frac{\text{I}'}{\text{I}}=\cos\alpha\left(\frac{1}{3}+\frac{2}{3}\cos^2\alpha\right)$$

and

$$\text{T}'=2\pi\sqrt{\frac{\text{I}'}{\text{M}h'g}}=2\pi\sqrt{\frac{\text{I}\left(\frac{1}{3}+\frac{2}{3}\cos^2\alpha\right)}{\text{M}\frac{\text{R}}{\sqrt{3}}g}}$$

$$=\sqrt{\frac{1}{3}+\frac{2}{3}\cos^2\alpha}$$

If, as a special case, $t=15$ mm.
$\Delta r=0.001$ mm.
Then $\cos\alpha=0.9999998$

and the resulting error in T would be much less than $\frac{1}{1,000,000}$s. Even an error in r two and one-half times as great, which could be easily detected, would produce a negligible error in T.

Other special cases, such as abnormal density throughout a certain segment of the ring, have been computed, but the results are of no particular assistance in discussing the experimental data, and therefore need not be given here.

4. THE AZIMUTH ERROR.

There remains to consider only the azimuth error—that is, an error in adjusting the plane of the ring at right angles to the knife edge. (Rhoads.)

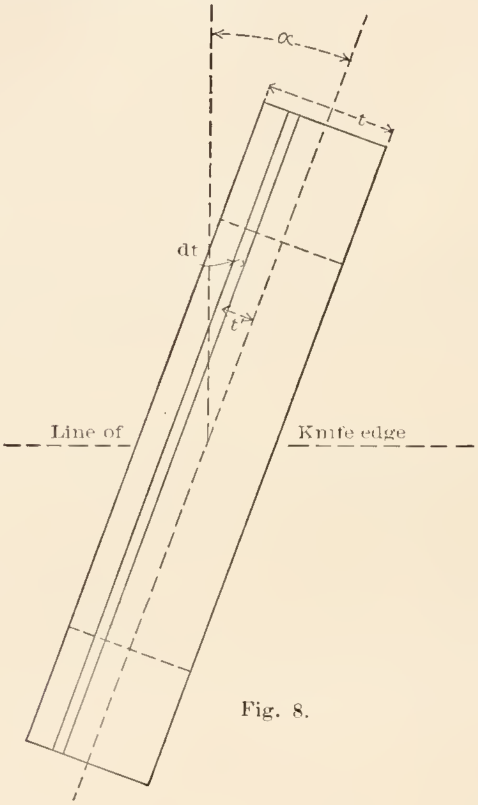


Fig. 8.

Consider a ring lamina of thickness dt (normal to its plane), and radii R and r. To determine its period of vibration around an inner circumferential axis making an angle α with its plane.

The moment of inertia of the lamina around a central axis will be:

$$\frac{\pi}{4}\rho dt(R^4-r^4)(1+\cos^2\alpha)=\Delta i_o.$$

The complete ring will be made up of a number of such laminae, which will not, however, be symmetrically situated with respect to the axis of rotation.

The moment of inertia of the complete ring about the central axis will be:

$$I_o=\frac{\pi\rho}{2}(1+\cos^2\alpha)(R^4-r^4)\int_o^{\frac{t}{2}} dt+2\pi\rho(R^2-r^2)\sin^2\alpha\int_o^{\frac{t}{2}} t'dt$$

$$=\frac{\pi\rho t}{4}(R^2-r^2)\left[(2-\sin^2\alpha)(R^2+r^2)+\frac{t^2}{3}\sin^2\alpha\right].$$

About a parallel axis through the inner circumference, we have:

$$I_P = I_0 + mr^2$$

$$= \frac{m}{2}\left\{R^2 + 3r^2 + \frac{1}{2}\left(\frac{t^2}{3} - R^2 - r^2\right)\sin^2\alpha\right\}$$

and

$$T\alpha = 2\pi\sqrt{\frac{R^2 + 3r^2 + \frac{1}{2}\left(\frac{t^2}{3} - R^2 - r^2\right)\sin^2\alpha}{2gr}}\ .$$

$$= 2\pi\sqrt{\frac{R^2}{gr} + \frac{t^2 - 4R^2}{12gr}\sin^2\alpha} \qquad [\text{Since } R^2 = 3r^2]$$

and, if we put $t^2 = KR^2$

$$T\alpha = T\sqrt{1 + \frac{K-4}{12}\sin^2\alpha}$$

$$= T\left(1 + \frac{K-4}{24}\sin^2\alpha + \ldots.\right)$$

In the actual rings K=0.0113 [about] so that:

$$T\alpha = T\,(1 - 0.166\,hr^2 + \alpha\,\ldots\ldots)$$

From which expression the following table of changes in the period ($\varDelta T$) produced by various errors in azimuth has been calculated:

α	$3'.5$	$8'.4$	$17'$	$34'$	$1°\ 7'$
$\varDelta T$	$0^{s}.00000016$	$0^{s}.0000010$	$0^{s}.0000041$	$0^{s}.000016$	$0^{s}.000066$

Evidently if α can be made less than $8'$ in practice, the azimuth correction will be quite negligible.

CONSTRUCTION OF THE RINGS.

The first question in the matter of construction is that of choice of material. Obviously the material should be of a hardness comparable with that of agate, of which the knife-edge is best made: homogeneous, free from slow changes in shape, having a definite temperature coefficient, and a large ratio: $\frac{\text{Young's Modulus}}{\text{Density}}$

Probably the ideal material would be fused quartz, and next, properly annealed glass; but the difficulty and expense of construction with either of these would be much greater than with the tool steel actually used. Troubles with permanent magnetization which might perhaps be anticipated with a hardened steel ring have not been found, and of course the finished ring can be demagnetized if necessary. Uncertainties as to the degree of homogeneity and permanence of form which could be obtained with this material could only be settled by trial.

Owing to the mechanical difficulties of the work and the necessarily exacting conditions, no manufacturing mechanician could be found who was willing to undertake the making of these rings, and it was therefore taken up and completed at the University of Wisconsin. On this account it will, perhaps, be desirable to devote somewhat more space to the matter of construction than would otherwise be done. The finishing of the glass-hard ring must, of course, be done by grinding, and during this process the ring must be so held as not to distort its figure and, at the same time, in such a way that the inner and outer cylindrical surfaces and one face can be finished without in any way disturbing the adjustment of the ring on its support: otherwise errors of eccentricity, etc., would be likely to occur.

Two forgings of "Crescent special" tool steel were obtained from the Crucible Steel Company of America and two of a special self-hardening steel from the Westmoreland Steel Company of Pittsburg. A fifth forging of phosphor bronze (the hardest available nonmagnetic metal, unless, possibly, some nickel steel) was also obtained, it being intended to vibrate this with a small agate plate interposed between the ring and the knife-edge; but only the first rough work has been done on this. With a view to getting greater homogeneity all of these blanks were made so that more than one-half inch of material had to be cut away at the center and rim, and one-fourth inch from the faces, this, of course, being done with the annealed ring before hardening.

The hardening of such a large piece of metal is not a simple matter, and, indeed, one of the "Westmoreland" rings cracked quite in pieces shortly after hardening; however, the other Westmoreland and one "Crescent" ring were successfully hardened. After a little preliminary grinding to remove the "skin," the rings were artificially aged by several days' "tumbling" in an ordinary foundry rattler, and being heated and cooled through about 100° C. A little further grinding proved the mechanical arrangements then available to be inadequate and the rings were laid aside for nearly a year while the grinding facilities were being improved: this gave them time to assume a more permanent condition.

The funds at command did not permit the construction of a special grinding machine—so a small milling machine was rigged up for the purpose. The general result may be seen in plate 1. Profiting by the first experience, a solid spindle head was built, having a heavy vertical axis running in conical bearings and carrying a large horizontal face plate. Great care was taken as to the accuracy of the bearings, the proper support of end thrust and the relief from belt strain. This self-contained spindle head was mounted on the milling machine carriage and could be given at will a vertical, in and out, or transverse horizontal motion with respect to the grinding wheel which was rigidly fastened to the top of the milling machine. Projecting from the top of the face plate were three hardened steel lugs (on which the ring rested), the tops of which were first ground until coplanar. Around these lugs, between the ring and the face plate, was a flat zigzag of insulated wire, waxed to the plate below, and having on its upper surface small lumps of wax which projected above the plane of the steel lugs. After the ring had been put roughly into position the wire would be heated electrically, and the whole mass of the ring slowly warmed until the lumps of wax softened and stuck to the steel; the ring would then be centered, temporarily held in position by clamps bearing immediately over the lugs, and left to cool. Mounted in this way the ring was held very solidly and at the same time three surfaces were exposed for grinding. Of course before all this the spindle carrying the ring had been adjusted with great accuracy to be respectively parallel and at right angles to the two motions of translation which were to be used in generating the cylindrical and plane surfaces; it having been found before by test that these two motions were themselves near enough mutually rectangular. The degree to which various "taper" effects could be avoided was not, however, limited to the accuracy of these preliminary tests and adjustments, for by means of weights and springs the relation of various parts of the machine to each other could be altered during the grinding and any tendency to cut "taper" minimized in this way. It is true that by so doing irregularities and tremors were doubtless introduced which would have been absent with a properly constructed machine, but with the arrangements at hand this was the best that could be done. Of course the design of the several linear constraints on a milling machine are not at all what would be chosen for work such as this, but by careful manipulation very satisfactory results were obtained.

In finishing a flat side, the surface was tested after every cut with a standard straightedge, and the high spots were taken off on the next cut; these finishing cuts could not be measured, but were probably about $.1\mu$. In a similar way watch was kept for possible taper in the inside hole, and no systematic variations in the inside diameter as great as 0.002 mm. were allowed. After the surfaces were finished the ring would be turned over and again waxed down; failure to be properly seated on the three steel points would be detected by the first cut or would be shown by subsequent micrometer measurements. Such measurements showed that when finished, there was with one ring a maximum difference of about 0.001 mm. in thickness between extremities of a diameter, and considerably less than this with the other. All the grinding was done wet, and though chatter marks due to vibration of the machine were never eliminated, still they were uniform and fine and the general surface had a surprisingly high polish (see pl. 2). Though the process here described was slow (it took, with the unavoidable interruptions, about a month to "finish" a ring), it proved capable of giving rings of sufficiently accurate figure for the purpose in hand.

MEASUREMENT OF THE RINGS.

As before stated, measurements of internal diameter and thickness were made only with ordinary micrometer gauges, care being taken about temperature disturbances, but for the determination of the external diameter a special comparator was constructed. A few words will sufficiently explain the points considered in its design (pl. 3). Since the general plan was to make contact settings on the ring, these to be directly compared with a line-standard meter, the essential features of the instrument are: A rigid end stop; accurate ways, on which slide two carriages, one (intermediate) carrying the ring (with its plane horizontal), the other a second end stop, and a microscope focused on the standard bar. The one carriage has a transverse slide carrying the ring, for the purpose of adjusting it so that its center is in line with the two stops. The support is furthermore so arranged that the ring can be rotated around a vertical axis through its center and perpendicular to its plane and to the ways (for testing "roundness"); and a vertical, linear motion along this axis is provided so the diameter may be measured at various points from face to face. The construction is such that to a sufficient degree of accuracy the plane of the ring is parallel to the ways and to the line of the contact points. The end stops are round steel rods, hardened and ground, two sets of actual contact surfaces being provided, plane and spherical (radius 4 inches). The practice was to have a spherical end abut against a plane face. There is a chance for a constant error to enter here, in case the contact pieces are not symmetrical with respect to the same axis, i. e., do not touch the ring and each other in the same way. Therefore some measurements were also made with two plane faces abutting against each other, and, since they agreed to within the limit of error with those made with one plane and one spherical surface, it was concluded that this constant error was negligible. In general, "touch" contact was used in bringing the ring against the fixed stop and electrical contact (single dry cell and volt-meter) in bringing the moving point against the ring and against the fixed stop. The electrical method is more delicate, but the other is quite satisfactory. During the observations the ring was protected quite thoroughly by asbestos and cotton, and its temperature was given by two thermometers resting directly on the upper surface.

Standard meter.—This was a new nickel-steel bar (H form), by the Geneva society, which had just been calibrated by the National Bureau of Standards, Washington; the corrections determined by them have been applied to all measurements. The temperature coefficient of the bar is so small that no very special precautions were necessary to control its temperature under the conditions of this work. In getting the final corrected value of the diameter, however, the proper correction was applied to reduce the bar interval for the temperature at which it was calibrated (15.9° C.) to the temperature of the measurements (23° C.); this involves a slight exterpolation of the temperature coefficient as given by the Bureau (for the interval 10° C. to 20° C.), but no serious error is in all probability introduced thereby. The observing microscope was of Geneva society construction, with micrometer eye-piece and objective illumination. The micrometer screw was, unfortunately, not a very good one, but by using a group of one-tenth mm. intervals, into which one millimeter space on the standard was divided, these being evaluated by careful comparison with each other and with a known millimeter, it was possible to avoid using any great interval of the screw, so that uncertainties from this source were very greatly reduced.

The measurements made with this comparator may be grouped as follows:

1. Measurement of various diameters to test the "roundness" of the ring. No variations as great as 0.001 mm. could with certainty be detected, and the rings were therefore considered *round*.

2. A series of measurements of a single diameter of the rings at several temperatures to determine the temperature coefficient. It was not possible to work over a very large range of temperatures, but the agreement of the results is quite satisfactory, as can be seen from figure 9. From figure 9 the uncorrected values of D_2 for the standard temperature (23° C.) have obtained, and in a similar way for D_1.

3. Measurements of diameters at various points between the two faces. Differences were here found in each ring ranging over about 0.01 mm., due undoubtedly to errors in the vertical guideways of the milling machine. The following figure 10 shows the distribution of these variations, the quantities plotted being differences in diameter and the corresponding position on the ring. A sufficiently exact allowance for these irregularities has been made, as follows:

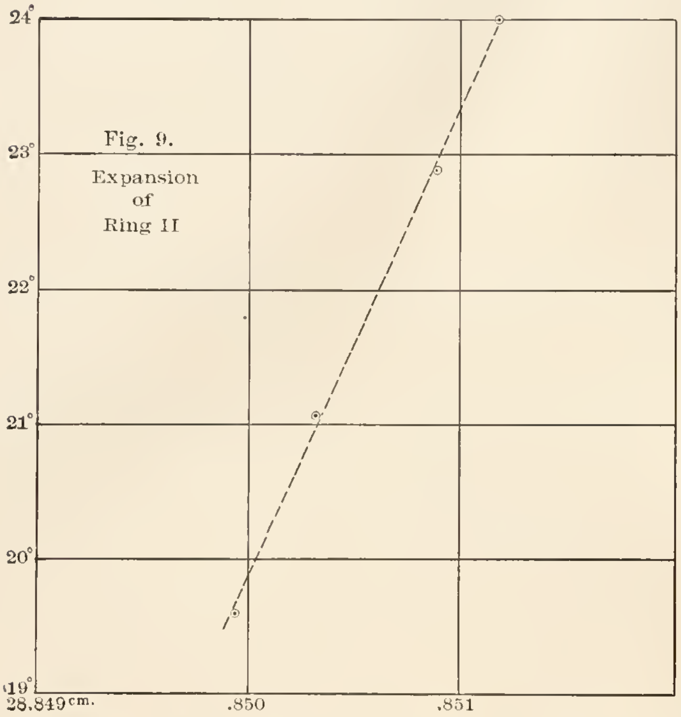


Fig. 9.
Expansion of Ring II

Consider the actual ring as made up of a perfect ring with a certain small mass, the irregular rim, added:

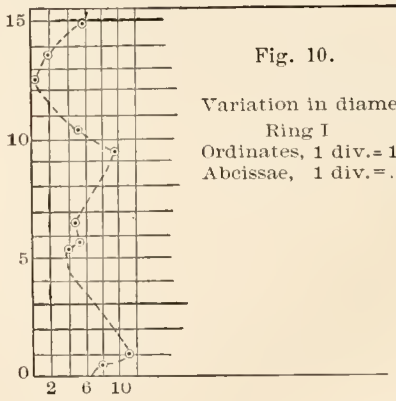


Fig. 10.

Variation in diameter
Ring I
Ordinates, 1 div. = 1 mm.
Abcissae, 1 div. = .002 mm

Let Δm = this small additional mass.
M = mass of actual ring.
R = minimum external radius of actual ring.
$K = R + \Delta R$ = radius of gyration of Δm about the center of ring.
$\Delta' R$ = an increment of R such that
$R + \Delta' R$ = radius of a perfect ring equal as to mass and moment of inertia to the real ring.

Then:

$$\text{moment of inertia of the actual ring} = \frac{2}{3}(M - \Delta m)R^2 + \Delta m K^2$$

$$= \frac{2}{3}MR^2 - \frac{2}{3}\Delta m R^2 + \Delta m R^2 + 2\Delta m R \Delta R$$

$$= \frac{2}{3}MR^2 + \frac{1}{3}\Delta m R^2.$$

[Neglecting terms of second order in Δm and ΔR.]

Hence, to determine $\Delta'R$, we have

$$\frac{2}{3}M(R+\Delta'R)^2=\frac{2}{3}MR^2+\frac{1}{3}\Delta m R^2$$

and—

$$\Delta'R=\frac{1}{4}\frac{\Delta m}{M}R$$

The ratio $\frac{\Delta m}{M}$ can be found by the aid of the graphical construction figure 10; in this way the corrections $\Delta'R_1$ and $\Delta'R_2$ have been found, which are to be added to the minimum values of R_1 and R_2 to give the effective radii of the rings.

In all the length measurements it was the custom to make five or more successive contacts and readings of the moving contact against fixed contact; the other carriage and ring would then be put on the ways, and five or more contacts and readings taken of ring against end stop and moving stop against ring; the ring would then be moved and another series of contacts taken of stop against stop. In case the primary object happened to be to measure *differences* in diameter, zero readings (stop against stop) would be less frequently taken.

MEASUREMENT OF THE PERIOD.

The pendulums were swung in a brass air-tight case (see figure 11 page 18) on an agate knife edge of 120° angle. This was given its final grinding and polishing by Mr. E. G. Fisher of the United States Coast and Geodetic Survey, whose kindness I am glad to acknowledge. A coincidence method was used for comparing the period of the pendulums with the beat of the standard mean solar clock of the Washburn Observatory, kindly made available by Prof. G. C. Comstock. The arrangement was as follows: on the flat face of the pendulum toward the observer were etched eight very fine radial lines about 3 mm. long, symmetrically distributed at intervals of 45°, and at about the distance (2 cm.) from the outer circumference where, as determined above, their effect on the period would be a minimum. Thus, while one line was immediately over the knife edge, the opposite one was vertically underneath and executing the longest possible linear arc of vibration. This line was observed with a telescope of considerable magnifying power, and was brilliantly illuminated for an instant once every two seconds. This was very simply brought about by the use of the flash apparatus belonging to one of the United States Coast and Geodetic Survey one-half second pendulum outfits, loaned through the courtesy of Superintendent Tittmann. The horizontal slit of the apparatus was periodically opened by the clock circuit, while on the slit was focussed the horizontal image of a Nernst glower, in such a manner that the beam afterwards fell upon the etched line on the ring. The linear amplitude at the beginning of a swing was from 8 to 9.5 mm., and at the end from 3 to 5 mm.; with the magnification used, the coincidence of the etched line with the cross wire of the telescope could be determined with ample accuracy. The times of coincidence were noted on a chronometer whose rate with respect to the clock was followed closely, and all intervals reduced to clock seconds. Finally, from observations for which I am indebted to Professor Comstock, the mean rate of the clock was determined and the corresponding correction applied. As the observations extended almost continuously over a period of more than two weeks, it is safe to say that diurnal variations of clock rate do not affect the result.

Further points to be considered in connection with the determination of T are—

1. Adjustment of the case and pendulum.
2. Temperature corrections.
3. Amplitude corrections.
4. Pressure corrections.
5. Corrections for vibration of the support.

1. The principal adjustments are to have the knife edge horizontal and the plane of the pendulum at right angles to it. The leveling of the edge was tested with a 5″ level supported on

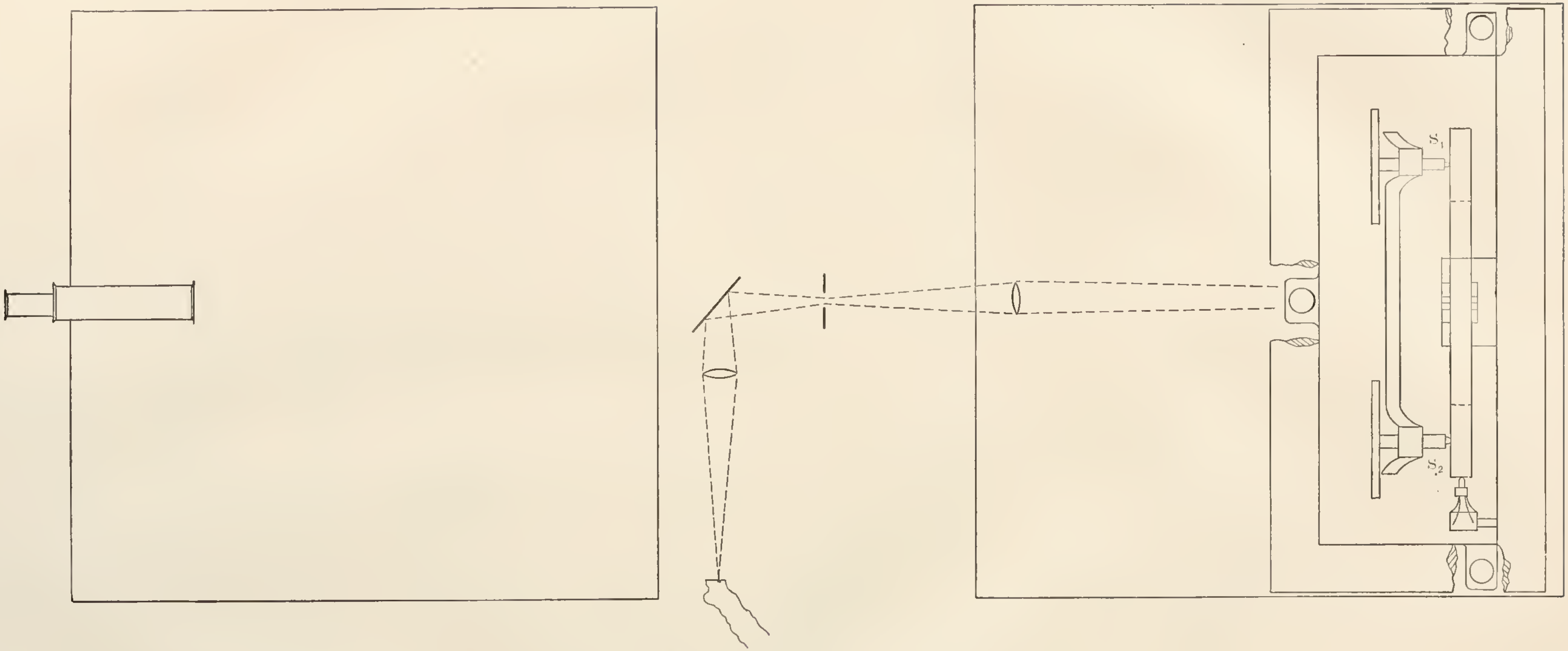


Fig. 11.—Plan of piers, pendulum case and scheme of illumination.

the knife edge and reversed. The azimuth adjustment was tested by means of a similar level, pivoted, and provided with a glass contact point which rested against the face of the ring over the knife edge (see fig. 12). Evidently if the ring is *not* at right angles to the knife edge, a rotation of it around the edge will result in a motion of the level bubble; and a simple calculation shows that this device with a 5″ level is more sensitive than is necessary to enable one to adjust to within the limits (± 8′) indicated as desirable in the discussion under theory. After the ring was adjusted two stop screws (S_1 S_1, fig. 11), rigidly fastened to an axis fixed to the bottom of the case, were swung into position and set until they made simultaneous contact with both sides of the ring. They served to locate permanently the correct plane, and the ring was always tested with respect to them before and after each swing.

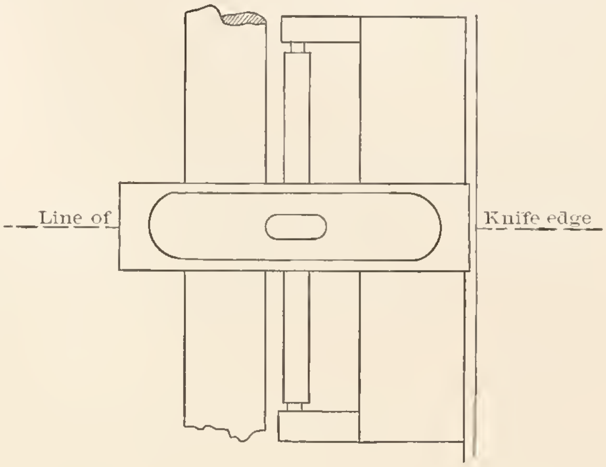


Fig. 12.

Mechanical arrangements were of course provided for lowering, raising, and starting the pendulum from outside the case, and these operated without at all displacing the ring from its proper position.

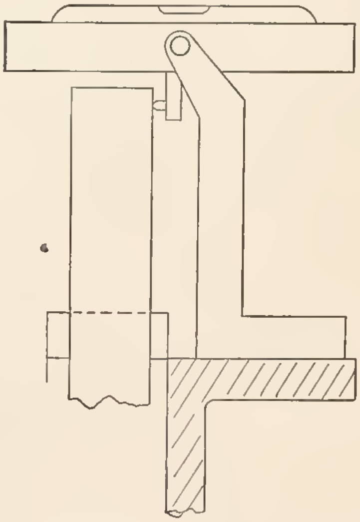
2. *Temperature correction.*—From the pendulum formula:

$$T^2 = KR$$

we find:

$$\Delta T = \frac{1}{2} \sigma \Delta\theta T$$

where σ is the coefficient of thermal expansion of the ring, and ΔT the small change in period produced by the small changes in temperature $\Delta\theta$. Using the measured coefficient of expansion for the two rings, the values of ΔT have been calculated. There were two thermometers in the pendulum case, one near the bottom of the ring, the other above the middle, and as they usually differed by less than 0.1° C., the mean (of their readings at the beginning and end of a swing) was taken as the temperature of the ring.



3. *Amplitude correction.*—At the beginning and end of each set of observations, the double amplitude was measured and the reduction to an infinitesimal arc obtained by graphical interpolation from the usual expression:

$$T_0 = T_a - \left[\frac{1}{64}(a_1 + a_2)^2 - \frac{1}{192}(a_1 - a_2)^2\right]$$

The initial half amplitudes were about 1° 12′ and the final averaged about 35′.

4. *Pressure correction.*—The average pressure inside the pendulum case during observations was about 1 cm. of mercury, at which pressure corrections for buoyancy and entrained air are negligible.

5. *Correction for the vibration of the support.*—The correction for the vibration of the knife-edge support was determined by the method of Schuman.[a] For this purpose the two rings were supported side by side on a steel knife edge, which took the place of the usual agate one. One pendulum, the "driving" one [Ring I] was given a vibration of about the usual amplitude, the other, the "driven," having been brought to rest with the greatest care; and the operation consisted in measuring the gradually diminishing amplitude of the driving pendulum and the gradually increasing amplitude of the driven one. The period of Ring I was first adjusted by means of small attached weights to agreement with that of Ring II to within $0^s.00002$, and it was so arranged that one of the etched lines on Ring II, and a fine wire attached to Ring I, could be simultaneously observed with a high power telescope, and the amplitude measured with a micrometer eyepiece. These amplitudes, measured at known intervals of time after the starting of Ring I, were found, when plotted, to be linear functions of the time. According to Schuman, if:

Ψ_1, Ψ_2 = amplitude of the driven pendulum at times t_1 and t_2,
Φ_1, Φ_2 = simultaneous amplitudes of the driving pendulum,
T = half-period of the pendulums,
α = apparent lengthening of the driving pendulum on account of the vibrations of the case,

we have

$$\alpha = \frac{\left[\frac{\Psi_2}{\Phi_2} - \frac{\Psi_1}{\Phi_1}\right] 2g \left[\frac{\mathrm{T}}{\pi}\right]^3}{t_2 - t_1}$$

The values of Ψ and Φ were determined at an interval $t_2 - t_1 = 240^s$, by graphic interpolation from the direct observations, and the following computed values of α obtained:

cm.
1. Top of pendulum case off. . . $\alpha = 0.00063$
2. Top of pendulum case off. . . $\alpha = 0.00065$
3. Top of pendulum case on. . . $\alpha = 0.00074$
4. Top of pendulum case on. . . $\alpha = 0.000756$

To determine the corresponding change in period, we have, if—

T = observed period
T′ = corrected period

$$\mathrm{T} = 2\pi\sqrt{\frac{l+\alpha}{g}} = \mathrm{T}' + \frac{\pi^2}{g}\frac{1}{\mathrm{T}}\alpha$$
$$= \mathrm{T}' + 0.02\alpha.$$

Hence, using the mean value of α with "top on" it is found that:

$$\Delta\mathrm{T}_{\mathrm{I}} = 0^s.0000150$$

To determine the corresponding correction for Ring II, β, we can write, according to Schumann,

$$\beta = \alpha \frac{m_{\mathrm{II}} s_{\mathrm{II}} \mathrm{T}_{\mathrm{II}} \varepsilon_{\mathrm{II}}}{m_{\mathrm{I}} s_{\mathrm{I}} \mathrm{T}_{\mathrm{I}} \varepsilon_{\mathrm{I}}}$$

where

$m_{\mathrm{I}}, m_{\mathrm{II}}$ = masses of pendulums.
$s_{\mathrm{I}}, s_{\mathrm{II}}$ = distances of center of gravity from point of support.
$\mathrm{T}_{\mathrm{I}}, \mathrm{T}_{\mathrm{II}}$ = periods.
$\varepsilon_{\mathrm{I}}, \varepsilon_{\mathrm{II}}$ = constants which depend on the form of the pendulums and the support.

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[a] Schumann, Zeits. f. Math. und Physik. 44 Jahrgang, pp. 124 to 126.

In the present case it will be safe to assume:

$$\frac{s_{II}}{s_I}=\frac{T_{II}}{T_I}=\frac{\varepsilon_{II}}{\varepsilon_I}=1$$

and

$$\frac{m_{II}}{m_I}=\text{ratio of thicknesses,}$$

$$=\frac{14.2}{15.4}$$

So that

$$\Delta T_{II}=0^s.0000136.$$

For the determination of T the pendulums were allowed to vibrate uninterruptedly for from six to nine hours, according to circumstances, a few coincidences being noted at the beginning and end of this period, from which the coincidence interval and the period could be calculated in the usual way. Each ring was vibrated in eight different "positions," that is, with the knife edge bearing on eight different elements of the internal surface, corresponding to the eight etched lines above referred to. The following tables summarize all the determinations of T for both rings, together with the corrections and reductions.

RING I.—*Maximum variations of opposites about 0.000046.*

[Radius=$14^{cm}.409044$. Thickness=$15^{mm}.40$.]

Date.	Position.	Mean amplitude.	Pressure.	Duration of swing.	Temperature.	Weight.	Observed T.	Reduced to 23° C.	Reduced to infinites. arc.	Mean for each position.	Mean of opposites.	Mean of all positions.	Corrected for clock rate.
		mm.	*mm.*	*h. m. s.*									
July 16 ..	1	6.20	11.5	5 26 28	23.15	1	1.002508	2507	2504	2507	2493	1.002483	1.002432
July 19 ..	1	6.70	9.0	8 44 00	23.80	1	2518	2513	2509	--------	--------	--------	--------
July 16 ..	2	7.00	20.0	4 11 00	23.45	1	2525	2523	2519	2507	2483	--------	--------
July 19 ..	2	7.50	3.5	5 33 00	23.70	1	2502	2499	2496	--------	--------	--------	--------
July 25 ..	2	5.30	12.0	9 53 00	23.13	2	2509	2509	2496	--------	--------	--------	--------
July 17 ..	3	7.00	11.0	8 15 00	23.10	2	2515	2515	2511	2502	2479	--------	--------
July 19 ..	3	9.80	7.0	4 29 46	23.60	1	2539	2536	2527	--------	--------	--------	--------
July 20 ..	3	5.40	8.0	9 59 00	23.30	2	2508	2506	2504	--------	--------	--------	--------
July 23 ..	3	6.05	10.0	9 44 00	22.70	2	2493	2493	2492	--------	--------	--------	--------
July 24 ..	3	5.90	10.0	9 16 00	23.10	2	2491	2490	2488	--------	--------	--------	--------
July 17 ..	4	7.10	10.0	3 56 00	23.30	2	2476	2474	2470	2476	2479	--------	--------
July 20 ..	4	5.30	00.0	9 42 12	27.90	1	2496	2496	2495	--------	--------	--------	--------
July 21 ..	4	6.20	7.0	5 33 00	23.20	2	2457	2456	2453	--------	--------	--------	--------
July 25 ..	4	6.50	8.0	7 03 00	22.50	3	2485	2488	2485	--------	--------	--------	--------
July 25 ..	4	3.70	11.0	4 03 00	22.50	2	2473	2476	2475	--------	--------	--------	--------
July 17 ..	5	6.50	10.0	6 31 00	23.65	1	2476	2473	2470	2480	--------	--------	--------
July 21 ..	5	5.50	10.0	9 50 00	23.10	1	2491	2491	2489	--------	--------	--------	--------
July 18 ..	6	5.90	10.0	9 53 00	23.40	1	2474	2472	2470	2460	--------	--------	--------
July 22 ..	6	5.70	24.0	10 06 00	23.20	1	2453	2451	2450	--------	--------	--------	--------
July 18 ..	7	6.50	8.0	6 35 00	23.60	2	2449	2446	2445	2456	--------	--------	--------
July 22 ..	7	5.70	8.0	9 49 00	23.05	3	2466	2466	2464	--------	--------	--------	--------
July 18 ..	8	6.50	8.0	6 31 00	23.80	......	2474	2469	2466	2483	--------	--------	--------
July 23 ..	8	6.30	8.0	8 37 00	22.85	......	2501	2502	2499	--------	--------	--------	--------

Final corrected period=$1^s.0024165$.

RING II.—*Maximum difference* $(T_6-T_2)=0.000275$.

[Radius$=14^{cm}.42580$; thickness$=14^{mm}.21$.]

Position.	Mean amplitude.	Pressure.	Duration of swing.	Temperature.	Observed period.	Reduced to 23° C.	Reduced to infinites. arc.	Mean for each position.	Mean of opposites.	Mean of all positions.	Corrected for clock rate.
	mm.	*mm.*	*h. m. s.*								
1	6.0	9.0	9 9 43	22.70	1.002979	2981	2979	2972	3068	....	....
1	7.0	1.2	4 13 00	22.50	2966	2969	2965	....	....	1.003071	1.003020
2	6.5	8.0	6 32 00	22.20	2941	2946	2943	2943	3080	....	....
3	6.5	10.0	9 28 00	22.70	2972	2974	2971	2959	3067	....	....
3	6.0	13.0	6 48 00	22.70	2947	2949	2947	....	....	....	....
4	6.0	8.0	7 25 00	22.30	3083	3037	3035	3035	3071	....	....
5	5.6	9.0	9 24 00	22.30	3163	3167	3165	3165	....	....	....
6	6.5	8.0	4 30 00	22.60	3219	3221	3218	3218	....	....	....
7	7.0	8.0	4 11 00	23.00	3187	3187	3183	3176	....	....	....
7	6.6	10.0	6 35 00	33.20	3173	3172	3169	....	....	....	....
8	6.2	10.0	11 07 00	22.45	3106	3109	3107	3107	....	....	....

Final corrected period$=1^s.0030069$.

The first thing to be noticed is the much greater variation of T for different positions, in the case of Ring II than Ring I; for Ring II the range being $0^s.000275$, and for Ring I, $0^s.00005$, the latter being of the same order of magnitude as the accidental variations between individual determinations at the same point. In both cases the variation with position is quite regular, a minimum T on one side corresponding to a maximum at the opposite point, with intermediate values between as would be expected; and it is very noticeable that the means of the periods for diametrically opposite points agree almost as well for Ring II as for Ring I. The large variations for Ring II were quite unexpected, for its behavior in the course of construction had not suggested that there was any great difference in the material at different points; and it would seem probable that a difference in density which would produce the observed differences in period would result in a difference in hardness or texture which the grinding wheel would be sensitive to detect. The existence of actual flaws or crevices is unlikely, since the ring was originally forged. Errors of figure which would produce these variations of period are:

(1) Eccentricity of inner and outer circumferences.

(2) Ellipticity.

(3) Nonparallelism of faces.

It is certain that neither (1) nor (2) is present in sufficient magnitude to produce the observed effects; (2) would have been detected by the direct measurements and (1) would have shown in grinding.

As before stated, the faces of Ring II were slightly out of parallel, the maximum difference in thickness being less than $0^{mm}.001$; whereas, it was shown above that a difference of $0^{mm}.01$ would produce only about one-quarter of the maximum observed difference in period, and would be equivalent to a regular change in density in which the maximum variation in density was one one-thousandth of the mean density, i. e., $\frac{\Delta\rho}{\rho}=0.001$. One is apparently forced to the conclusion that Ring II is nonhomogeneous and that the ratio $\frac{\Delta\rho}{\rho}$ is, perhaps, 0.004. It should be added that the ring was examined with a flip coil and a ballistic galvanometer, but no magnetization was detected.

The calculation of the effect of a special case of nonuniform density (see p. 10 above) showed that though the maximum difference of period for different positions might be considerable, the mean period would differ by less than a tenth of this amount from the period of the corresponding perfect ring; and also showed that (for the special case considered) the particular pair of diametrically opposite periods (so to speak) which are equal to each other are, to a close approximation, equal to the period of a perfect ring. However, without knowing more about the real cause of the irregularities in Ring II, it is impossible to draw any conclusions as to the magnitude or even the sign of the correction which should be applied to the observed period, and the best that can be done is to take the mean.

To determine g we have then the following corrected values:

$$R_1 = 14.409044$$
$$T_1 = 1.0024165$$
$$R_2 = 14.42580$$
$$T_2 = 1.0030069$$

From these

$$g\ (1) = 980.526$$
$$g\ (2) = 980.511$$

Considering the irregular behavior of Ring II these values are in very satisfactory agreement.

The results of this work can be taken, it is hoped, both as throwing light on the reliability and practicability of the method and as furnishing a new absolute determination of g, though in order to compare the value here found with previous results, either the ring pendulum must be swung in Washington or a relative determination made between there and Madison. It is believed, however, that the work demonstrates:

(1) The possibility of making glass-hard rings of steel of sufficiently accurate figure for the purpose.

(2) That some rings show a very satisfactory uniformity of period for different positions.

(3) That even where considerable asymmetry exists the mean period corresponds very closely to the period of the corresponding perfect ring.

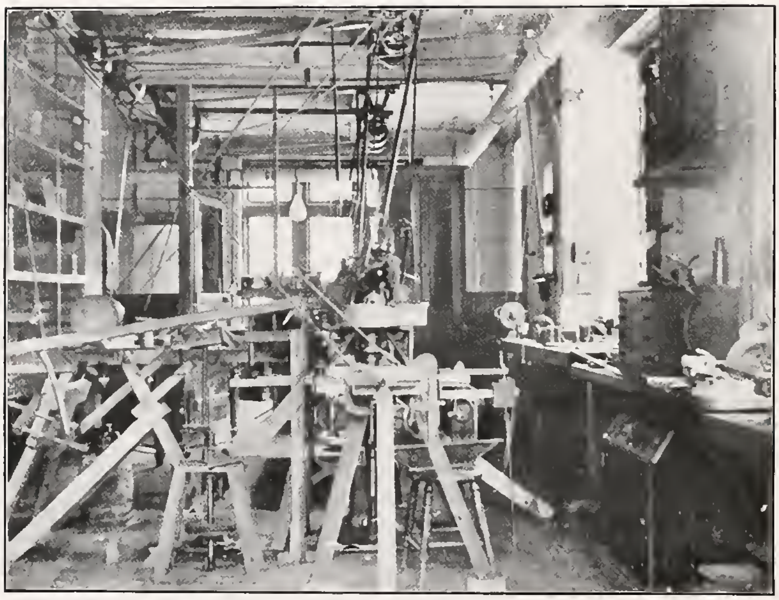
(4) That different rings will yield extremely concordent results.

(5) Finally, that with rings prepared with the degree of precision which has been attained, the method will be valuable as a check upon determinations of gravity made by methods hitherto in use.

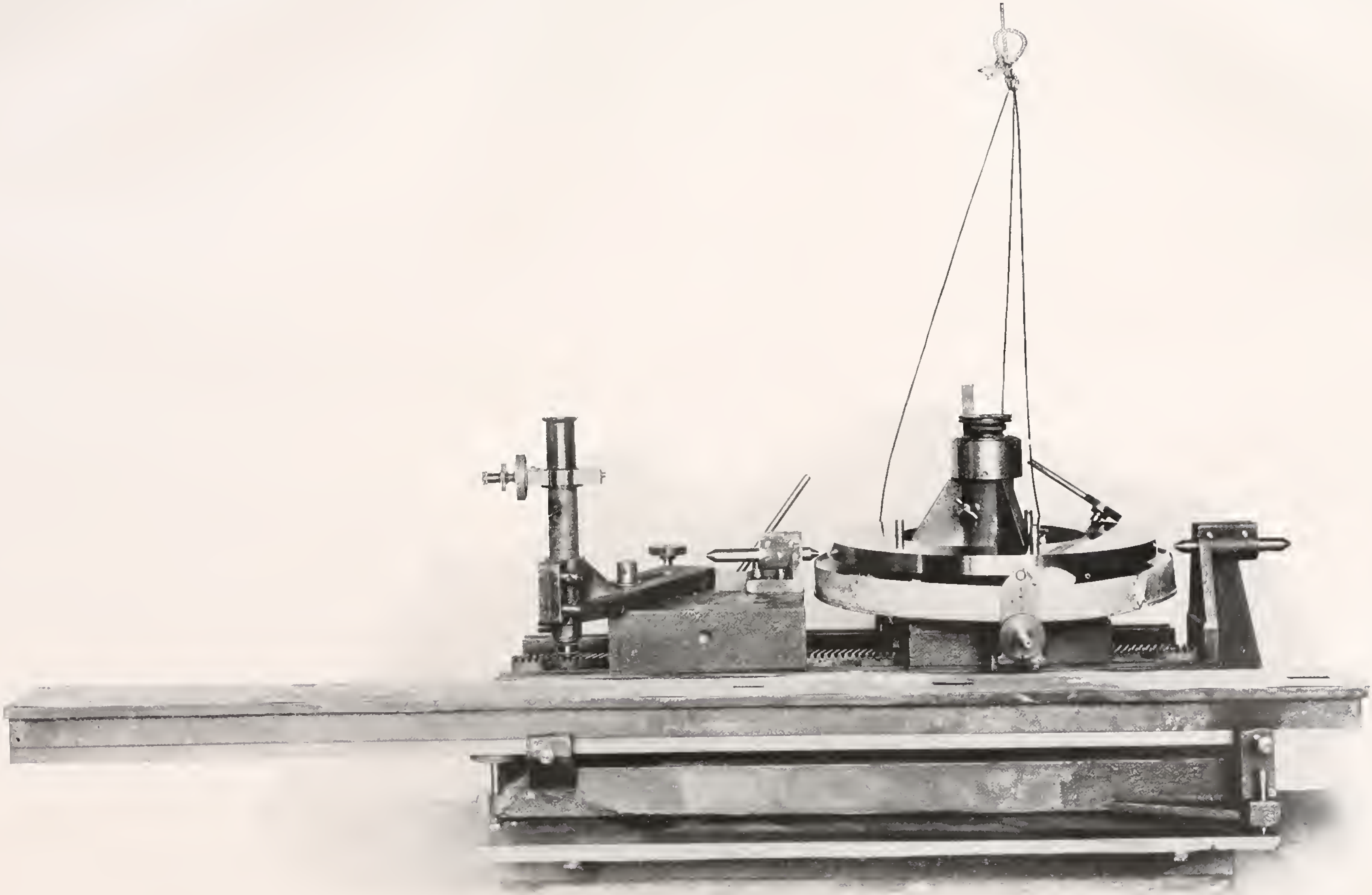
In conclusion, I wish to acknowledge my indebtedness to the University of Wisconsin for the facilities accorded for the work, and to Mr. H. G. Fisher, mechanician of the department of physics, for faithful and painstaking assistance in the construction of most of the apparatus.

August, 1904.

FINISHED STEEL RING.



MILLING MACHINE ARRANGED FOR GRINDING.



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CLAYTONIA GRONOV.

A MORPHOLOGICAL AND ANATOMICAL STUDY.

BY

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CLAYTONIA GRONOV. A MORPHOLOGICAL AND ANATOMICAL STUDY.

By Theo. Holm.

(With plates 1 and 2.)

I. CLAYTONIA AS A GENUS.

A glance at the literature and a consideration of the species themselves must necessarily convince even the most critical systematist that *Claytonia*, as heretofore defined, can not possibly be confounded with *Montia*, nor *Montia* with *Claytonia*. They both have been excellently described and seemingly well understood now for at least a century and a half.

Sometimes the accumulation of new material with additional new species may alter the views of the systematist in regard to the proper limitation of some genus, but this has not been the case with *Claytonia*. From the skillful treatment of such eminent systematists as Fenzl and Gray, the genus has been received and explained as it always was, and has, of course, been kept separate from the monotypic *Montia*. Though by no means a large genus, indeed rather a small one, *Claytonia* represents an assemblage of species of marked variation in habit but with the floral structure principally the same. As classified by Gray,[a] the species are divided into five sections based upon characters derived from the vegetative organs mainly: *Euclaytonia*, the large-rooted *C. megarrhiza*, *C. Virginica*, etc.; *Limnia*, the fibrous-rooted annual or perennial *C. Sibirica*, *C. perfoliata*, etc.; *Alsinastrum*, the stoloniferous *C. Chamissonis*; *Naiocrene*, the bulbiferous *C. parvifolia*, and finally *Montiastrum*, the leafy-stemmed and alternate-leaved annuals *C. diffusa* and *C. linearis*, of which the latter is, furthermore, distinct by the flowers having the petals obviously unequal, but unguiculate as in the other species, and by the number of stamens being sometimes reduced to only three.

While thus the vegetative organs exhibit a very pronounced variation in *Claytonia*, the floral structure appears essentially the same. The position of the calyx leaves is the same in all the species enumerated by Gray, the anterior covering the posterior. The petals are always prominently unguiculate and more or less coherent at the very base; their relative length may be somewhat different within the same flower, as noticed in *C. linearis*. The stamens, normally five, are inserted near the base of the petals, and finally the ovary is ovoid, bearing a long style with three short branches, papillose only on their inner surface. It will be seen from this that the flower of *Claytonia* throughout the genus—from *Euclaytonia* to *Montiastrum*, inclusive—shows the same diagram, and that the modification sometimes observable in the relative size of the petals and in the number of stamens does not disturb the primary arrangement of the individual parts of the flower.

It is now surprising to see that, notwithstanding such uniformity in floral structure, *Claytonia* has in late years[b] been divided and a number of its species been referred to *Montia*, with which they have nothing in common. Here again the literature and a renewed examination of *Montia* would have shown what *Montia* is and how correctly it was described and understood by Linnæus. Let us then recapitulate some of the most essential points in the flower by which the monotypic *Montia* differs from "all the other genera of the order *Portulacaceæ*." The exactly opposite

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[a] Proceed. Am. Acad., New Ser., Vol. 14, 1887, p. 278.

[b] Synoptical Flora of North America, Vol. I, 1895–97, p. 272.

arrangement of the calyx leaves, the posterior of these covering the anterior;[a] the somewhat zygomorphic, gamopetalous corolla with the three stamens inserted at the apex of the corolla tube; the turbinate ovary with a minute style and three long, subplumose stigmata. Having advanced these brief remarks upon the generic characters of *Claytonia* and *Montia*, we might now proceed to describe some morphological and anatomical points in *Claytonia*, and, of course, we receive the genus in the same way as it was understood before and outlined so well in the works of Gray, Fenzl, Jussieu, Bentham and Hooker, Engler and Prantl, etc.

II. THE INFLORESCENCE.

The aerial stems are in *Claytonia* nearly always terminated by an inflorescence, usually preceded by one pair of opposite leaves, which by Wydler and Eichler have been defined as foreleaves; the flowers themselves are mostly destitute of such foreleaves, but there are species in which one of these, the fertile, is readily visible as a minute bract, especially in the lower portion of the inflorescence. Frequently the foreleaves are the only leaves of the aerial stems, but in some few species the stems are quite leafy from the base to the inflorescence in *C. Chamissonis* Esch., where the leaves are opposite, while in *C. linearis* Dougl. and *C. parvifolia* Moc. they are alternate.

In regard to the inflorescence, this is of the cymose type, but seems never to be regularly or completely developed in our genus. It sometimes begins as a very regular cyme, but the lateral ramifications soon turn to monochasia of the type cicinnus or scorpioid cyme, as described by Wydler[b]. Most complete is the cyme perhaps in *C. Sibirica* L.; the stem is terminated by a flower, and a lateral inflorescence is developed in the axil of each of the two prophylla. The one of these lateral inflorescences may continue this regular cymose ramification at least at intervals, while the other, usually very soon, turns to a monochasium; nearly all the flowers are in this species provided with one of the two foreleaves (the fertile), but they are relatively small, especially in the monochasia. A like composition of the inflorescence may also be observed in *C. sarmentosa* Mey., but in most of the specimens examined of this species a few-flowered scorpioid cyme seemed to be the typical. In large specimens of *C. linearis* Dougl., the inflorescence begins as a cyme, but the lateral branches become immediately leafless monochasia of the same type as described above; in small specimens, on the other hand, only one prophyllon is developed, and the inflorescence consists only of one or four flowers representing a true monochasium.

Partly a true cyme and partly a scorpioid cyme is the inflorescence of *C. megarrhiza* Parry and *C. arctica* Adams; an apparently regular cyme is to be found in *C. Chamissonis*, Esch., at least in the lower portion, but while the one lateral branch becomes a four or five flowered leafless monochasium, the other most frequently develops as a long vegetative shoot. In the other species which we have examined a scorpioid cyme is the only kind of inflorescence represented, mostly with the secondary prophylla entirely suppressed, as in *C. Virginica* L., *C. Caroliniana* Michx., *C. asarifolia* Bong., *C. parviflora* Dougl., *C. lanceolata* Pursh, *C. gypsophiloides* Fisch. et Mey., *C. spathulata* Dougl., and *C. arenicola* Hend.; the last species possesses long, many-flowered monochasia in which all the flowers are provided with a prophyllon. In *C. parvifolia* Moc. the inflorescence has only very few flowers, since the one of the two lateral branches, as it seems, constantly develops into a vegetative shoot; this species is, furthermore, peculiar by the two opposite prophylla being developed only as minute, hyaline, and scale-like leaves, besides that the numerous stem leaves subtend small bulblets, which are said to fall off and to develop new individuals.

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[a] Almquist S. Om blomdiagrammet hos *Montia* (Botan. Notiser 1884: 156, and Botan. Centralbl. 21:91. 1885). The fruit and the seeds in *Montia*, as well as the mechanism by which the seeds are ejected, is carefully described by Professor Urban (Jahrb. bot. Garten Berlin 4:256, 1886).

[b] Flora, 1851: 348.

III. THE MORPHOLOGICAL STRUCTURE OF THE SHOOT.

The primary shoot represents a monopodium in nearly all the species. The main axis bears in these only leaves, which are always green and developed as proper leaves; it is from the axils of these that the flower-bearing stems develop in the first year, when the species is an annual, but much later if it is a perennial. A rhizome is often developed and in a very different manner, which depends not only upon the structure of the rhizome itself, but also upon the structure of the root system. The species of *Claytonia* exhibit altogether a striking diversity as far as concerns their mode of growth, and it is strange to see how differently certain species behave in this respect, although they are otherwise to be considered as near allies. A classification of the species from a biological view point must, therefore, result in the separation of related types, at least in some instances.

These biological types may be arranged as follows:

1. ANNUALS.

A.—The shoot is terminated by an inflorescence (*C. linearis* Dougl., *C. diffusa* Nutt., *C. dichotoma* Nutt.).

B.—The apex of the shoot is vegetative, represented by a rosette of leaves (*C. Sibirica* L., *C. arenicola* Hend., *C. perfoliata* Dow., *C. parviflora* Dougl., *C. gypsophiloides* Fisch. et Mey., *C. spathulata* Dougl.).

2. PERENNIALS.

C.—As B, but with a fleshy, horizontal rhizome and filiform secondary roots (*C. asarifolia* Bong.).

D.—As C, but the rhizome is very short and slender, and bulblets are developed in the axils of the stem leaves. (*C. parvifolia* Moc.).

E.—Monopodial, as those above (from B to D inclusive), but the rhizome is erect and short with a very large root, the primary (*C. Virginica* L., *C. Caroliniana* Michx., *C. lanceolata* Pursh, *C. megarrhiza* Parry, *C. arctica* Adams).

F.—Monopodial, with stolons above ground and slender root (*C. sarmentosa* Mey.).

G.—Not monopodial, with filiform roots and stolons underground, often terminated by bulblets. (*C. Chamissonis* Esch.).

Seven well-marked biological types are thus characteristic of these eighteen species of *Claytonia*. Let us examine these a little further.

Among the annuals, *C. linearis* Dougl., *C. diffusa* Nutt., and *C. dichotoma* Nutt., it appears as if the primary axis becomes continued into an inflorescence. We use the expression "appears" since the material which we have examined was not quite sufficient or satisfactory for this purpose; moreover, only dried specimens were at our disposal. The larger specimens were profusely branched in the first of these species, and the true ramification could not be made out beyond that the leaves were all alternate and that there was no trace of any basal rosette, so very distinct and readily observable in all the other annuals of the section B. In some small specimens the cotyledons were still preserved, and they were linear and above ground. Only two inflorescences were developed in these specimens, and from the same height, and either were both axillary and pertaining to the cotyledons, or the one was axillary and the other one terminal. The latter explanation seems to be the more probable, inasmuch as there was no evidence of any rudimentary terminal bud. However, a renewed examination of fresh material may prove the opposite.

All the other annuals which we have examined possessed a rosette of leaves from the axils of which the flower-bearing stems had developed. The primary root is long and slender. *Claytonia Sibirica* L. belongs to this category, but it appears as if this species also occurs as perennial, judging from a note in Gray's paper cited above. This author states that it is "a pure annual when it grows in exsiccated soil, but when better nourished it is more enduring and bears offsets on stout stolons from the crown, and so, in the absence of much winter's cold, its life is continued and extended from year to year." We have not been able to secure any material that showed such modification, but it is interesting to know that a perennial form does exist of this species, and that it is stoloniferous; in certain other genera and of remote orders similar perennial and stoloniferous specimens have been recorded of species that are otherwise typically annual.[a]

The next large group (2) comprises such species as are typically perennial, and the first of these, *C. asarifolia* Bong., possesses a horizontally creeping and quite fleshy rhizome, the apex of which bears a number of large leaves with axillary inflorescences. The primary root has vanished and is replaced by many filiform secondary ones, which proceed from the very short internodes of the rhizome. A like but much more slender rhizome is developed in *C. parvifolia* Moc., a species that is very characteristic by its alternate stem leaves and by the presence of bulblets in the axils of these. The bulblets resemble very much those of *Dentaria bulbifera*, *Saxifraga cernua*, etc. (Pl. 1, fig. 1.) We now pass to section E, in which the rhizome is vertical and very short, but in which the primary root sometimes attains an enormous development. To here belong *C. megarrhiza* Parry, *C. Virginica* L, and their allies. Of these the former is the most remarkable of the genus. The very small seedling (Pl. 1, fig. 2) has the cotyledons raised above ground by a short but very distinct hypocotyl (H in fig. 2); the primary root (R) is long and very slender with a few ramifications, densely covered with root hairs. At this stage two leaves, succeeding the cotyledons, are already visible, and the plant is now ready to meet the first winter. The first sign of change in the equipment of this little plant is the loss of the cotyledons; thereupon follows a gradual wrinkling of the hypocotyl, by which the apical bud becomes pulled down beneath the surface of the ground, and the root continues its growth vertically and to a very considerable depth. In the following spring the leaves develop and form soon a small rosette, while the hypocotyl and the basal portion of the root has commenced to increase in thickness; lateral, slender roots become also developed. (Pl. 1, fig. 3.) How soon the flowering begins we do not know, but it is very likely that it takes the plant three or four years before it produces flowers.

In fully matured specimens the leafy rosette is very large, the hypocotyl still visible as a cylindric, thick, and prominently wrinkled body above a long, very fleshy, and thick root, the primary; the lateral roots persist also and increase quite considerably in thickness, but not to such an extent as the main root (Pl. 1, fig. 4). If we lay a longitudinal section through the rosette and the hypocotyl, we notice at once a number of small, young inflorescences and leaves ready to push out during next spring. These inflorescences are stalked and erect, and the young flowers are covered by the (fore) leaves. The hypocotyl persists during the whole life of the plant, and constitutes a portion of the wrinkled crown above the root. Characteristic of *C. megarrhiza* and *arctica* is, thus, the continuous growth in length and thickness of the primary root, besides the overwintering of the leaves and inflorescences.

It is now interesting to study the morphological structure of *C. Virginica* L., which no doubt is a near ally of *C. megarrhiza*; biologically, however, they are very distinct. Let us state at once that *C. Virginica* does agree with *C. megarrhiza* as far as concerns the monopodial shoot and the persisting primary root, though not the entire root. The development of the plant is as follows:

As already described by Gronovius,[b] "Monocotyledonum instar protrudit unicum foliolum." and so is the only sign of the seedling above ground a single leaf with a small blade borne on a long, filiform petiole (Pl. 2, figs. 10 and 12). This leaf is borne upon a small tuberous body underground, which terminates into a long, filiform root (R in fig. 10) with a few ramifications and densely clothed with hairs. An anatomical study of the tuberous body shows at once that this is also a part of the root, and no hypocotyl is thus developed. The base of the petiole closely surrounds a minute leaf (*l'* in fig. 11), which sometimes develops during the first season (*l'* in fig. 13), and this leaf resembles the proper leaves of the full-grown plant. During the first season the base of the root increases rapidly in thickness, while the slender portion dies off and no trace of this is to be found in the following spring. The development of leaves continues at the same time as the root grows in thickness, forming a more or less globular body with many

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[a] The author: On the vitality of some annual plants. (Am. Journ. of Sci., vol. 42, 1891, p. 304.

[b] Flora Virginica, Pars. I, 1743, p. 25.

superficial, transverse wrinkles (Pl. 2, fig. 15), and with several long roots developing in small tufts from the sides. Some three or four years elapse before the flowers appear, and the fact that the floral stems are not preceded by a leafy rosette, as in the former species, makes it somewhat difficult to appreciate that the stems are actually axillary and that the shoot represents a monopodium. But if we examine the apex of the tuberous body—the root—we readily notice that the center is occupied by minute leaves and inflorescences, the position of which answers that of a monopodium and also that of a shoot of *C. megarrhiza*, with the exception that the leaves do not winter over in *C. Virginica*. In this way these two species show a marked distinction in respect to the persistence of the entire root and the overwintering of the leaves in *C. megarrhiza* in contrast to the reduction of the root and the early fading away of the leaves in *C. Virginica*.

Judging from the appearance of the vegetative organs in *C. Caroliniana* and *C. lanceolata*, these two species show evidently the same course of development as we have observed in *C. Virginica;* but they ought to be studied.

The last perennial and monopodial species is *C. sarmentosa* Mey. (Pl. 1, figs. 5 and 6). This is nearest related to *C. megarrhiza* with which it has in common a long, perennial root, persisting in its entire length, and an overwintering rosette of leaves. But it differs, and very prominently so, by the main root being quite slender, by the leaf-bases being somewhat swollen, and by its ability to wander by means of stolons above ground, developed from the axils of the leaves, in our specimens of leaves from the previous year. The stolons consist either of one single internode terminated by a rosette of leaves (fig. 5), or they bear several long-petioled leaves with stretched internodes, preceding the terminal, vegetative bud (fig. 6). Secondary roots develop from the internodes of these stolons (*r* in figs. 5–6).

The successive development of inflorescences and leaves is, however, identical with that of *C. megarrhiza* and *C. Virginica*. We have thus in *C. sarmentosa* a truly stoloniferous species, yet with the primary root persisting as in the other species, and with the shoot being monopodial. Furthermore the monopodial structure of the primary axis becomes repeated in the axillary branches, the stolons.

These species, described above, represent then several types of rhizomes, but only a few of these are stoloniferous, and the plants show but a very limited ability to wander, for instance, *C. asarifolia* by its creeping rootstock, *C. sarmentosa* by its stolons, and *C. parvifolia* by its deciduous bulblets. We now pass to describe the vegetative propagation of *C. Chamissonis*, which in this particular respect appears to be the best equipped of all the members of the genus. Besides propagating by seeds, this species gives, also, an excellent illustration of a stoloniferous and bulbiferous plant. Our figure 7 on Pl. 1 shows a small specimen, the smallest we could find in order to represent the plant with its rhizome in natural size; nevertheless, it is perfectly sufficient for giving an idea of the mode of growth.

A flower-bearing shoot has developed from a bulb, and the stem above ground is terminated by a two-flowered inflorescence, preceded as usual by a pair of opposite leaves; but in contradistinction to most of the other *Claytoniæ*, the aerial stem is leafy from the base to the flowers, and all the leaves are opposite, including those of the subterranean stolons and bulbs. The root system is poorly developed, there being only some filiform, almost unbranched roots proceeding from the minute internodes of the bulb, from which the shoot has developed. Long and slender stolons with small, opposite, scale-like leaves are visible in the axils of the bulb scales and of one of the lowermost leaves of the stem; these stolons, which are often branched, are either terminated by a small, pointed bud or by an ovoid bulb with thick, fleshy scales of a crimson color. Both forms of stolons are underground, and they both send up an aerial shoot in the coming year. This kind of propagation takes place at a very early stage, already in the first year when the seed has germinated. Such seedlings show, thus, a pair of small, hairy cotyledons above ground, from the axils of which stolons develop. The immediate direction of these stolons was, however, vertical instead of horizontal, since they were developed in some distance above the surface of the ground, the cotyledons being epigeic, as described above; the primary root is quite long, but very thin and slightly ramified; its duration does not exceed one season, since the floral shoots always die off after the ripening of the seeds while the stolons and the bulbs winter over.

The structure of the seedling showed very plainly that the shoot is not monopodial but that it is terminated by an inflorescence, as in the specimens that had developed from stolons, as figured and described in the preceding.

If we now compare Gray's systematic classification of the species with our table, based upon the structure of the shoot alone, it is evident that certain species, otherwise closely related, have become separated from each other and referred to distinct sections, in some instances to sections of their own—monotypic. The members of *Euclaytonia* have been divided, and both *C. sarmentosa* and *C. asarifolia* appear to be distinct from these and distinct among themselves. *Limnia*, on the other hand, stays unchanged, and so do the monotypic *Alsinastrum* and *Naiocrene*, besides *Montiastrum*. So, after all, the systematic classification compares fairly well with our arrangement of the species, and of the two the former is, no doubt, the most natural, even if some of the species may represent very distinct biological types.

Nevertheless, several analogies exist by which these types pass over into each other, and by which the genus becomes actually quite definite and naturally outlined. Not speaking of the uniformity in floral structure observed in all the species, the shoot itself, with its branches and root system, does also show some degree of uniformity, at least in a general way. The inflorescence is of the cymose type throughout the genus; the monopodial structure is common to nearly all the species, annuals as well as perennials; the primary root stays as a more or less typical taproot in most of the species; finally, the tendency of developing bulblets is well expressed in some of these plants.

IV. THE ANATOMICAL STRUCTURE OF THE VEGETATIVE ORGANS.

While dried and pressed material may be sufficient to the study of a part of the morphological structure, it is seldom of much use for anatomical purpose, especially not when the plants are more or less succulent, as in the present genus. We therefore regret that our material preserved in alcohol only consists of a few species, collected from time to time; but whatever importance may be attached to the result of our investigation, a brief sketch of the anatomical peculiarities of some of these species may serve, at least, as a modest contribution to the knowledge of these plants heretofore but little known from this particular point of view.

THE ROOT.

The somewhat modified structure of the roots in certain species necessitates the treatment of these to themselves. We may begin with *C. megarrhiza*. In this the ultimate ramifications of the lateral roots are the only ones wherein the primary arrangement of the tissues is still preserved and of which the structure is identical with that of a normal root. We notice here a hairy epidermis, covering a hypoderm of very wide cells, inside of which there is a cortical parenchyma, consisting of only two layers, the innermost differentiated as a thin-walled endodermis. The pericambium is similarly thin-walled and continuous, surrounding a central linear group of very narrow scalariform vessels and two groups of leptome, the elements of which are exceedingly narrow.

If we now examine the slender, apical portion of the primary root in its second or third year of growth, we notice a marked difference from the former by the absence of all the tissues from epidermis to the pericambium, inclusive. The root has grown in thickness, and the pericambium has now, by rapid cell division, developed several (about five) peripheral strata of cork and a secondary cortex, which consists of about twelve layers of starch-bearing cells. The innermost portion of the central cylinder shows a number of vessels, in the center of which the primordial are quite distinct from the younger by their narrow lumen. The leptome is located outside the wider vessels, separated from these by broad strata of cambial tissue, which extends also between the leptomatic groups themselves, thus covering the oldest part of the hadrome—the protohadrome vessels. This structure is, to some extent, also observable in the thickest roots.

But in these we notice a more or less distinct layering, like annual rings, which have been produced by the continuous formation of independent groups of leptome with a few vessels in the secondary cortex. These rays of collateral mestome-bundles are furthermore separated from each other by broad rays of pith. The central cylinder, with the primordial groups of leptome and hadrome, is hardly discernible in these thick roots; the entire central group of these tissues is mostly destroyed, and the root shows generally a broad, hollow center.

While examining some older roots of this species we often noticed that the long, lateral ramifications showed a tendency to grow together in several places, thence to become separated, and sometimes to grow together again at a greater depth (pl. 1, fig. 4). The complete preservation of the central cylinders in such roots, where they were free and where they had grown together, seems to prove that a fusion had actually taken place rather than a cleaving of a single root. Another peculiarity which was frequently observed in the very thickest portion of the root was that the internal structure did not only show one central cylinder with its heavy mass of secondary cortex, but also several much smaller and apparently independent mestome-cylinders. Considering the fact that each of these mestome-cylinders possessed exactly the same structure as that of a slender root, viz, that it was covered by several layers of cork surrounding a secondary cortex and a central portion of leptome, cambium, and vessels, make us believe that these represent lateral roots, and that they remain inclosed within the loose and very heavy coat of cork layers, which is always noticeable in matured roots of this species. In some cases, especially where several of these mestome-cylinders were massed together, some of these showed the same tendency to melt together as the free roots; but also in these were the central cylinders perfectly isolated, and the only tissues in which the fusion was observable was the cortex and the cork, the latter forming one single coat around two of these mestome-cylinders. The thick root of *C. megarrhiza* thus represents the primary root of the plant, and it persists for several years, with a gradual increase in thickness. The thickness, however, does not seem to be due only to the formation of secondary tissues within the main root alone, but also to the development of lateral roots, which not only increase in thickness themselves but which, furthermore, remain inclosed and covered by the cork of the primary root.

Similar cases of roots being inclosed has been described as characteristic of some other plants, for instance: *Bromeliaceæ*,[a] *Eriocaulaceæ*,[b] *and Ophrydeæ*.[c]

In *Claytonia Virginica* L., the underground, dark-brown, tuberous body from which the flowering stems and leaves proceed is generally described as a tuber, or sometimes as a corm, but, as stated above, this organ represents a root, the base of the primary. The long, filiform apex of the main root (Pl. 2, fig. 10) dies off during the first season, while the basal portion persists, and increases gradually in thickness; it soon becomes globular, but when it is fully matured it represents a more or less laterally compressed body, with a roundish outline. At this stage numerous filiform lateral roots are observable; they appear in small tufts on the edges of the mother root, which is yet very distinctly diarchic. The minor structure of these roots at their various stages is as follows: The lateral roots are of two kinds, some that are capillary, smooth, and almost unbranched, and others that are thicker, prominently wrinkled and ramified. Of these the latter develop from the central cylinder of the mother root, while the former appear as basal lateral ramifications of these. The wrinkled roots are able to increase in thickness, but only a little, and they never attain the swollen appearance of the mother root. Their increase in thickness depends upon the divisions of the pericambium developing a cork outward and a secondary cortex inward, throwing off the older tissues from the epidermis to the endodermis incl.; a cambial tissue has also developed to the same extent as described under *C. megarrhiza*.

The most noticeable characteristic of these roots is their contractile power, which is effected by means of a wrinkling of the cork layers, in which the radial cell walls show very distinct undulations. A much more simple structure is possessed by the smooth and slender ramifica-

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[a] Jörgensen, A.: Bidrag til Rodens Naturhistorie (Bot. Tidsskr. Copenhagen, ser. 3, vol. 2. 1877–79. p. 150.

[b] The author: *Eriocaulon decangulare* L. (Bot. Gazette, vol. 31. 1901. p. 23).

[c] Same: The root structure of North American terrestrial *Orchideæ* (Am. Journ. of Sc., vol. 18. 1904. p. 208).

tions. In these the original structure remains unchanged (Pl. 2, fig. 18). The hairy epidermis is thin-walled; the cortex (C in fig. 18), consists only of three layers, of which the innermost is differentiated as an endodermis (End. in fig. 18); the pericambium (P) is continuous, and surrounds two rays of hadrome alternating with two groups of leptome.

If we now examine the primary root we notice that the structure of its filiform apex, which only persists during the first season, agrees exactly with that of the capillary lateral roots, which have just been described. But the structure of the swollen base is different. In this the pericambium becomes gradually very active, besides that a cambium develops inside the leptome and extends from there around the primordial vessels. This increase continues from year to year, accompanied by the development of collateral mestome-bundles in the starch-bearing cortex. The mode of growth is like that observed in the main root of *C. megarrhiza*, though with the important distinction that in this species the apex continues to grow, while it dies off in *C. Virginica*. Moreover, in the latter species the central cylinder persists for a very considerable period, and the secondary cortex with its coat of cork layers remains active throughout the life of the plant. The lateral roots are quite numerous in both, but in *C. Virginica* they do not traverse the cortex vertically as fully developed roots, but they proceed at once to the periphery until they become free, as is the usual course followed by lateral roots.

A very long, but relatively slender, primary root is possessed by *C. sarmentosa*, and it persists for several years. It is not contractile, but combines the functions of a storage and a nutritive root. The increase in thickness is quite moderate, and the central cylinder, with its mass of narrow vessels and groups of leptome, does not break down even in the older roots, while the peripheral tissues become replaced by layers of cork and starch-bearing secondary cortex. Lateral roots occur, but they are scarce; the primordial tissues are all noticeable in these, even if some slight increase in thickness does take place; the endodermis is moderately thick-walled, and the pericambium is continuous.

If we now examine the root system of one of the annual species—for instance, *C. arenicola*—we notice that both the slender, main root and its almost capillary ramifications are able to grow in thickness.

The epidermis and hypoderm are thrown off very soon, together with the cortex, and are replaced by two or three layers of secondary cortex, surrounding the central cylinder of hadrome and leptome, besides some cambium. The lateral roots are all diarchic, but the very irregular position of the numerous (about thirty) narrow vessels in the primary root made the number of primordial rays indeterminable.

In species where an underground stem becomes developed—for instance in *C. parvifolia*, *C. asarifolia*, and *C. Chamissonis*—the primary root is no longer observable in matured specimens, but is replaced by secondary, which proceed from the short internodes. The structure of such roots is very simple, since they show no signs of increasing in thickness, and neither are they contractile. They have an epidermis with many hairs, directly covering a cortex of about five layers, inside of which is a thin-walled, or sometimes slightly thickened, endodermis; a continuous pericambium surrounds two distinct hadromatic rays, alternating with two groups of leptome.

In bringing these facts together it appears as if the root system of our species of *Claytonia*, represents four physiological types: Nutritive, attachment, contractile, and storage roots. Of these, the first type is well exemplified in the secondary roots of *C. parvifolia*, *C. asarifolia*, and *C. Chamissonis;* the second in the annual *C. arenicola;* the third in the slender lateral roots of *C. Virginica;* while a combination of both contractile and storage roots may be observed in the main root of *C. Virginica* and *C. megarrhiza*. In *C. sarmentosa*, on the other hand, the root seems to combine the function of a nutritive with that of a storage root.

THE STEM.

The above-ground stem is of short duration in *Claytonia*, and lasts only one season. In some species it bears only two large green leaves and an inflorescence (*C. Virginica*, etc.), in others it bears several, but smaller, leaves, which are either alternate or opposite (*C. Chamissonis*), in the axils of which may be developed either inflorescences, vegetative shoots with distinct internodes, or small bulblets.

However, the stem structure is almost identical, and characteristic of the genus seems the lack of collenchymatic and stereomatic tissue, as mentioned by Becker.[a] The cuticle is always distinct, and is prominently wrinkled in *C. Chamissonis*, *C. megarrhiza*, and *C. sarmentosa*. In regard to epidermis, we notice in *C. Virginica* (Pl. 2, fig. 17) an excessive thickening of the outer cell wall, with numerous layerings; in the other species the outer cell-wall is generally thickened, but only moderately. The cortical parenchyma is rather open from the intercellular spaces being quite wide, and the innermost stratum is differentiated as an endodermis, usually thin walled throughout, and showing the Casparyan spots very plainly; in *C. arenicola*, however, the endodermis showed the cell-walls slightly thickened. Inside the endodermis are four very broad collateral mestome-bundles, separated from each other by thin-walled parenchyma, medullary rays; besides that there is a narrow group of this same tissue in the center.

If we now compare the structure of the rhizomes, we find in the stolons of *C. Chamissonis* almost the same development of the various tissues as in the stem above ground. But in the stolons the cortex contains deposits of starch, and the endodermis has the inner cell-wall slightly thickened; besides that, there is some thick-walled mestome-parenchyma between the leptome and the endodermis. Of the four mestome bundles, the two are much broader than the others, and the pith seems to be less developed than in the stem. The stolons of this species possess no cambium, and are thus incapable of growing any further in thickness; they are not of any long duration, either, since they evidently separate from the mother plant at the close of the first season, when they are able to continue their growth independently.

A more developed structure is possessed by the above-ground stolons of *C. sarmentosa*. In these the cuticle is thick and prominently wrinkled, covering an epidermis of small but somewhat thick-walled cells; the cortex consists of about eight quite compact layers, but without starch. The thin-walled endodermis surrounds a secondary cortex of about six layers, with abundant deposits of starch, inside of which is a closed ring of several collateral mestome-bundles with intrafascicular layers of cambium. The center of the stolon is occupied by a narrow cylinder of starch-bearing pith. In this species the stolons are thus able to increase in thickness, and our material showed plainly that they remain active and in connection with the mother plant for at least two or three years.

The horizontally creeping rhizome of *C. asarifolia* persists for several years, and shows many layers of cork, forming a thick coating around a broad, starch-bearing parenchyma of a secondary cortex. The mestome-bundles are all collateral and arranged in a circle; they consist of leptome, cambium, and many narrow vessels, especially pitted ducts. A very compact, starch-bearing pith occupies the greater portion of the central cylinder.

In *C. parvifolia* there is also a horizontal rhizome, but this is partly above ground, and of a much weaker structure. The epidermis is at length thrown off without being replaced by any layers of cork, while the cortex and endodermis persist; the former of these contains chlorophyll. There are only five collateral mestome-bundles, without cambium, and these are separated from each other by rays of the broad central pith.

A somewhat greater diversity in regard to the structure is thus observable in the rhizome than in the flower-bearing stems, which is quite natural when we consider the various modifications exhibited by the former, viz: The perennial creeping rhizome of *C. asarifolia*, the annual stolons of *C. Chamissonis*, in contrast to the perennial ones of *C. sarmentosa*.

THE LEAF.

We meet here with several, and quite important, modifications of structure, which is by no means surprising, when we remember that the leaves winter over in some species, *C. megarrhiza*, *C. arctica*, and *C. sarmentosa*, but die off in all the others before the summer has passed, not speaking of such leaves as are developed as mere bulb scales, in *C. Chamissonis*, for instance.

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[a] Becker C.: Beitrag zur vergleichenden Anatomie der Portulacaceen. Inaug. diss. München, 1895.

It may, therefore, be advisable to treat of some of these species by themselves, beginning with *C. Chamissonis.* The stem bears many pairs of opposite leaves, which are held in an almost vertical position, and their structure is as follows: The cuticle is distinct, wrinkled near the margins of the blade, but is otherwise smooth. The outer cell-walls of epidermis are moderately thickened, and the radial are more or less undulate, especially on the upper, the ventral face of the blade. Stomata abound on both faces; they are raised a little, and possess two subsidiary cells, which are parallel with the stoma, and the air chamber is wide and deep. No trichomes of any kind were observed, but small, stiff hairs were, nevertheless, observed upon the earliest leaves, succeeding the cotyledons. The chlorenchyma is differentiated into a typical palisade tissue on the ventral part of the blade, and as an open pneumatic tissue on the dorsal. No mechanical tissue, neither as stereome or collenchyma was observed, and the mestome-bundles are only surrounded by a thin-walled parenchyma sheath, and deeply imbedded in the chlorenchyma.

In the bulb-scales of this same species the thin-walled epidermis lacks, of course, stomata, and the mesophyll is merely represented as a homogenous tissue of closely packed roundish cells filled with starch. The mestome-bundles are very small and only three in number.

In *C. Virginica* the stomata are most abundant on the dorsal face of the blade, and they have often two pairs of parallel subsidiary cells instead of but one; moreover, the cells of the ventral epidermis are usually somewhat larger than those of the dorsal. In regard to the chlorenchyma, this shows the differentiation as in the former species, but the pneumatic tissue is still more open, on account of the very irregular shape of the cells, leaving very wide intercellular spaces. The mestome-bundles are also small in this species and are not supported by any kind of mechanical tissue. The basal leaves have very long and slender petioles, in which there is a chlorophyll-bearing cortex with very wide intercellular spaces, besides lacunes. There is one crescent-shaped central mestome-bundle and two small lateral, which are orbicular in transverse sections; each of these is surrounded by a special thin-walled endodermis.

If we now examine the overwintering leaf of *C. megarrhiza*, we notice in this a very thick and smooth cuticle, covering an epidermis, with the outer cell-walls prominently thickened, but perfectly glabrous. The stomata (Pl. 2, fig. 9) are somewhat raised, and possess mostly two pairs of subsidiary cells, more or less parallel with the stoma. They appear to be equally distributed on both faces of the blade. A thick homogenous parenchymatic tissue represents the chlorenchyma, the individual cells of which are shaped like palisades, vertical on the leaf blade and filled with chlorophyll. The mestome-bundles are small and deeply imbedded in this tissue. No support of mechanical tissue was observed.

Although the leaves of *C. sarmentosa* are green during the winter, thick and fleshy like those of *C. megarrhiza*, they nevertheless show a very different structure. The stomata are almost exclusively confined to the dorsal face, and the cuticle is very thin. In this species the chlorenchyma is plainly differentiated into a ventral palisade tissue and a dorsal pneumatic, which consists of irregularly branched cells, like those observed in *C. Virginica.* Otherwise the structure of the mestome-bundles, etc., is like that of the previously described species.

The isolateral leaf-structure exhibited by *C. megarrhiza* is a character that has been observed in several other alpine species, pertaining to remote genera; the prominent development of the chlorenchyma into a palisade tissue seems to confirm the general supposition that in alpine plants the assimilation governs the structure of the chlorenchyma. On the other hand, the plainly dorsiventral structure with the very open pneumatic tissue, as represented by *C. sarmentosa*, is a good illustration of a plant adapted to an atmosphere charged with excessive moisture. In this case the transpiration seems to be a more important factor than the assimilation, as far as concerns the differentiation of the chlorenchyma into both a palisade and a pneumatic tissue.

It is somewhat surprising to observe a very open pneumatic tissue in the leaf of *C. Virginica*, which is not an inhabitant of wet localities or is in any way exposed to a damp atmosphere. Nevertheless, the leaf-structure of this species is more open than that of *C. Chamissonis*, a plant that grows exclusively in very wet places—in beaver swamps or along creeks in the aspen zone of the Rocky Mountains, for instance. Such controversies in structural respect are frequent—very frequent, indeed—and the present knowledge of plant structures is yet much too incomplete to enable us to offer any plausible explanation.

It seems, however, as if the species of *Claytonia* which we have examined exhibit certain structures which may be regarded as generic; for instance, the absence of stereomatic and collenchymatic tissues, the structure of the stomata (in contrast to those of the monotypic *Montia*), the four mestome bundles in the stem, the diarchic root, the lack of trichomes, of reservoirs, etc. By considering the external morphological structure of the various organs, we meet also here with some certain degree of uniformity throughout, even if some of the species may be regarded as very distinct from a biological point of view.

Brookland, D. C., *October, 1904.*

EXPLANATION OF PLATES.

PLATE 1.

Fig. 1. Bulblet of *Claytonia parvifolia*, magnified.

Fig. 2. *Claytonia megarrhiza*, a seedling, natural size; Cot.=the cotyledons; H=the hypocotyl; R=the primary root.

Fig. 3. Same species in the second year, natural size; letters as above.

Fig. 4. Same species, but at a later stage, natural size; the lateral roots have grown together with the primary.

Fig. 5. *Claytonia sarmentosa*, natural size; *r*=a secondary root developed from the stolon.

Fig. 6. Same species; a leafy stolon, natural size; *r*=secondary roots.

Fig. 7. *Claytonia Chamissonis*, natural size, showing a plant developed from a bulb, and bearing three stolons, the one of which is terminated by a bulb.

Fig. 8. *Claytonia diffusa;* a stem-leaf, natural size.

PLATE 2.

Fig. 9. Stomata of the leaf of *Claytonia megarrhiza*, ×360.

Fig. 10. *Claytonia Virginica*, a seedling, natural size; Cot.=the cotyledon; R=the primary root.

Fig. 11. Same species; the tuberous portion of the primary root; l^1=the first leaf succeeding the cotyledon (Cot.); *r*=lateral roots; magnified.

Fig. 12. Same species; the blade of the cotyledon, magnified.

Fig. 13. Same species; a seedling, showing the cotyledon and a proper leaf, l^1; natural size.

Fig. 14. Same species in its second year, where the filiform apex of the primary root has fallen off; letters as above; natural size.

Fig. 15. Same species, showing the globular, primary root (R) with several filiform, lateral roots of a specimen about four years old; magnified three times.

Fig. 16. Same species; the stomata of the leaf×360.

Fig. 17. Same species; transverse section of the stem; Epid.=epidermis; Hyp.=the hypoderm. ×480.

Fig. 18. Same species; transverse section of a filiform, lateral root; Ep.=epidermis; C=cortex; End.=endodermis; P.=pericambium; L.=leptome. ×840.

Fig. 19. The diagram of the flower of *Montia rivularis;* A=the axis; C^1=the posterior, C^2=the anterior calyx-leaf; copied from Almquist (l.c.).

PLATE I

Auctor ad nat. delin.

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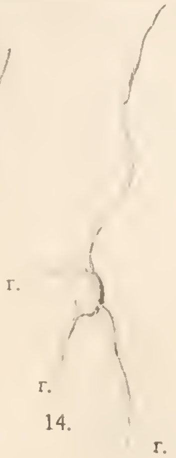

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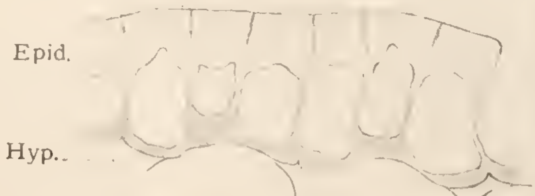

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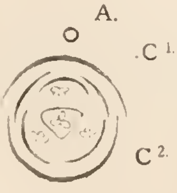

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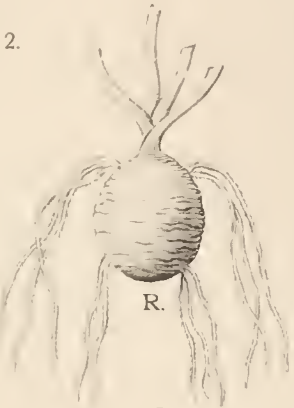

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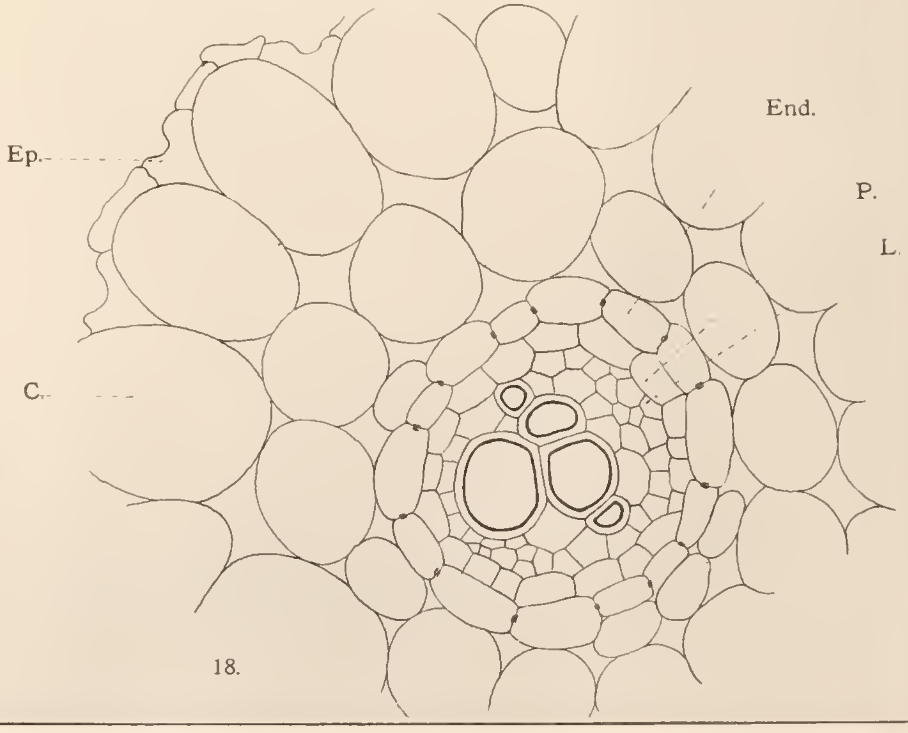

18.

Auctor ad nat. delin.

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A RESEARCH UPON THE ACTION OF ALCOHOL UPON THE CIRCULATION.

BY

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AND

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CONTENTS.

THE ACTION OF ALCOHOL UPON THE CIRCULATION.

By HORATIO C. WOOD and DANIEL M. HOYT.

INTRODUCTION.

When Dr. H. C. WOOD graduated in medicine in 1862 the profession knew of but two heart stimulants, namely, ammonia and alcohol; for it was taught that digitalis is a powerful heart sedative, to be used in cases of excessive heart excitement, and when, as in aneurism, it was desirable to lessen the force of the blood current.

Not many years after the physiologists, and subsequently the clinicians, began to learn that digitalis is not a cardiac depressant but a most powerful and useful cardiac stimulant—a stimulant which for most purposes still stands at the head of the list of remedies of the class. Alcohol, on the other hand, yet remains a question of dispute, so far as concerns its action upon the circulation. Probably since the days of Noah, certainly up to the present moment, whatever the judgment of the profession may be, the action of the laity is that alcohol is a prompt heart stimulant. If a man faints in a drug store, or in a public assembly, or in the street, unless the crowd be so far given to temperance principles that no whisky flask is available, said flask is forthcoming.

Nearly fifty years of medical life has led Dr. H. C. WOOD to attach much importance to widespread popular beliefs, not in regard to the truth of their theory but of their practical results. For years the profession looked upon the mediæval practice of the use of balsams on wounds as a dirty, obnoxious procedure. Now we know that the old vulnarian used remedies which were actively germicidal, and that in the midst of mediæval filth, with its hosts of hungry organisms, he was practicing a rude antiseptic surgery.

For years indefinite there has been a widespread belief that fistula in ano and similar discharging tubercular sores ought not to be healed in consumptive people; the profession decided that they simply helped to exhaust the system and must be done away with; but the latest specialists in tuberculosis have come to the belief that these tubercular sinuses may be really curative by the antitoxin which they produce interferring with tubercular processes more serious because situated in a more vital part. The facts that alcohol is used to the amount of tons annually in diseased conditions affecting the circulation; that it is not powerless for good or for evil; that the physiologists are in absolute discord in regard to its influence upon the circulation, and that the clinicians are becoming, in the presence of this physiological diversity of opinion, doubtful and uncertain in the use of the drug, can not be gainsaid. As proof of the divergency of opinion among competent pharmacologists, two quotations may be cited—one, written in 1900, by H. C. WOOD, professor of therapeutics in the University of Pennsylvania, as follows:

> Upon the heart the small dose of alcohol acts as a direct stimulant, the large dose as a depressant or paralyzant. The influence of minute doses upon the vasomotor system is not thoroughly worked out, but there appears to be a widening of the blood paths at a time when the heart is still stimulated, so that there is a marked quickening of the blood movement. (Treatise on Therapeutics. J. B. Lippincott Co., 11th ed., p. 287.)

The other coming from the pen of JOHN J. ABEL, professor of pharmacology in Johns Hopkins University is:

> So far as present experimental evidence goes, we may say: 1. That alcohol as such, that is, when it is introduced into the circulation with the avoidance of local irritation, is not a circulatory "stimulant." 2. Alcohol in moderate quantities, say a pint of wine, has no direct action on the heart itself, either in the way of stimulating or depressing

it. 3. Alcohol in moderate quantities has also no direct action on the walls of the blood vessels, either on their muscular portions or on the peripheral terminations of their vasomotor nerves. (Physiological Aspects of the Liquor Problem. Houghton, Mifflin & Co., vol. 11, p. 91.)

Led by the importance of this subject, the authors of the present memoir applied to the National Academy of Science for a grant from the Bache fund of $300; this sum of money has become the basis of the present investigation. The literature of alcohol has been studied over and over again, with impartiality and with partiality, with critical acumen, with partizanship, with judicious candor, with shallowness and with thoroughness, and so variously that it has seemed to us that the possibility of further usefulness in any such study is exhausted. In the two works already cited the reader can find the past epitomized. The intent of the present research is to investigate the question de novo, with mind kept as free as is humanly possible from the predisposing effects of previous beliefs. The experiments are reported in the memoir in unusual detail, so as to afford experts opportunity for studying the evidence which is brought forward.

It is perhaps proper to state that although the actual work of making the experiments was chiefly performed by Doctor Hoyt, Doctor Wood took part in and overlooked all experiments of importance, so that the authors of this memoir are equally responsible for the accuracy of the experimental work and of its results.

EXPERIMENTATION.

The experiments which we have made with alcohol had for their intent the finding out of certain facts, and therefore naturally arrange themselves into series, each series being directed to the determining of an individual fact or of several facts closely allied. These series are—

First. Experiments made upon the uninjured animal to determine the effect of alcohol upon the arterial pressure.

Second. Experiments made upon dogs suffering from an infective fever to determine whether alcohol acts under these circumstances as it does upon the normal animal.

Third. Experiments made upon dogs with variously situated sections of the spinal cord, in order to determine the effect of alcohol upon the arterial pressure when the general vascular system has been separated from its dominant vasomotor centers.

Fourth. Experiments as to the effect of alcohol upon the arterial pressure after the aorta has been tied in the middle thoracic or upper abdominal region.

Fifth. Experiments made upon normal dogs with the Ludwig stromuhr to determine the effect of alcohol upon the rate of the blood flow.

Sixth. Experiments to determine the influence of alcohol upon the isolated reptilian heart.

SERIES FIRST.

In this series we performed two sets of experiments—those in which the alcohol was given by inhalation and those in which it was administered intravenously.

In the inhalation experiments the method adopted was to allow the dog to breathe through a tracheal tube which was connected with a double tube bottle in such way that the air had to bubble through a considerable mass of 80 per cent alcohol. It was found that under these circumstances the air was loaded with the vapor of alcohol, whilst an abundant supply of air was furnished the animal. Usually the inhalation was not accompanied by any struggling or excitement, but it was not found possible to produce a complete anæsthetic unconsciousness. This was contrary to the result reached many years ago by Dr. H. C. Wood, that animals could be anæsthetized with simple alcohol placed in an imperfectly closed inhaler.

It is evident that the anæsthesia which was produced in the earlier experiments of Doctor Wood was largely the outcome of a slow asphyxiation due to an imperfect supply of air. Alcohol when given in the method adopted in the present series of experiments usually failed to produce rise of the arterial pressure, and in the exceptional case only caused such rise very late in the poisoning, at a time when the respiration had been profoundly affected by pulmonary congestion and œdema due to the local action of the alcohol upon the pulmonic mucous membranes. At such times the pulse was slow and full, and it was clear that the circulatory changes were the outcome of asphyxiation. In most of the experiments the animal died suddenly by respiratory failure, there either being no unconsciousness until the act of death had been entered upon or was about to begin. It has not seemed to us necessary to report the experiments of this series in detail, but we have tabulated one typical experiment, in which there was no rise of arterial pressure.

EXPERIMENT 1.—*Alcohol given by inhalation. No morphia. Small amount of ether. Reflexes normal before beginning experiment.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0		126	113	
.40				Alcohol begun.
1.40		126	119	
2.40		120	115	Pulse irregular. Animal perfectly quiet.
3.40		117	115	Reflexes active. Imperfect diastole every other beat.
14.40		99	112	Tendency to dicrotism.
15.20				Reflexes sluggish.
22.20 to 22.40		57	103	Sudden respiratory failure. Postmortem, lungs oedematous, the larger bronchial tubes full of fluid.

The following experiments were directed simply to studying the effects of the intravenous injection of alcohol upon the circulation in the normal dog. In all of the experiments ether was used during the preparation of the artery and vein, care being taken to allow the effects of the ether to go off before the first record of blood pressure. In a few instances a small amount of morphia was also given to the animal operated upon.

EXPERIMENT 2.—*Weight, 7½ kilos. Alcohol, 10 per cent, until strength increased as given in remark column.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0		104	152	
0.20 to 1.40	5			
2.20		90	146	
3.00 to 3.20	5			
3.40		90	143	
5.20		90	155	
6.20		78	145	
8.50 to 9.10	10			Animal very quiet.
9.30		75	149	
10.10 to 10.30	11			
10.50		87	152	
11.50 to 12.10	5			
13.10		75	151	Reflexes present.
15.10 to 15.30	5	72	151	
16.10 to 16.30	5			
17.10		84	149	
18.10 to 18.30	5			
3.710		99	155	
38.10	5			
42.10	20			20 per cent solution of alcohol.
42.10		90	160	
43.10	20			33 per cent solution of alcohol.
43.50		90	148	
44.50	12			50 per cent alcohol. Clot formed.
48.50 to 49.10	12			50 per cent alcohol.
49.10		72	60	
49.30		60	115	

EXPERIMENT 3.—*Alcohol 50 per cent.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0	....	183	148	
6.00 to 6.20	4	....	....	
6.40	....	210	157	
8.40 to 9.00	4	....	....	
10.00	....	210	166	
11.00 to 11.05	4	....	....	
13.05 to 13.10	4	....	....	
13.30	....	186	165	Clot.
18.30 to 18.50	6	225	165	No appreciable change.
19.50 to 21.50	6	....	....	
23.50	6	....	....	
25.50 to 26.10	8	....	....	
26.30	....	168	139	
28.30	....	192	155	
28.30 to 28.50	8	156	137	
29.50	Inj......	186	155	Amount of injection not stated.
29.50	....	162	141	
30.50 to 31.10	12	....	....	
31.30	....	144	126	
34.30 to 35.10	Inj......	....	....	Amount of injection not stated.
35.30	....	36	21	Sudden fall of pressure; prolonged systole.
36.30	....	36	99	
38.30	....	144	129	
38.30 to 38.40	4	....	....	
39.40	Inj......	....	....	Figures as to amount of injection not clear.
40.20	....	30	108	Pulse full and slow; no prolongation of systole.
40.40	....	....	....	Tendency to dicrotism.
41.40 to 42.00	10	....	....	
43.00	....	57	76	
43.20 to 43.40	26	....	....	Pressure fell at once to zero.

EXPERIMENT 4.—*Normal dog. Weight, 6 kilos. Rectal temperature, 38° C. 8 centigrammes of morphia given with ether. Alcohol, 50 per cent.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0	....	70	98	
1.00 to 1.05	5	....	....	
2.35	....	72	96	
3.50 to 4.00	....	72	102	
6.00	....	70	108	
6.30 to 7.00	10	....	....	
7.30	....	86	113	
9.00	....	80	98	
10.30	....	72	120	Animal quiet.
12.30 to 13.10	15	....	....	
14.10	....	106	135	
15.40	....	86	96	
16.17	20	....	....	
18.00	....	....	....	Respiration stopped.
19.30	....	74	63	Prolonged systole.

An examination of the foregoing experiments will show that in Experiment 2 alcohol had no distinct effect upon the arterial pressure until it was given in such amounts as to reduce the pressure. In Experiment 3, there was a rise of the arterial pressure, 18 millimeters, in the course of about as many minutes. In Experiment 4, a rise of the arterial pressure of nearly 40 millimeters was reached. These experiments seem to show that alcohol has a tendency to produce a slight rise in the arterial pressure in the normal dog, but that this tendency is not pronounced and may fail to occur, even when small and carefully calculated doses are employed.

SERIES SECOND.

In this series we made only two experiments, which were performed on dogs suffering from distemper accompanied with the usual systemic disorder and marked fever. These experiments are as follows:

EXPERIMENT 5.—*Dog suffering from distemper. Temperature, 40.5° C. Very weak and ill. Weight, 4 kilos. Ether used. Alcohol, 50 per cent.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0	....	134	157	Howling.
1.00 to 1.10	5	....	....	Animal quiet before injection was finished.
1.20	....	124	152	
3.20	....	112	147	
4.20	5	....	....	
4.30	....	172	138	
4.40 to 4.50	5	....	....	
7.50	....	124	145	
19.50	....	148	112	

EXPERIMENT 6.—*Dog suffering from distemper. Temperature, 40.3 C. Weight, 7 kilos. Ether used. Alcohol, 50 per cent.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0	....	136	185	Reflexes normal.
1.02	15	....	....	
4.00	....	136	195	
6.00 to 6.30	10	....	....	
8.00	....	148	186	
10.00	....	136	201	
12.00 to 12.10	5	....	....	
16.10	....	136	187	
16.40 to 16.50	1	....	....	
18.20	....	138	191	
18.50	6	....	....	
19.20	5	....	....	
19.30	....	....	....	Pulse dicrotic; respiration slow.
20.30	....	94	105	
21.30	....	....	....	Cut pneumogastrics.
22.30	....	218	225	Animal killed.

An examination of the records just given will show that in Experiment 5 it was not possible to cause rise of the arterial pressure by alcohol. whereas in Experiment 6 a slight but distinct rise was produced, so that it would appear that in the dog suffering from the general prostration and circulatory disturbance of an infective fever alcohol has no consistent pronounced influence in elevating the blood pressure, but at times does have such effect. The drug therefore seemingly acts upon the circulation in fever in no way differently from that in which it acts upon the circulation in health.

A remarkable effect noted in these dogs, not connected with the circulation, was the influence of the alcohol upon the nervous system, an influence so pronounced as to suggest that very possibly in human fever alcohol is of service as a calmative agent. The animals were suffering from fever and its discomforts; were of necessity restrained in the ordinary dog trough; were violently restless and howling at the time of the intravenous injection of the alcohol. The alcohol was not given in sufficient dose to produce a recognizable narcosis, yet within two or three minutes after its injection the animal became perfectly quiet and apparently blissfully content.

SERIES THIRD.

In the experiments included in this series the spinal cord was always cut somewhere in the cervical region, artificial respiration being maintained. Every effort was made to keep uniformity of rate and activity in the respiratory movements, and in nearly all the experiments the condition of the cord was tested by the effect of asphyxiation upon the circulation, so that it was physiologically demonstrated that the vasomotor system was completely paralyzed. Further, the completeness of the section of the cord was confirmed by post-mortem examination. The section of the cord is a surgical procedure requiring so much cutting and time and involving so much suffering that the animal was perforce thoroughly anaesthetized during the surgical procedures, but in every experiment time was allowed after the operation for the effects of the anaesthetic to disappear, so that the conjunctival reflexes were normal.

EXPERIMENT 7.—*Young, vigorous dog. Weight, 4 kilos. Alcohol used, 50 per cent. Cord cut in upper cervical region.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0		198	32	
0.05		150	32	
0.10 to 0.20	4			
0.40		180	50	
0.50 to 1.00	3			
1.20		134	60	
1.50		156	50	
1.55 to 2.05	3			
2.15		144	80	
2.25	4			
2.45		160	60	
2.50 to 3.00	5			
3.10		120	90	
3.50		120	70	
4.40 to 4.50	5			
5.10		84	40	

EXPERIMENT 8.—*Cord cut in lower cervical region. Much hemorrhage. At post-mortem some of the extreme anterior fibers not cleanly cut. Asphyxia, no rise. Alcohol, 50 per cent.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0		100	58	
1.00 to 1.20	5			
1.25		30	47	
2.25		46	70	
4.55 to 5.00	2			
5.10		82	59	
6.10 to 6.15	5			
7.45		50	72	
9.45 to 9.50	2			
10.10 to 10.15	2			
10.25		26	50	
10.45 to 10.50	2			
11.20				

Experiment 9.—*Cord cut in the upper cervical region. Alcohol used, first injection, 50 per cent; after that to the end of the experiment, 42 per cent.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
	....	57	70–80	
	10	....	....	
0.34	....	63	85	
0.60	....	....	115	
1.56	....	....	113	
3.00	5	....	113	
3.50	....	63	114	
4.00	10	....	....	
4.30	....	57	103	
6.10	....	54	107	
6.20	10	....	....	
7.00	....	42	106	
	....	48	123	
	5	....	....	
7.40	....	....	95	
	....	....	118	
10.30	15	....	....	
11.30	....	....	133	Prolonged systolic and markedly dicrotic pulse.
	....	51	128	
12.00 to 13.10	14	....	....	
14.00	....	54	146	
14.30 to 16.00	13	....	....	
18.00	....	57	140	
19.00	6	....	....	
20.00 to 20.30	18	....	....	
20.45	....	6	71	
21.30	....	12	61	

Experiment 10.—*Cord cut in lower cervical region. Alcohol used, 50 per cent. There was much hemorrhage.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0	....	204	46	
0.60	....	204	46	
2.00 to 2.20	5	....	....	
2.20	....	180	46	
3.20 to 3.40	6	....	....	
3.50	....	180	48	
4.00 to 4.20	10	....	....	
4.20	....	195	63	Pulse waves very small.
5.40 to 5.50	10	....	....	
5.50	....	210	56	
5.50 to 6.50	10	....	....	
6.50	....	168	59	
7.50 to 8.00	10	....	....	No appreciable change in pressure at any time between injections.
8.00	....	216	55	

Experiment 11.—*Cord cut in cervical region. Weight, 10 pounds.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c.c.			
0		155	49	
0.10 to 0.30	8			
0.30		153	69	
1.30		141	52	
1.50 to 2.10	Injection			Amount of alcohol not recorded.
2.30		144	50	
3.10 to 3.50	4			
3.50		132	55	Clot forming.

Experiment 12.—*Weight of dog, 10.5 kilos. Cord cut in the lower cervical region. Considerable hemorrhage during the operation. Alcohol used, 50 per cent.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c.c.			
0		58	67	
1.30 to 1.50	15			
3.30		60	90	
5.00		60	83	
6.00	3			
6.05 to 6.35		64	70	
7.05 to 7.25	5			
7.55		70	82	
9.55 to 10.25	11			
10.55		50	54	
12.55		62	78	
14.25 to 14.35	5			
14.45		78	73	
16.15 to 16.45	10			
20.45 to 22.15	15			
25.15		68	95	
26.45 to 27.15	10			
27.35		52	97	
30.05		72	100	
30.35 to 31.05	10			
32.35		68	97	
34.35 to 36.05	16			The heart stopped apparently in full diastole. The animal was supposed to be dead, but the heart immediately resumed action when the pneumogastrics were cut.
38.25		38	154	
41.25 to 41.52	10			
41.55		94	137	
	30			Death during injection.

An inspection of these experiments will show that in Experiment 7, in which the dog was young and vigorous, the arterial pressure was raised over 100 per cent in spite of the consentaneous marked decrease in the rate of the pulse; that in Experiment 8 the pressure was raised about 25 per cent at the maximum in spite of the fact there had been a great deal of hemorrhage from the operation; that in Experiment 9 the pressure was elevated as much as 50 per cent at the maximum, the pulse being reduced in frequency; that in Experiment 10 although there was much hemorrhage the elevation of pressure at the maximum was about 25 per cent; that in Experiment 11 the maximum rise of pressure was about 40 per cent; that in Experiment 12 the maximum rise of pressure under the use of alcohol was about 50 per cent.

In none of these cases was the arterial pressure kept for a great length of time at the highest point, but there was always a prolonged maintenance of the pressure above the normal.

SERIES FOURTH.

In the present series of experiments the effort was made to study the action of alcohol upon the blood pressure when the aorta had been previously tied.

Experiment 13.—*Aorta tied above renals and below diaphragm. Alcohol, 50 per cent. Morphia used.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0		80	200	
0. 30 to 0.40	5			
3.40		68	199	
3.40 to 4.10	5			
8.10		53	205	
9.10 to 9.40	10			
10.40		52	143	
14.40		74	202	
14.40	10			
17.40		84	196	
21.40		68	189	
24.40		66	188	
26.40	30			Sudden death.

Experiment 14.—*Aorta tied above renals, below diaphragm. Alcohol, 50 per cent. Ether but no morphia.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0		100	180	
1.00 to 1.05	3			
3.05		120	185	
5.35		136	186	Animal restless.
7.35		132	185	
9.05 to 9.35	3			
11.35		140	175	Reflexes present. Animal cries.
13.35		126	175	
13.45 to 13.50	4			
16.50		160	176	Reflexes absent. Animal quiet.
19.50 to 20.20	5			Respiration stopped.
20.50				Slight respiratory effort.
21.50				Artificial respiration. Reflexes absent.
22.20		52	119	
26.20		88	178	
27.20	2			Clot.
32.20	10			Death.

Experiment 15.—*Aorta tied at the diaphragm, which was perforated. Ether used. Alcohol, 42 per cent.*

Time in minutes and seconds.	Drug.	Pulse.	Pressure.	Remarks.
	c. c.			
0			158	
3.00 to 3.20	10			
4.00			150	
7.00			166	
8.00 to 8.20	5			
9.50			155	
11.20	10			
11.50			108	
11.50				Heart prolonged diastole. Cut pneumogastrics. Respiration stopped.
12.50			222	
13.20			202	Artificial respiration.

An examination of the experiments of this series will show that alcohol under the circumstances produced no constant influence upon the circulation. The results were very unsatisfactory so far as the circulation is concerned, because of the enormous disturbance of the respiration and of the general system produced by the tying of the aorta. There was so much unrest and motion, and the circulation was so irregular, that the series is probably of no value as throwing light upon the action of alcohol upon the circulation. These experiments ought to be repeated upon curarized dogs, with artificial respiration, if any weight at all is to be attached to them.

The conditions under any circumstances, however, are so abnormal that it has not seemed to us that any results reached would be of importance, and we have therefore not carried this matter to a further conclusion.

STROMUHR.

Over twenty-five years ago Dr. H. C. Wood asked Professor Schmiedeberg, in his laboratory at Strassburg, to show him how to use Ludwig's stromuhr; the reply was, "Nobody can use the stromuhr except Professor Ludwig, and Ludwig himself could not do so if it were not for his diener Hans. So Doctor Wood went to Leipzig, told the story to Professor Ludwig, who with considerable glee called Hans and said: "Hans, Schmiedeberg says I could not use the stromuhr if it was not for you; that you are the man who does it; so show the professor how."

There are, however, no excessive practical difficulties in the use of the stromuhr, provided complete destruction of the coagulability of the blood be secured. In the present work we found great difficulty in preventing the coagulation of the blood in or about the tubes of the stromuhr. The rabbit is so small an animal that it did not seem to us wise to employ it, so all our experiments were made with dogs.

Wittee's peptone was given intravenously to the amount of over 3 grams per kilo to the dog without sufficient result on the blood to make the experiment workable. Leech extract, or the active principle of the leech salivary gland, we were unable to buy in the American market. Following the method recommended by Franz as closely as we could did not bring the desired result for reasons that are not clear to us. We succeeded, however, in getting successful experiments by using the following plan, based upon the work of Franz: According to the statements of Franz, the active anticoagulating principle of the leech is most largely situated in the salivary glands anterior to the tenth ring, but is also to a greater or less extent diffused through the rest of the body. We found it very difficult with our laboratory centrifuge to properly act upon a large gummous mass such as that formed with the whole of the leech, whereas the centrifuge acted well with the leech heads.

We therefore cut off the heads of the leeches, cut them into very small pieces, rubbed them up with very fine sand, and to the mass added 5 c.c. of a seven-tenths per cent normal salt solution for each leech represented. This was heated for twenty minutes over a water bath at 212°. The bodies of the leeches we treated in the same manner as the heads, and the two separate masses were allowed to stand in a room of low temperature for twelve hours. The mass containing the leech heads was then centrifuged for twenty minutes; the sand contained in the lower portion of the centrifuge was then washed, the wash liquid centrifuged, and the two fluids obtained added together. The mass containing the bodies of the leeches was filtered through cheese cloth under pressure; the filtrate was then centrifuged. The mass was again washed with salt solution, the filtrate centrifuged, and the two results obtained added. The fluids obtained from the heads were now added to those derived from the bodies, and the two constituted the liquid leech extract which was injected.

For obvious reasons no definite amount of the saline was used in making the leech extracts, consequently the dose of the solution given to the dog was measured by the number of leeches represented and not by the number of cubic centimeters of the solution injected. Franz states three leeches per kilo as the amount necessary to prevent coagulation; the lowest amount with which we were successful was three and a half leeches per kilo, but it is very probable that the fresh European leech contains more of the active principle than do such travelled leeches as we employed, since it may well be that the amount of active principle in the leech is lessened by the transportation across seas and the necessary long keeping.

The stromuhr used in these experiments was connected with the carotid artery and the jugular vein on the same side of the neck in the ordinary manner. Morphia was used in sufficient amount to keep the animals perfectly quiet during the experiment. Ether was also administered during the insertion of the stromuhr, time being afterwards allowed for the influence of the ether to be entirely dissipated before the stromuhr norm was taken. The alcohol was given intravenously. The experiments were as follows:

In the details of the experiments the record of time during the experiment is in minutes, that of the filling of the stromuhr in seconds. The alcohol used was always 25 per cent.

EXPERIMENT 16.

Time in minutes.	Drug.	Stromuhr time in seconds.	Remarks.
	c. c.		
0		21	Norm.
2	1		
3		18	
4		18	
8		16	
10	2		
12		16	
17	2		
19		15	
22	3		
24		13	
25	5		
29		14	
30	5		
33		14	
35	8		
39		17	
41	10		
43		20	
45	15		
47		25	
50	20		
53		43	Respiratory death.

EXPERIMENT 17.—*Weight of dog, 8.05 kilograms.*

Time in minutes.	Drug.	Stromuhr time in seconds.	Remarks.
	c. c.		
0		22	
1	2		
3		20	
4	2		
5		17	
6	2		
7		15	
8	3		
9		14	
10	4		
11		14	
12	5		
14		14	
15	10		
19		14	
20	20		
24		14	
28	12		
32		21	
			Respiratory death.

EXPERIMENT 18.—*Very young dog, weight 6.006 kilograms.*

Time in minutes and seconds.	Pressure, arterial.	Drug.	Rate of pulse.	Stromuhr time in seconds.	Remarks.
		c. c.			
0.30	....	....	....	....	
2.30	81	....	130	....	Respiratory curves absent or slight.
18.30	65	....	144	35	Distinct respiratory curves.
19.00	68	....	154	35	
19.30	70	....	152	35	
20.00	....	1	....	....	
20.30	66	....	144	17	
21.30	68	....	152	17	
22.30	....	2	....	....	
24.30	69	....	156	20	
25.30	72	....	....	16	
26.30	....	4	....	....	
31.30	60	....	138	30	
32.00	61	....	148	29	
40.00	53	....	166	74	

In looking over the foregoing experimental record, it will be seen that in Experiment 16, under the influence of 8 c. c. of 25 per cent alcohol, there was a decrease in the time required to fill the stromuhr of from twenty-one to fourteen seconds, or, in other words, an increase of 33 per cent in the rapidity of the flow of the blood. This increase in the rapidity of the flow of blood was maintained after the further injection of 5 c. c. of alcohol, but gradually lessened on the repetition of the dosage, so that after 36 c. c. of the alcohol it had practically disappeared. The paralyzant influence of the alcohol then became more and more apparent, and when 45 c. c. in addition to that previously used had later been injected, the rate of flow through the artery was less than half of the norm.

In Experiment 17, in a dog weighing 8 kilos, 9 c. c. of alcohol reduced the time necessary for the filling of the stromuhr from twenty-two to fourteen seconds—i. e., increased the rapidity of the blood flow a little over 33 per cent. It is remarkable that the further injection of 35 c. c. of alcohol had no further effect upon the rate of the blood current, but when 12 additional c. c. were subsequently given the flow came down to about the norm.

Experiment 18 was a more complicated one than the others. In it the blood pressure was studied at the same time as the rate of blood flow. The administration of 1 c. c. of alcohol brought down the time necessary for the filling of the stromuhr from thirty-five to fifteen seconds; in other words, more than doubled the rate of flow. When 6 c. c. of additional alcohol had been given, the increase of the rate of flow decreased until finally the paralyzant effect of the alcohol upon the circulation became very apparent, so that seventy-four seconds were required to fill the stromuhr instead of thirty-five, the norm. It should be noted that the changes in the rate of flow were not paralleled by any changes in the arterial pressure. A peculiarity of this experiment is the extraordinary effect reached by the injection of a very small amount of alcohol. It should be noted, however, that the dog which was experimented upon was not only a very small dog, weight 12 pounds, but that it was also a very young puppy, and therefore presumably abnormally sensitive to the influence of drugs.

SERIES SIXTH.

In studying the action of alcohol upon the isolated frog's heart we have used successively the various forms of apparatus known to us, in order to reach results which should be as far as possible free from fallacies, and to discover the possible sources of the difference of the reports made by other observers.

We have made a number of experiments with the ordinary Kroneker apparatus. Unfortunately, in the moving from the old to the new University of Pennsylvania laboratories, all the records of these experiments were lost. The tracings had, however, been studied, and the conclusion reached that no constant effect was demonstrable in them as produced by alcohol, except that very large doses of alcohol depressed the heart. It has seemed to us, as the result of our experiments, that the Kroneker apparatus is not applicable to the study of problems like that which we are considering, namely, whether a certain drug does or does not increase the heart work. Under the best conceivable circumstances the isolated frog's heart is under conditions which are unnatural, and which may seriously affect the influence of drugs upon the viscus. In most of our experiments with Kroneker's apparatus, owing to the canula being inserted not into the aorta but into the ventral or dorsal portion of the auricle, the ligature was so low down as to compromit the ganglia lying in the lower third of the auricles, so that the preparation was practically an apical one. The difference between such a preparation and that of the heart proper is shown by the fact that whereas the frog's isolated heart ought to beat from 25 to 40 beats a minute, in our experiments with the Kroneker apparatus in most cases it beat 4 to 5 times a minute, and often would not rhythmically pulsate at all unless artificial stimulation was applied to it.

It is true that in some cases we succeeded in tying above the ganglia, under which circumstances the preparation was one of the heart itself and not an apical one, and the viscus could beat rhythmically. It is evident that with an apical preparation it is not possible to satisfactorily study a drug which may act upon the heart ganglia, and in any series of experiments with the Kroneker apparatus confusion is liable to arise from an attempt to compare the results of experiments in which the preparations have been really diverse, some with and some without uninjured cardiac ganglia. Of course, exactness on the part of the experimenter will minify this possible source of fallacy.

More serious objections to the Kroneker apparatus for use by the pharmacologist are the following:

First. To maintain the slow circulation of the blood through the loose tissues of the frog very little force is required, so that the batrachian heart is arranged for and accustomed to but little resistance to its efforts; in the Kroneker apparatus, during the period of record, the heart is beating against a comparatively heavy column of mercury, and is therefore under unnecessarily unnatural conditions.

Second. An objection which applies equally to the usual forms of the Williams apparatus as to the Kroneker, is the difficulty of interpreting the graphic results. In the interpretation of the writing the height of the wave is usually taken as the measure of the heart work; it is plain, however, that this height is chiefly the measure of the force of the current, since it is entirely possible that the heart should not thoroughly empty itself in systole against the resistance of the mercurial column; further, it is certainly conceivable (in our opinion must be) that a heart, which during diastole is only partially dilated and therefore at the time of systole has in it comparatively little blood, may by a sudden, sharp, very complete contraction raise the mercurial column higher than, or at least as high as, it would be elevated by another heart which dilating very freely beats with a slow, prolonged, but not very forcible, contraction. In one case the graphic result would be a high, narrow cone; in the other case it would be a broad, perhaps flat-topped, wave. The second heart might be doing much more work than the first, although the ordinary method of reading the graphic results would assign to the first heart the victory of doing the larger work. In other words, it seems to us plainly possible that a drug may greatly increase the work done by a heart without proportionately increasing the power of that heart to overcome resistance and to raise a column of mercury.

Third. A source of fallacy with the Kroneker apparatus is the varying condition of the heart as to its blood supply; this is readily appreciated by reference to the following fig. 1. It will be seen at once that when the stopcocks L and F are open the blood flows from burette B to burette A, and the heart has through it a regular circulation; when, however, a record is to be made the stopcocks L and F are closed, so that the heart is beating against the resistance of the mercury column, and has no blood passing through it during the record period. After the record has been made, the blood is again allowed to flow through the heart, and so with alternate periods of feeding and starving the heart continues its movements as long as may be. It is evident that the conditions under which the heart is doing its work are again unnecessarily unnatural, and further, that it is not possible to make a continuous uniform application of the drug under study to the heart.

Fourth. A possible source of fallacy is found in the difficulty of closing the stopcocks F and L at exactly completed diastole, for it is evident that if in one record the heart had been thoroughly dilated when closure was made, and in the other record the heart had been lacking even 10 per cent of full dilatation, the rise of the mercurial column would be different in the two records, although the real power of the heart is the same during the two periods.

The four considerations given above seem to us sufficient to prevent reliance on drug experiments made with Kronecker apparatus, except when the influence of the drug is so overpowering as to overcome the limit of error due to the conditions of the trial.

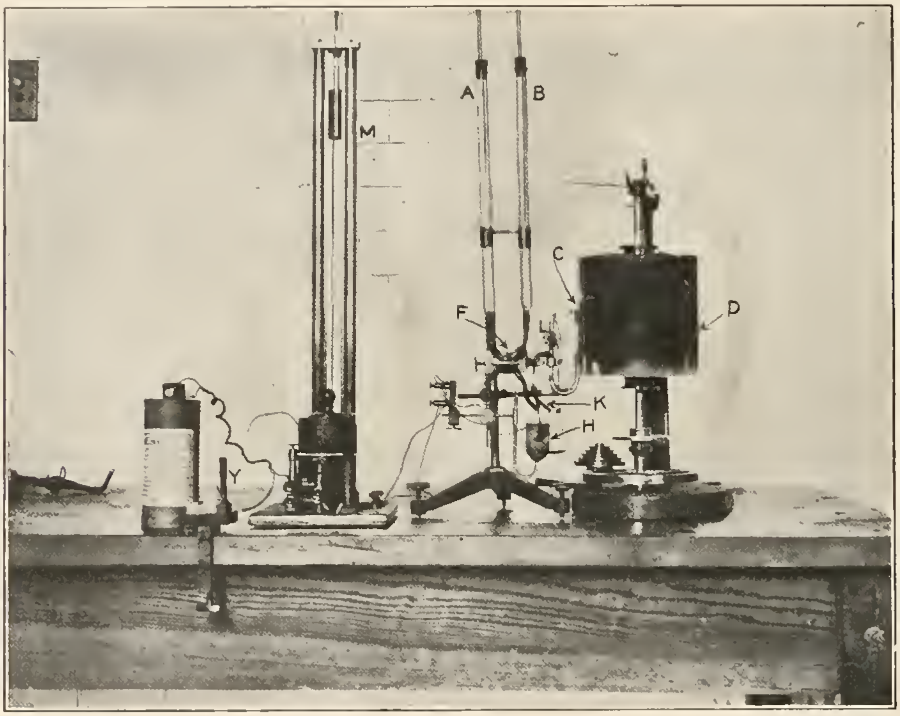

Fig. 1.

In the Williams apparatus a double canula is placed in the *ductus arteriosus* and the whole heart is employed, so that some of the difficulties of the cardiac study are avoided. Two forms of the Williams apparatus have hitherto been in use, and have been supplied to the university laboratories by the Harvard Apparatus Company.

In the first of these forms of apparatus the blood flows through the heart during the whole experiment, avoiding in this way one of the difficulties of the Kronecker apparatus, and the graphic record is made of the movements of the salt solution in the closed receptacle K, in which the heart is placed. Two methods of study have been practiced in regard to these movements. In one method the movement of the salt solution is simply measured by the eye, as the column pulsates backward and forward over a graded scale. In the other method the movements are imparted to a comparatively heavy column of mercury which records them upon a revolving drum. In the Harvard apparatus, fig. B, with which we experimented, the graphic method was employed.

The objections to the first form of the Williams apparatus as supplied by the Harvard Company, are: First, the great nonintermittent outside pressure upon the heart, K, fig. 2, produced by the liquid in which the heart is immersed and the column of mercury connected with that liquid, in accordance with the ordinary laws of hydrostatics; second, the difficulty of interpreting the graphic records, which has already been spoken of, applies to this as to all other graphic methods of studying the frog's heart; third, at least in the individual form of apparatus supplied by the Harvard Company as we put it up, the pressure on the inside of the heart is excessive, due to the height of the reservoir above the heart.

The second form of the Williams apparatus seems to us to involve three inherent sources of possible fallacy. First, the heart is working against excessive resistance in raising the column of mercury; second, if by loosening of the clamp or in other method the size of the orifice at which the blood escapes becomes in the slightest degree altered, an enormous effect must be produced upon the mercurial column, since the movements of the mercurial column mark simply the relation between the resistance at that point and at the point of pulsation;[a] third, close, accurate interpretation of the graphic results is for reasons previously explained difficult if not impracticable.

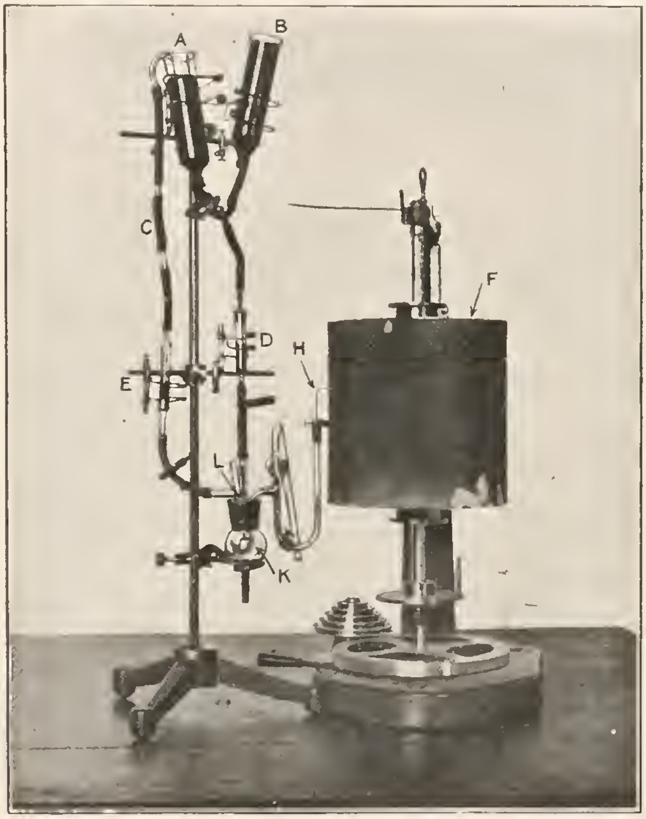

Fig. 2.

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[a] In using this apparatus we found that much freer movements took place in the mercurial column when the second valve at D, controlling the backward flow of the blood, was left open; the increased movements of the mercury being evidently due to an increased fall of the column, the result of the reflux of the column of blood into the heart during the diastolic period. It is plain, however, that under these circumstances the internal pressure upon the ventricles during diastole must equal the weight of the column of mercury, increased according to the laws of hydrostatic pressure, and that in this fact is found a most unnatural condition, the effect of which can not be estimated. We have experimented with Williams's apparatus both with and without the distal valve; those experiments which yielded the best-looking tracings were without the valve, but we are not at this time able to trace out the differences in the experimental results.

The force of the objections to even the best form of the Williams apparatus was not appreciated by us until we had made a number of experiments upon the isolated heart of the frog. The record of those experiments which we made with the second form of the Williams apparatus are as follows:

EXPERIMENT 19.

Time in minutes.	Rate.	Height.	Resultant.	Remarks.
1	56	14	784	
3	56	14	784	
4				¼ of 1 per cent of alcohol.
5	56	12	672	
6	58	12	696	
9	56	12	672	

EXPERIMENT 20.

Time in minutes.	Rate.	Height.	Resultant.	Remarks.
8	24	18	432	
10	24	20	480	
11				1 per cent of alcohol.
13	24	26	624	
16	21	20	420	
17	19	22	418	
19	18	20	360	
21				3 per cent of alcohol.
23	17	20	340	
25	18	18	324	
31	17	14	238	
35	18	10	180	

EXPERIMENT 21.

Time in minutes.	Rate.	Height.	Resultant.	Remarks.
2	24	32	768	
3	21	32	672	
5	20	32	640	
6				¼ of 1 per cent of alcohol.
11	31	30	930	
12	21	28	868	
14	32	30	960	
16	32	32	1,024	
22	29	30	870	
24				1 per cent of alcohol.
26	25	30	750	
28	26	30	780	
30				5 per cent of alcohol.
32	21	30	630	
35	20	28	560	

EXPERIMENT 22.

Time in minutes.	Rate.	Height.	Resultant.	Remarks.
12	8	8	64	
13	9	8	72	
15	8	8	64	
16				¼ of 1 per cent of alcohol.
18	10	8	80	
20	9	8	72	
31	10	8	80	
35	10	10	100	
40	11	10	110	
43	10	10	100	
51	10	10	100	
58				½ of 1 per cent of alcohol.
61	9	10	90	
68				¾ of 1 per cent of alcohol.
75	9	6	54	
84	8	8	64	
87				1 per cent of alcohol.
89	8	6	48	
100	8	8	64	

Looking over the records of these experiments will show that in Experiment 19 the exhibition of one-fourth of 1 per cent of alcohol was followed by a distinct fall of the heart work; that in Experiment 20 the use of 1 per cent of alcohol was followed by a temporary rise, soon giving way to a distinct fall, which became more accentuated when 3 per cent of alcohol was used; that in Experiment 21 one-fourth of 1 per cent of alcohol apparently produced a very decided and persistent rise of heart work, which lasted until the alcohol was increased to 1 per cent, when there was a pronounced fall, not, however, below the norm; whilst later 5 per cent of alcohol rapidly decreased the heart work to below the norm; that in Experiment 22 the heart work was distinctly and persistently increased by the exhibition of one-fourth of 1 per cent of alcohol, the increase being maintained for over half an hour, until the exhibition of three-fourths of 1 per cent of alcohol produced a fall below the norm.

On the whole these experiments seem to us to indicate that in small doses alcohol increases the work of the isolated frog's heart, but the results obtained were distinctly discordant and unsatisfactory. In all these experiments the hearts of small frogs were used, and after much experience with Kroneker's apparatus, Williams's apparatus, and the one shortly to be described, it is clear to us that experimental results reached by the use of small hearts are not reliable. The resistance in either the Kroneker or the Williams apparatus, when the small heart is used, is out of all proportion to the cardiac power, and feeble muscle fiber may well stretch, give way, or lose functional ability rapidly under the strain. Moreover, in the Williams apparatus, when the heart is small it is difficult to avoid injury to it in the insertion and securing of the canula in the truncus arteriosus, and we know of no way of judging with certainty whether the heart has or has not been injured. Whatever the reasons may be, of this fact we are confident, namely, that even with the best forms of "frog's heart apparatus," if the experimental results are to be persistent in the one experiment and consistent in the various experiments, it is essential that the hearts of very large bullfrogs or of large snakes or tortoises be employed. We believe that the failure to obtain a rise in Experiment 19 from the one-fourth per cent of alcohol was probably due to injury of the heart in the making of the preparation.

Led by what we consider to be the difficulties inherent to the older forms of apparatus, we have devised and used one which is snown in fig. 3, an apparatus which is of course a modification of the Williams apparatus. This apparatus consists, beginning at the left, in a pair of Mariott bottles, united by a Y-shaped tube with a clip so arranged as to shut off either bottle at will. Then, of the ordinary Williams apparatus, with this modification, that at the distal end the blood is allowed to pass through a glass tube and to drop into a beaker glass for a fixed period of time. In using this apparatus the pressure upon the heart can be varied by elevating the bottles A and B and the resistance to the systole by elevating the drip tube H. We have found in practice that the elevation to the bottles and to the drip tube must have such relation that the drip tube shall be at least as high as the pressure point in the bottles.

Our experience shows that in order to get the best results with this apparatus some care and experience are necessary in so adjusting the height of the reservoir bottles above the heart that the amount of pressure upon the heart during diastole and the amount of resistance to the heart during systole shall be properly proportioned to the size and power of the organ. In the frog, and probably other reptiles, the internal diastolic cardiac pressure is very slight, so that in the isolated heart it is very easy to have conditions, both during diastole and systole, which are entirely unnatural.[a]

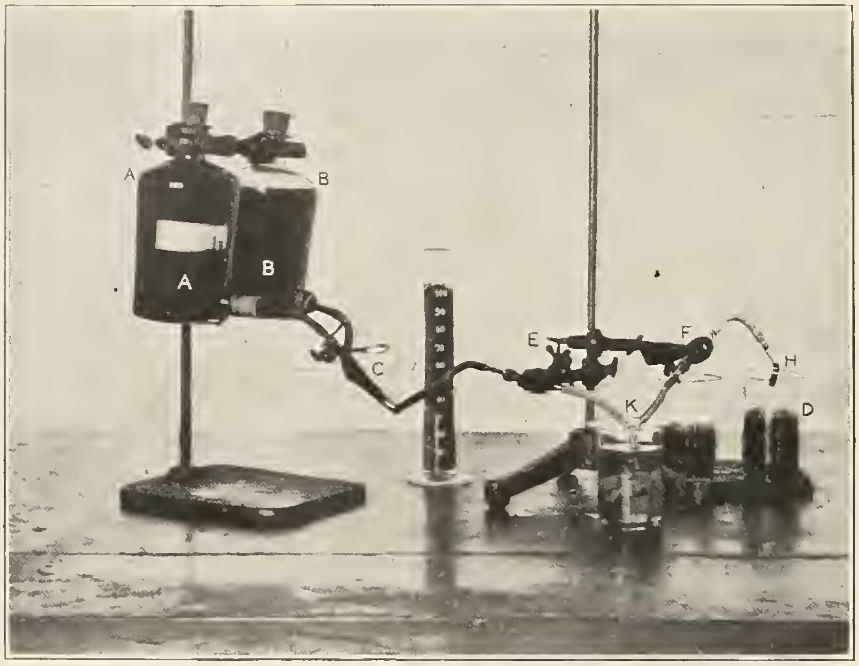

Fig. 3.

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[a] In trials with the pure Ringer solution as a nutrient fatigue developed so rapidly as, in our opinion, to make trustworthy results impossible. The fluid which we finally used was similar to that originally employed by Williams, except in the substitution of bullocks' for rabbits' blood. Our fluid consisted of a mixture of one part of defibrinated bullocks' blood to two parts of a half per cent of saline solution. In order that the heart might have a constant supply of oxygen, in no case was the same blood passed twice through the heart. In one of the large reservoir bottles was placed the pure nutrient fluid, in the other nutrient fluid containing the required percentage of alcohol, so that by simply changing the clip, without altering the pressure or in any way disturbing the heart condition, pure nutrient fluid or alcoholized fluid could be run through the viscus at will. We had some difficulty in working the Williams valve until our *diener*, suggested the use of the skin of the frog, which we found when used fresh or even after keeping in saline solution would do admirably.

EXPERIMENT 23.—*Moderately large frog.*

Time in minutes and seconds.	Rate.	Amount.	Remarks.
		c. c.	
2.58 to 3.03	24	84	
3.03 to 3.08	15	99	
3.08 to 3.13	14	105	
3.13	....	....	¼ of 1 per cent alcohol.
3.13 to 3.18	16	112	
			Clogged valve cleaned.
3.28 to 3.33	....	120	
3.33 to 3.38	....	152	
3.44	....	....	Blood without alcohol.
3.46 to 3.51	....	65	Heart irregular in action.
3.51 to 3.56	....	84	
3.57	....	....	¼ of 1 per cent alcohol.
4.01 to 4.06	....	85	
4.10	....	....	Air in tube since beginning taken out.
4.12 to 4.17	....	111	
4.17 to 4.22	....	107	
4.22 to 4.27	....	103	
4.31	....	....	Blood without alcohol.
4.34 to 4.39	....	99	
4.39 to 4.44	....	95	
4.44 to 4.49	....	100	
4.49	....	....	½ of 1 per cent alcohol.
4.52 to 4.57	....	109	
4.57 to 5.02	....	110	
5.02 to 5.07	....	96	
5.07	....	....	Blood, 1 per cent alcohol.
5.13 to 5.18	....	56	
5.20 to 5.25	....	43	

EXPERIMENT 24.—*Rather small frog.*

Time in minutes and seconds.	Rate.	Amount.	Remarks.
		c. c.	
1.35 to 1.45	....	....	
2.04 to 2.09	26	18	
2.10 to 2.15	26	19	
2.15	....	....	¼ of 1 per cent alcohol.
2.15 to 2.20	....	....	
			Apparatus out of order; 10 minutes to get started.
2.26 to 2.31	40	83	
2.31 to 2.36	36	91	
2.36	....	....	Blood without alcohol.
2.38 to 2.43	34	86	
2.43 to 2.48	34	87	
2.48 to 2.53	32	87	Four minutes.
2.53 to 2.58	32	90	
2.58	....	....	½ of 1 per cent alcohol.
3.01 to 3.06	32	104	
3.06 to 3.11	32	93	
3.11 to 3.16	32	91	
3.16	....	....	Blood without alcohol.
3.21 to 3.26	30	55	
3.26 to 3.28	....	22	Two minutes.
3.28	....	....	1 per cent alcohol.
3.29 to 3.34	32	48	
3.34 to 3.39	....	25	

In the last experiment perhaps the alcohol used was too strong—one-half per cent instead of one-fourth. Much fussing and use of heart, also, before last trial.

EXPERIMENT 25.—*Large frog.*

Time in minutes and seconds.	Rate.	Amount.	Remarks.
		c. c.	
3.03 to 3.08	40	90	
3.08 to 3.13	39	91	
3.13 to 3.18	39	93	
3.18	....	....	¼ of 1 per cent alcohol.
3.20 to 3.25	40	101	
3.25 to 3.30	38	102	
3.30 to 3.35	40	103	
3.35 to 3.40	38	102	
3.40	....	....	Blood without alcohol.
3.43 to 3.48	37	92	
3.48 to 3.53	38	92	
3.53	....	....	⅓ of 1 per cent alcohol.
3.54 to 3.59	36	97	
3.59 to 4.04	38	96	
4.04 to 4.09	....	95	
4.09	....	....	Blood without alcohol.
4.11 to 4.16	36	88	
4.16 to 4.21	36	86	
4.21	....	....	½ of 1 per cent alcohol.
4.22 to 4.27	36	86	
4.27 to 4.36	36	68	

EXPERIMENT 26.—*Land tortoise.*

Time in minutes and seconds.	Rate.	Amount.	Remarks.
		c. c.	
4.19 to 4.24	42	149	
4.24 to 4.29	41	149	
4.30	....	....	½ of 1 per cent alcohol.
4.32 to 4.37	41	175	
4.37 to 4.42	36	175	
4.42	....	....	Blood without alcohol.
4.44 to 4.49	39	125	

EXPERIMENT 27.—*Snake.*

Time in minutes and seconds.	Rate.	Amount.	Remarks.
		c. c.	
3.48 to 3.53	34	55	
3.53 to 3.58	28	60	
3.58 to 4.03	28	60	
4.03	....	....	½ of 1 per cent alcohol.
4.05 to 4.10	25	66	
4.10 to 4.15	28	68	
4.15 to 4.20	33	68	
4.20	....	....	Blood without alcohol.
4.22 to 4.27	33	61	
4.27 to 4.32	36	61	
4.32	....	....	½ of 1 per cent alcohol.
4.34 to 4.39	34	70	
4.39 to 4.44	36	69	
4.45	....	....	Blood without alcohol.
4.47 to 4.52	37	54	
4.53	....	....	⅔ of 1 per cent alcohol.
4.55 to 5.00	41	62	
5.00 to 5.05	40	56	
5.06 to 5.11	40	45	
5.11	....	....	Blood without alcohol.
5.13 to 5.18	42	39	
5.19 to 5.24	44	79	
5.24	....	....	⅔ of 1 per cent alcohol.
5.30 to 5.35	44	99	
5.36 to 5.41	....	91	
5.41	....	....	Blood without alcohol.
5.42 to 5.47	44	73	

EXPERIMENT 28.—*Snapping turtle.*

Time in minutes and seconds.	Rate.	Amount.	Remarks.
		c. c.	
4.05 to 4.10	9	177	
4.10 to 4.15	....	175	
4.16	....	....	½ of 1 per cent alcohol.
4.17 to 4.22	9	197	
4.22 to 4.27	12	213	
4.27	....	....	

In studying the experiments which have here been recorded in detail, it will be noted that in Experiment 23 under the influence of one-fourth of 1 per cent of alcohol the heart work increased from a maximum of 105 to 150 c. c., then on the withdrawal of the alcohol fell to 84 c. c., but rose again to 111 on the renewal of the alcohol, to fall again to 100 when the alcohol was withdrawn; to rise to 110 again when the alcohol was added in half per cent, this rise being followed, however, by a rapid fall in the amount of the heart work, which on the increase of the alcohol in the blood to 1 per cent came down to 43 c. c. per minute. The technical details of this experiment were not satisfactory in that at one time the apparatus had to be taken entirely apart on account of coagulation of blood in it, and that later the process had to be again stopped in order to remove air which had been shut in the tube.

In Experiment 24 the work of the heart rose from 19 c. c. during the prealcoholic period to 91 c. c. during the alcoholic period, falling, however, very distinctly when the alcohol was withdrawn from the blood; increasing later to 104 when the alcohol was increased to one-half per cent, and falling rapidly to 22 when the alcohol was withdrawn, rising again on the addition of 1 per cent of alcohol temporarily, the rise being followed by a fall. The first part of this experiment was in its technique not thoroughly satisfactory and the alleged norm of 19 c. c. is almost certainly incorrect. The apparatus in the beginning failed to work properly, for reasons which were not clearly made out; requiring ten minutes for taking everything apart and getting the tubes together again before the blood flowed freely. The original norm was probably incorrect, but the subsequent readings were clearly accurate.

The two experiments, 23 and 24, whose results we have just epitomized, were made with medium-sized hearts derived from frogs of corresponding size. For reasons which have been heretofore assigned, it seems to be impossible to get with such hearts satisfactory results, and we therefore do not think that very much weight can be given to these Experiments 23 and 24.

The remaining experiments of the series were made with powerful hearts, capable of overcoming the resistance and other abnormal conditions of the heart under study.

In Experiment 25, under the influence of one-fourth per cent of alcohol, the heart work rose from 93 to 103; that is, 12 per cent; fell 12 per cent when the alcohol was withdrawn, rose about 5 per cent under the influence of one-third per cent of alcohol, fell to 10 per cent below the original norm when the alcohol was withdrawn; the heart subsequently failing under the influence of one-half of 1 per cent of alcohol.

In Experiment 26, made with a land tortoise, the norm of heart work was found to be 149 c. c., rising to 175 on the addition of one-half of 1 per cent of alcohol to the nutritive fluid, to fall to 125 when the alcohol was withdrawn.

In Experiment 27, in which a snake was used, the heart work norm was 60 c. c.; the addition of one-half of 1 per cent of alcohol made it rise to 68 c. c., about 13 per cent; then the work fell to the original norm when the alcohol was withdrawn, to rise again about 15 per cent on the addition of one-half of 1 per cent of alcohol to the blood; to fall again 10 per cent below the norm when the alcohol was withdrawn, again to rise temporarily under the influence of two-thirds of 1 per cent of alcohol, to fall again much below the norm on the withdrawal of the alcohol, again to increase under the influence of two-thirds of 1 per cent of alcohol 16 per cent, to finally fall when the alcohol was withdrawn.

In Experiment 28, with the large heart of a good-sized snapping turtle, one-half of 1 per cent of alcohol raised the heart work from 177 to 213, a gain of 20 per cent.

In addition to the experiments, the details of which have been given, we have made others with the hearts of large frogs, in which the results reached were entirely concordant with those just tabulated. It should be noted that in many of these experiments the alcohol was repeatedly used and withdrawn and used again, and that each time the heart work rose and fell with the giving and withdrawing of the alcohol, and that in no experiments with the large heart did the alcohol fail clearly and positively to manifest its influence.

The results of all the experiments which we have made clearly establish that when the isolated reptilian heart is placed under conditions as nearly natural as is possible, the amount of blood which it will pump during a fixed period—i. e., the amount of work which it will do—is increased usually from 10 to 15 per cent by the addition of one-quarter to one-half per cent of alcohol to the nutrient fluid. In these experiments it was usually apparent that the increased work was manifested by the increase in the amount of blood thrown out by the heart at one systole, and it appeared to us that the alcohol increases the completeness of the diastole.

RELATION TO PREVIOUS INVESTIGATION.

The facts which we believe we have experimentally determined in regard to the action of alcohol upon the circulation are:

First. In the normal dog alcohol does not usually, either in small or large dose, distinctly increase the arterial pressure, although occasionally such an effect appears.

Second. The action of alcohol upon the circulation in dogs suffering from an infective fever, at least so far as the blood pressure is concerned, is similar to its influence upon the normal dog.

Third. After section of the spinal cord in the cervical region, with artificial maintenance of the respiration, alcohol distinctly and consistently increases the arterial pressure; in other words, alcohol increases arterial pressure after the general vascular system has been separated from its dominant vaso motor centers.

Fourth. (Series 5.) The exhibition of small doses of alcohol increases very markedly the rate of flow of blood through the large arteries, as measured by Ludwig's stromuhr; this increase of rate being consistently maintained under the repetition of the intravenous injection of alcohol until the time comes when the rate of flow gradually lessens under the paralytic influence of the toxic dose of alcohol upon the heart and blood vessel. The increase of the rate of flow is in no wise dependent upon nor related to any elevation of the arterial pressure, as it may occur without the pressure being sensibly affected.

Fifth. (Series 6.) One-quarter to one-half per cent of alcohol added to the nutritive fluid feeding an isolated working reptilian heart markedly and persistently increases the amount of the fluid pumped in a given length of time by the heart; that is, markedly increases the work done by the heart. If one-half to 1 per cent of alcohol be added to the nutritive fluid there may be a primary condition of increase of work, followed in a few minutes by marked lessening of the work done. Larger percentages of alcohol immediately decrease the activity of the isolated reptilian heart.

The first question which naturally arises at this point is as to how far the above facts which we seem to have established agree with the results obtained by previous experimentators; let us look at this matter in a consecutive manner.

First. Without more elaborate discussion we think that anyone conversant with the literature of the action of alcohol upon the blood pressure will acknowledge that the general drift of the evidence is in accord with the results which we have reached. Most observers affirm they have been unable to get any increase of the arterial pressure by the use of alcohol, whilst others allege that they have obtained such increase. Attempts have been made by critics to reconcile these differences by asserting the incompetence of one set of observers, the critic attributing these qualities to one or the other set of observers according to his own opinion on the subject. It seems to us much more probable that both sets of observers have recorded correctly their observations, which were partial truths, the whole truth being that alcohol does not commonly elevate the blood pressure, but in some cases does so.

Second. We know of no experiments having been made as to the effect of the exhibition of alcohol upon the blood pressure in dogs suffering from an infective fever, but the results which we have obtained in dogs are in close concord with those reached by Cabot upon human beings suffering from various infective fevers.

Third. The only experiments with which we are familiar other than our own upon the action of alcohol on the arterial pressure after section of the spinal cord are those which were made in or about 1900 by Prof. JOHN J. ABEL, of Johns Hopkins University. In these experiments the results were exactly like those which we have obtained. In a letter written in 1904 by Professor ABEL to Dr. H. C. WOOD, Professor ABEL states that in all his spinal-cord experiments with alcohol great care was taken to see that the section of the cord was complete, and he further states that except in certain experiments, when owing to the animal having been extremely feeble and having suffered from violent hemorrhage during the operation, the blood pressure was almost exhausted before the administration of the alcohol, alcohol always caused distinct elevation of the arterial pressure after section of the spinal cord.

Fourth. In regard to the effect of alcohol upon the rate of the blood flow, the only experimental record in literature with which we are familiar is that of JOHN C. HEMMETER (N. Y. M. R., xl, 1891), who in a single experiment found that in the dog the blood flow was increased from 158 milligrammes per second to 399 milligrammes per second by the exhibition of alcohol. This single experiment is evidently in accord with the results which we have obtained.

Fifth. In regard to the action of alcohol upon the isolated reptilian heart, much work has been performed by various observers at various times, with results which have been discordant. In our study of the effect of the drug upon the reptilian heart the attempt was made to discover if possible the reason of this discordancy. The method of cutting the Gordian knot adopted by some authorities, namely, the assertion that everybody, who had obtained results different from those which they themselves had reached, did not know how to experiment properly, as already stated, does not seem to us philosophic. Having, however, exhaustively studied this subject already, we now merely state our conviction that the reasons of the discrepancies in literature have been made apparent, and that our results are not exceptional in any way.

INTERPRETATION.

The interpretation of the experimental facts which have just been stated does not seem to us difficult. The arterial pressure is the result of the interplay of two antagonistic forces, the propelling power derived from the heart and the frontal resistance offered by the blood vessels. If either of these forces be increased—that is, if the blood vessels be narrowed or the heart power augmented—the arterial pressure will rise. If either of these forces be diminished the arterial pressure will fall. If one of these forces be increased and the other diminished the arterial pressure may rise, may fall, may remain as it has been, according as the balance between the two forces rises, falls, or is maintained. The fact, therefore, that alcohol does not constantly elevate the blood pressure is no proof that it does not stimulate either the heart or the blood vessels, since it is evidently possible that it may stimulate one dominant factor of the blood pressure and depress the other so equally as to maintain the balance. Further, the fact that the influence of alcohol upon the blood pressure is not a constant one suggests the probability that it does disturb one or other dominant blood pressure factor, and is unable always to accurately keep the balance between the two altered forces.

The second fact in regard to alcohol and the blood pressure is that alcohol notably, consistently, and persistently elevates blood pressure after paralysis of the vasomotor system by high-up spinal section. This elevation of the blood pressure can not be due to a local action upon the blood vessel walls, otherwise it would manifest itself before section of the spinal cord, because any local action would necessarily show itself as much before as after removal of the dominant vasomotor nerve control. It appears to us that the effects of alcohol upon the blood pressure before and after section of the cervical cord are when taken together in themselves sufficient to show that alcohol concentaneously stimulates the heart and depresses the vasomotor centers. This conclusion is very strongly corroborated by the effect of alcohol in increasing the rate of the blood flow in the arteries. The blood flow may be increased by augmenting the force of the propelling power, or by diminishing the power of the resistance, or it may be enormously increased by simultaneously increasing the propelling power and decreasing the resistance. We have demonstrated that the rate of the blood flow is almost doubled by alcohol; indeed the amount of this increase is so great as in itself to suggest that there must be a double factor in its production. That the increased rate of blood flow is not caused by or consistently accompanied with increase in the arterial pressure we have demonstrated. Either simply cardiac stimulation or simple vasomotor constriction would increase the arterial pressure. Moreover, if an increase of the blood flow produced by the drug were simply due to cardiac stimulation, such cardiac stimulation would of necessity clearly register itself in the uninjured animal by a rise of the blood pressure, and this alcohol does not do; further, if the increased blood flow were the outcome of vascular depression, of necessity alcohol should in the uninjured animal produce fall of the blood pressure.

These three facts taken together, namely, lack of power to consistently increase or decrease blood pressure in the uninjured animal; possession of power to increase blood pressure after centric vasomotor paralysis; possession of power to enormously augment the rate of the blood flow, lead to one inevitable conclusion, namely, that a drug which possesses these things must simultaneously stimulate the heart and widen the blood paths by depressing the vasomotor centers. Such, then, must be the action of alcohol.

The correctness of this conclusion is further corroborated by the results of our study of the action of alcohol upon the isolated reptilian heart. It would, apparently, have been in order to have made studies upon the mammalian heart, but we have long since believed, as the result of careful study of the experimental methods and results heretofore published, that such experimentation is so surrounded with practical difficulties that the results reached are more apt to be misleading than true guides. The delicacy of the organ, the violence done to its natural conditions, the unexplainable results which have been reached by various experimenters seem to us to show that until the technique of the method is radically improved little can really be learned from such experiments unless in the case of a drug like digitalis, whose cardiac action is overwhelming.

On the other hand, the power of the reptilian heart under favorable circumstances to continue at ordinary temperatures its functions for many hours regularly and without pronounced abatement evinces a lack of sensibility and a robustness of resistance to unnatural conditions which are the basis of successful experimentation. Moreover, all our physiological and pharmacological data show that, so far as quality of drug action is concerned, there is no difference between the mammalian and reptilian heart. We can, therefore, confidently add to the facts previously summarized the further fact that there is direct proof that alcohol increases the heart work.

CONCLUSION.

Alcohol does not seriously affect in the normal animal blood pressure; elevates the blood pressure after vasomotor paralysis from action of the cervical cord; increases enormously the rate of the blood flow; directly stimulates the heart; therefore the general action upon the circulation of the moderate dose of alcohol is great increase in the rapidity of the circulation caused by cardiac stimulation, with vascular dilatation due to depression of the vasomotor centers.

Human experiments.—The conclusion just reached rests, as does most of our knowledge, in regard to the physiological action of drugs, upon experiments made upon the lower animals; but it has occurred to us that these results might with a certain measure of plausibility be tested by plethysmographic studies upon human beings. Some experience with the plethysmograph has led us to believe that with this instrument incorrect results can very readily be reached, and that too much reliance can readily be placed upon its indications. When the arm is used as ordinarily in the plethysmograph insensible movements backward or forward have an enormous influence upon the lever which records the movements of the contained fluid. We have made two experiments with the arm plethysmograph, using every precaution to avoid fallacies, and employing a person unaccustomed to the use of alcohol. In the first of these experiments whisky was taken, in the second Mumm's extra dry champagne. In examining the results of these experiments it must be remembered that although it is possible to make a plethysmograph, the movements of the lever of which shall have an absolute value—in other words represent the percentage of enlargement of the arm—such instrument must be made with great care and at much expense.

The university laboratory does not own such an instrument, and our present purposes have not required it; all that we have attempted to do is to show whether there is or is not a distinct increase in the size of the arm following the ingestion of alcohol. In the following tables, when the needle was above the norm, the amount of the ascent is given in millimeters preceded by a +; when the needle was below the norm the descent is given in millimeters with a —. As already shown these millimeters are no measure of the amount of expansion and contraction of the volume of the arm.

A.

Time in minutes.	Drug.	Plethysmographic lever.
0	Whisky 50 c. c.	Norm.
20	do	Norm.
30	do	+13 mm.
40	do	+15 mm.
60	do	+ 7 mm.
80	do	+ 5 mm.
90	do	— 1 mm.

B.

0	Champagne 198 c. c.	Norm.
7	do	+24 mm.
11	do	+13 mm.
14	do	—10 mm.
15	do	+27 mm.
19	do	+22 mm.
27	do	+27 mm.
30	do	+ 7 mm.
34	do	—11 mm.

The above records are entirely concordant with one another, differing only in the fact, which is constantly indicated in human life, that distilled liquors like whisky act more slowly than does champagne. In each experiment there was a distinct increase in the size of the arm—with the whisky slowly and gradually, with champagne, rapidly—developed; and with whisky much more permanently maintained than with champagne, the rise after a time being followed by a slight decrease in the size of the arm below the normal.

The increase in the size of the arm in these experiments is not readily explainable except with the supposition of increased amount of blood in the organ, due to dilatation of the arterioles and the greater circulation through the vessels of the extremities, the blood not tarrying so long in the great venous system of the abdomen and thorax. The results therefore are entirely concordant and corroborative with those reached by experiments upon animals.

REMARKS.

The conclusions which we have established throw much light upon the practical problem of the therapeutic effects and uses of alcohol, indicating that some results which have been supposed to be due to a direct action of the drug are secondarily produced by the increase of the activity of the circulation. A scientific journal like the present is hardly the place for a discussion of problems of practical medicine, but it may be allowable to point out how this new knowledge relates itself to the action of the drug upon the cerebrum. There is, on the one hand, at present no sufficient proof that alcohol is a direct cerebral stimulant such as caffeine, unless it be in exceptional cases of exhaustion or of narcotic habit it does not sensibly augment the working power of the brain. Again, so far as consciousness is concerned, its tendencies are to produce sleep rather than wakefulness, whilst the true cerebral stimulant, augmenting the functional activity of the cortical centers, lessens their tendency to go into a condition of functional rest, i. e., sleep. On the other hand, any habitué of feasts where alcoholic drinks circulate freely knows full well the increase of amount and brilliancy of conversation which occurs *pari passu* with the flushing of the cheeks. Evidently it is probable that this cerebral excitement and increased activity is due not to the direct action of the drug upon the brain but to the enormously increased flow of blood running riot through the cerebrum.

EXPLANATION OF PLATES.

PLATE I.

EXPERIMENT 17.—*Stromuhr.*

FIG. 1. The norm, after the leech extract, lower line representing seconds, upper line the time required for the filling of the stromuhr.
FIG. 2. Record two minutes after the injection of 2 c. c. of alcohol.
FIG. 3. One minute after the injection of a second 2 c. c. of alcohol, 4 in all.
FIG. 4. One and one-half minutes after fourth injection of alcohol, 9 c. c. in all.
FIG. 5. One and one-half minutes after the sixth injection of alcohol, 13 c. c. in all.
FIG. 6. After the injection of 28 c. c. of alcohol.
FIG. 7. After the injection of 48 c. c. of alcohol.
FIG. 8. After the injection of 60 c. c. of alcohol.

PLATE II.

EXPERIMENT 18.

FIG. 1. The norm, after the leech extract, showing pressure in the carotid artery and time required for the filling of the stromuhr.
FIG. 2. After 3 c. c. of alcohol.
FIG. 3. After 7 c. c. of alcohol.

PLATE III.

EXPERIMENT 21.—*Williams's apparatus. Frogs heart.*

FIG. 1. The norm.
FIG. 2. With the use of one-half per cent of alcohol.
FIG. 3. With the use of 1 per cent of alcohol.

PLATE I.

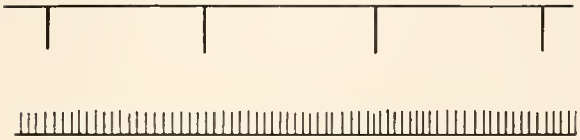

Fig. I.

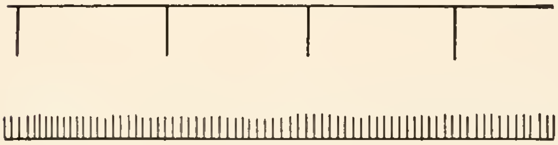

Fig. II.

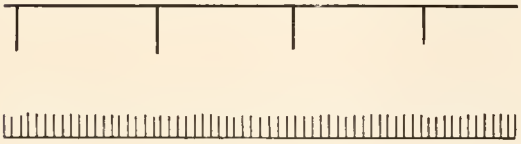

Fig. III.

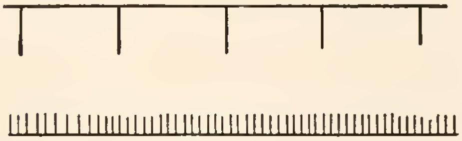

Fig. IV.

Fig. V.

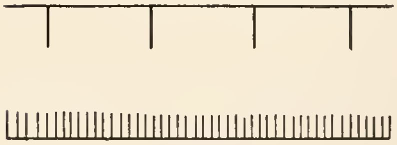

Fig. VI.

Fig. VII.

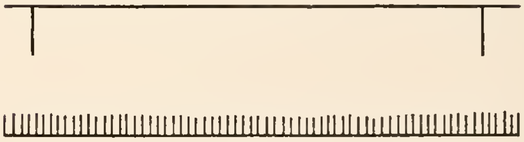

Fig. VIII.

EXPERIMENT 17.

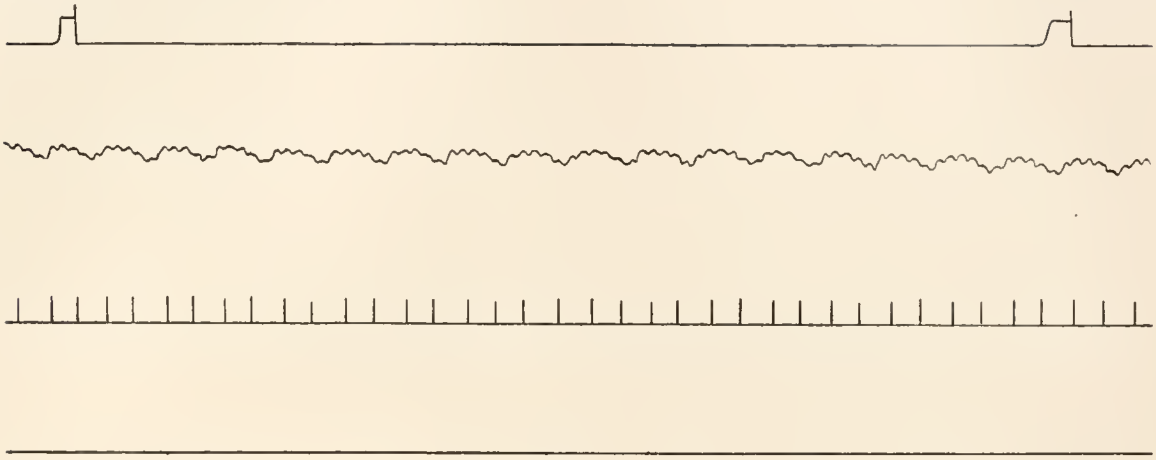

Fig. I.

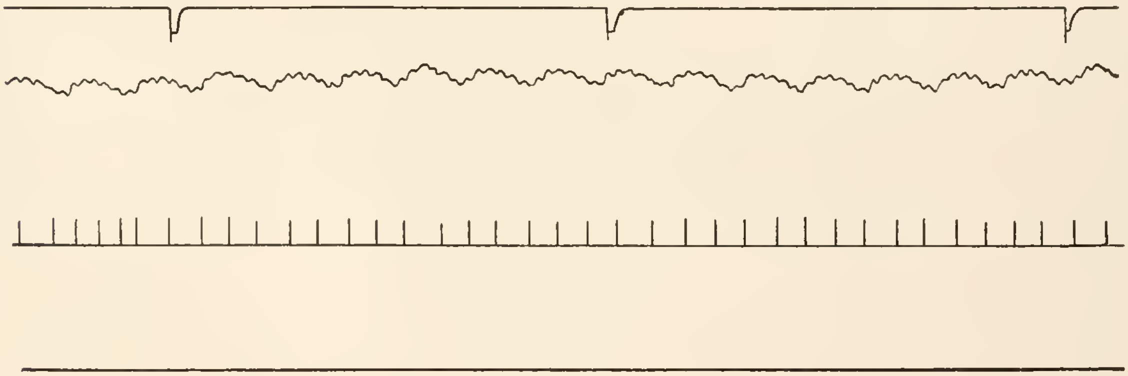

Fig. II.

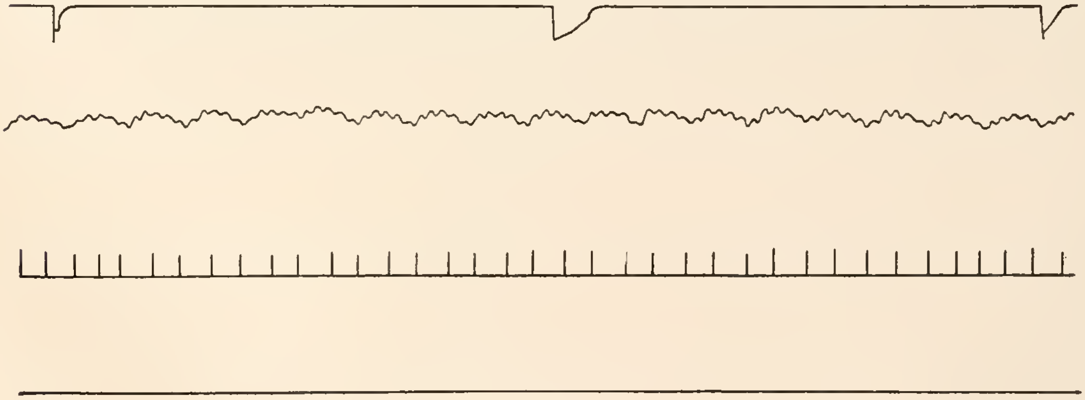

Fig. III.

EXPERIMENT 18.

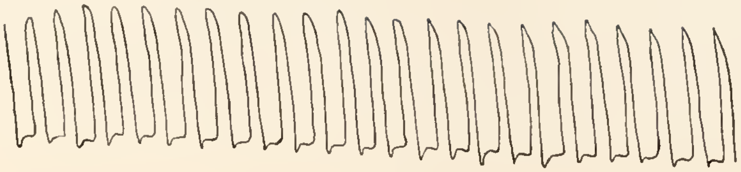

Fig. I.

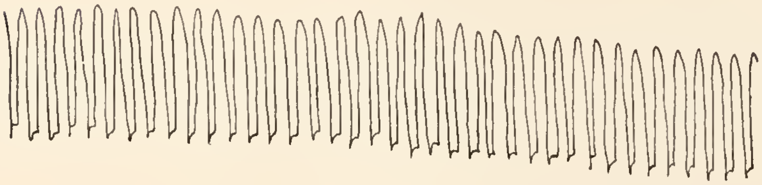

Fig. II.

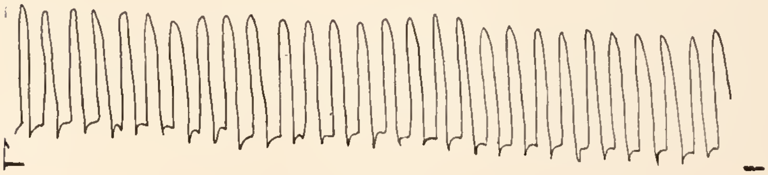

Fig. III.

EXPERIMENT 21.

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PHORONIS ARCHITECTA:

ITS LIFE HISTORY, ANATOMY, AND BREEDING HABITS.

BY

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AND

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INTRODUCTORY NOTE BY W. K. BROOKS.

As my name appears on the title-page of this Memoir as joint author, I take this opportunity to say that my own share in the work has been that of instructor and director only. The investigations are the exclusive work of Dr. R. P. Cowles, and while I have followed them in detail, and hold myself responsible for their soundness and accuracy, the credit for the research belongs to Doctor Cowles alone.

Dry Tortugas, Florida, *July 3, 1905.*

CONTENTS.

PHORONIS ARCHITECTA: ITS LIFE HISTORY, ANATOMY, AND BREEDING HABITS.

INTRODUCTION.

The study of *Phoronis architecta* was begun in the summer of 1901 and continued in the summer of 1902 at Beaufort, N. C. We are indebted to the Hon. G. M. Bowers, United States Commissioner of Fisheries, for the privilege of working in the Commission's station at Beaufort, where all the conveniences necessary for scientific investigation are at hand: to Prof. H. V. Wilson, director of the station in 1901, and to Dr. Caswell Grave, director during 1902, for many kindnesses.

While the study of the live material was for the most part done at Beaufort, the rest of the work was pursued in the zoological laboratory of the Johns Hopkins University.

Since the discovery of *Phoronis hippocrepia* by Wright in 1856, the affinities of this interesting genus have been more or less under discussion. Different investigators have sought to ally the Phoronidæ with the *Bryozoa*, the *Brachiopoda*, the *Sipunculida*, and other groups.

Roule (20) thinks that the Phoronidæ should be placed next to the Bryozoa in a natural classification. He does not consider that they have any affinity to the *Enteropneusta*, but from a study of the early stages of development he finds that they are related to the true *Chordata* (tunicates and vertebrates). He says, "lémbryon de Vertébré est une Trochophore renversée."

Lankester and McIntosh are inclined to consider *Phoronis*, *Cephalodiscus*, and *Rhabdopleura* as related forms, while Harmer (7) makes a comparison of *Phoronis* with *Cephalodiscus* and thinks that perhaps there may be some affinity.

Masterman (15, 16) in a series of papers made a comparison of the actinotrocha larva of *Phoronis* with *Balanoglossus* and its larva and also with *Cephalodiscus*. In this paper, he arrives at the conclusion that there is a close genetic relationship between the Phoronidæ, *Balanoglossus*, and *Cephalodiscus*. Since the appearance of Masterman's papers, Ikeda (9) has investigated the development of *Phoronis ijimai* and has made a careful study of several *Actinotrochæ* found in Japanese waters. Shortly after this, Longchamps (12) published a comparative study of the early development of several species of *Phoronis* and also of several species of *Actinotrochæ*, giving a very careful critical résumé of the work done by different investigators.

Menon (17) has lately published a short paper on the *Actinotrochæ*, in which he considers the Phoronidæ to be related to the *Chordata*, but thinks the relationship is to be traced through a form like *Rhabdopleura*.

This study of the development and anatomy of *Phoronis architecta* was begun before the publication of the last four papers mentioned, and when they appeared the abandonment of this investigation was seriously considered. However, since there seem to be specific differences and since there are several disputed points in the development, it seems best to publish the results of this study.

It is hardly necessary to enter into an historical account of the work that has been done on the development and anatomy of the Phoronidæ, since there are several papers which have reviewed the subject exhaustively.

METHODS.

Most of the material—eggs, larvæ, and adults—was fixed in a saturated solution of corrosive sublimate, to which had been added 2 per cent of glacial acetic acid. A fresh solution was made as soon as the fine white precipitate appeared, which is usually present in old solutions. This fixing agent gave very good results. Material fixed in Perenyi's fluid was found more valuable in some few respects than the acetic sublimate. When segmentation stages were treated with a 5 per cent solution of formaldehyde, the blastomeres stood out almost as distinctly as in the living material. The larger species of the two *Actinotrochæ* found in Beaufort Harbor is much more active than the other, and when it comes in contact with the fixing fluid the preoral lobe is bent upward into an unusual position. Consequently a few drops of 4 per cent solution of muriate of cocaine in 50 per cent alcohol was added to the water containing the *Actinotrochæ*. After this treatment they died in their usual form when put in the fixing fluid.

Flemming's fluid, as well as the acetic sublimate, was found to be a very valuable fixing agent for the *Actinotrochæ*. Heidenhain's iron hæmatoxylin was used in staining sections of the adult, and a secondary stain of alcoholic eosin or rubin gave very good results. The most satisfactory stain for sections of young larvæ and *Actinotrochæ* was found to be a solution of safranin in anilin water. Since it was very desirable to make a study of the adults throughout the year, and as it was not possible to remain in Beaufort for this purpose during the winter and spring months, specimens were collected and sent to Johns Hopkins University at different times. Here they were placed in aquaria filled with sea water, which was kept in good condition by a rich growth of diatoms on top of a layer of sand. Not only did the diatoms keep the water from becoming polluted, but they also afforded abundant food for the *Phoronis*, so that healthy individuals with their lophophoral tentacles fully expanded were continually at hand for a live study. The authors are much indebted to Dr. Caswell Grave, the originator of the diatom method in rearing *Echinoderm* larvæ, for the use of his aquaria. Drew's modification of Patton's method for embedding and orienting eggs was used with fairly good success, although a large percentage of the embryos were broken during the process. Most of the embryos were cut into sections 3 μ thick, but for some purposes sections 2 μ thick were used.

BREEDING HABITS.

Andrews's (1) observations on *Phoronis architecta* bring him to the conclusion that either the sexes are separate in that species or that if the individuals are hermaphroditic the male and female elements mature at different times. Many specimens examined by us during May, June, July, August, September, and October, both by means of sections and when alive, showed in no case ovaries and testes occurring at the same time in an individual, but ovaries and testes undoubtedly occur together in the same individual in *P. australis*. Benham (2) has observed this, as we have also, in material sent to us by Mr. Ikeda.

During the month of January the peritoneal tissues surrounding the blood cæca is very abundant, but as a rule at this time no eggs or spermatozoa are found in it. In one individual out of some 20 or 30 a few ovarian eggs were found, however. All of these specimens collected in January were without lophophoral organs, and we kept many of them in aquaria until the 1st of May. At this time lophophoral organs began to make their appearance in some, while in others they were absent. In all the specimens, however, either ovaries or testes were present, as was also the case in specimens collected at Beaufort in the early part of May. Further reference will be made to the lophophoral organs and their relation to the breeding season under the section which deals with the structure of the adult.

The breeding season of *Phoronis architecta* extends from March or April to November or December. Ikeda (9) has stated that "the breeding season of *Phoronis ijimai* ranges through about half of the year, say from November to June or July." There seems to be a surprising difference in the time of breeding between these two species. The *Actinotrochæ* at Beaufort are found throughout the summer and autumn, but they are especially abundant during August and September. Ikeda has suggested that *Phoronis* annually "changes its generation." It does not seem probable that this is the case for *Phoronis architecta*, because full-sized adults are found throughout the year in Beaufort Harbor, and specimens were kept alive for fifteen months in the laboratory of Johns Hopkins University.

THE LAYING OF THE EGGS.

During low tide in the summer and autumn it was easy to collect from 100 to 150 specimens of *Phoronis architecta* during an hour or two. About one-half of these would usually have male reproductive organs and the rest female reproductive organs. The *Phoronis* were placed in glass crystallizing dishes and after about twenty-four hours many of the individuals began to lay—usually at night—but the eggs were not retained among the tentacles in a mass, as described by most investigators, but were swept gently away from the lophophoral crown by the ciliation on the tentacles and on the anal region, so that they settled near by on the bottom of the dish. Sometimes, however, the newly laid eggs were carried up and down the tentacles in currents caused by the cilia, and occasionally a few eggs were found grouped near the tips of the tentacles, being held there loosely by a small quantity of mucus-like material. At no time, however, were eggs and larvæ aggregated in definite masses, as described by Ikeda (9), nor were they brooded among the tentacles, as Masterman (16) has observed in the case of *Phoronis buskii*. That eggs and embryos were not found by Longchamps among the tentacles of "*Phoronis d Helgoland*" is no doubt due to the fact that the same habit prevails in the above form that does in *Phoronis architecta*.

While the adults were laying, they were examined under the compound microscope. They showed large numbers of eggs which were floating freely back and forth in the body cavity as the animal contracted and expanded. Sections of adults in this condition show that all these free eggs contained the first polar body spindle. At intervals of about one minute an egg is extruded with considerable force from the nephridial opening, and in no case do the eggs at this moment have polar bodies. The wall of the nephridial ridge is transparent enough to see the eggs as they slip through the larger part of the nephridium. While passing through, they are pressed by the walls of the organ until they are about twice as long as broad (fig. 1). The fact that *Phoronis architecta* does not keep its eggs in masses within the tentacular crown, together with the fact that most of the individuals lay them at about the same time at night, makes it possible to preserve any one stage in the development of the embryo in sufficient quantity for a thorough study.

FERTILIZATION.

Ikeda (9) and Longchamps (12) made the observation that the eggs in the body cavity of the parent showed the spindles of the first polar body. This I found to be the case in *Phoronis architecta* (fig. 1). Eggs in the nephridia were found to be in the same stage, and in neither case was there any sign of an entering spermatozoon or a male pronucleus (fig. 1). There is no doubt of the fact that in *Phoronis architecta* the spermatozoon does not enter the egg until the latter has been expelled from the nephridium. Ikeda observed this fact for *Phoronis ijimai*.

SEGMENTATION.

The eggs of *Phoronis architecta* while still in the body cavity are somewhat irregular in shape, and, as mentioned above, are decidedly so while passing through the nephridium. However, after they are laid they become almost perfectly spherical and average 100 μ in diameter (fig. 2), thus measuring the same as the egg of "*Phoronis de Naples*." (Longchamps (12).) The egg is very opaque, being heavily laden with small yolk granules. It is surrounded by a delicate membrane, which, however, is not very conspicuous, being closely applied to the surface, but after fertilization it separates to some extent (fig. 2).

Observations on the segmentation of the egg of *Phoronis* are conflicting. This part of the development of *Phoronis* seems to have been treated hastily by most observers, probably because it is difficult to obtain sufficient material for its study. It is agreed that the segmentation is total. Foettinger (5) and E. Schultz (21) claim that the segmentation is unequal.

Caldwell (3) says that in the four-cell stage two smaller clear and two larger opaque cells are present. Masterman (16) finds that in the four-cell stage the blastomeres taper toward one pole, and that this results, when the third furrow appears, in the upper four being less in bulk than the lower four. Masterman's description, I find, applies to the eggs of *Phoronis australis*. Ikeda (9) did not discover any appreciable difference in the size of the blastomeres until the eight-cell stage. At this time, he says, "it will be seen that the upper four blastomeres are very slightly smaller than the lower four."

In *Phoronis architecta* the first cleavage plane is meridional and usually divides the egg into two practically equal blastomeres (fig. 3), although sometimes the division is decidedly unequal (fig. 4). The cleavage furrow begins in the region of the polar bodies (fig. 5). After the completion of the first cleavage and sometimes before, the first polar body divides (fig. 6). In fig. 6 is seen the reconstruction of the nuclei after the first cleavage. Immediately before the second cleavage the two blastomeres, which were closely applied to one another after the first cleavage, come to overlap. About fifteen minutes after the first cleavage the second cleavage takes place. It is meridional and at right angles to the first, dividing the two equal blastomeres into four equal blastomeres. As Ikeda has observed, the cleavage does not occur simultaneously in both blastomeres nor does it in later cleavages (fig. 7). The blastomeres of the four-cell stage which at first overlapped soon become applied to one another so that the two meet in a cross furrow (fig. 8). Shortly before the third cleavage occurs the cross furrow disappears and the blastomeres come to overlap. The third cleavage takes place fifteen minutes after the second cleavage, and it is equatorial. The blastomeres become drawn out into a more or less ovoid shape and, as division takes place, the upper four blastomeres become rotated in the direction of the hands of a watch (fig. 9). The eight blastomeres are approximately the same size, as a rule, and there is a small segmentation cavity present which from now on persists (fig. 10). The three polar bodies are distinguishable at this stage sometimes within the blastocœle and sometimes on the surface of the blastomeres. The blastocœle is open at the animal and vegetal poles. The sixteen-cell stage arises from the eight-cell stage by a meridional division of each of its blastomeres, but they do not all divide simultaneously (fig. 11), although the difference in time is very slight. After the sixteen-cell stage the individual blastomeres were not followed. The division takes place rather irregularly, but the blastomeres are all about of the same size.

The so-called "blastocœle pore," observed by Ikeda (9), was found occasionally in young blastulæ, but it does not seem to be of constant occurrence nor definite in position (figs. 12, 13).

Two hours after the first cleavage the blastula is composed of seventy or eighty cells, and it is still inclosed in the egg membrane. Four hours later the membrane disappears, and the ciliated blastula begins to swim (fig. 14).

The blastomeres were so much alike and so uniform in size that their individual history was not traced. It would seem probable from Masterman's work on *Phoronis buskii* (16) that the cell lineage might be followed in that form, for he finds considerable difference in the size of the blastomeres in the early stages of cleavage at least.

The apical pole of the ciliated blastula is provided with long cilia (fig. 14). The nuclei are situated nearer the outer than the inner surface, and the inner ends of the cells are filled with rather dense granules. In the segmentation cavity are found the so-called "corpuscles," which have been observed by most investigators working on the early stages of *Phoronis*. Caldwell's (3*a*) view that they are not mesoderm cells is undoubtedly correct. Our observations agree with those of Ikeda (9), for the "plasmic corpuscles" are much smaller than any of the cells of the blastula, and none with nuclei were found. In *Phoronis architecta* they do not appear until the late blastula stage (fig. 14), at which time the inner ends of the cells are densely granular. It seems very probable that the corpuscles are pushed out from the densely granular part of the cell, and that, as Caldwell and Ikeda have held, they are an extra supply of nourishment.

The blastulæ, gastrulæ, and young larvæ of *Phoronis architecta* are quite similar in appearance to those of *Phoronis d'Helgoland* which Longchamps (12) has figured. The development is more regular than that of most other species, which is probably due to the fact that the eggs and embryos are not harbored in the tentacular crown.

GASTRULATION AND FURTHER CHANGES IN THE FORM OF THE LARVA.

In the blastula, which has just begun to invaginate, the invagination is eccentric, thus giving the first indication of the bilateral symmetry of the larva. This is further emphasized in the young gastrula of *Phoronis architecta* by a thickening of the ectoderm cells, which becomes the ganglion of the *Actinotrocha*. The cells composing this thickening of the ectoderm are at the apical pole in the blastula and they bear long cilia, but as gastrulation takes place and as the embryo elongates the thickening comes to occupy a position nearer the anterior end of the larva (figs. 15, 15*a*, 15*b*). The published accounts seem to indicate that the ganglion makes its appearance much later in most species than it does in *Phoronis architecta*, although Roule (20) figures the "plaque cephalique" at a rather early stage in *Phoronis sabatieri*. The changes which take place in the shape of the blastopore are much like those described by other investigators. At the beginning of gastrulation the blastopore is wide open and circular in outline. The lateral lips of the blastopore then gradually draw together in the posterior region, inclosing that part of the wall of the archenteron between them (fig. 20*e*), which becomes a solid mass of cells continuous with the cells of the fused lips of the blastopore (figs. 18*d*, 18*e*). The cells of the solid mass are of the same character as those of the wall of the archenteron where the blastopore is open. They are quite granular, except at the periphery, where they project into the cavity of the blastocœle, and their nuclei are quite indistinct. Both of these facts are characteristic of the cells, making up the archenteric wall (fig. 18*c*).

As a result of the closing up of the blastopore posteriorly, the blastopore becomes oval in shape, and an indication of a ventral furrow, first observed by Caldwell and called a "primitive groove," appears. In *Phoronis architecta* this groove is only to be seen in one or two sections back of the blastopore, after which the ventral surface is convex (figs. 18*d*–20*e*). A "primitive streak," as described by Caldwell (3*a*) could not be made out. The gastrula, which is at first circular in horizontal section, becomes slightly elongated when the blastopore takes on an oval shape.

Gradually the blastopore lips close up more anteriorly until the blastopore becomes circular in outline but much smaller than it was originally. At the same time the anterior end of the larva begins to bend in a ventral direction and the archenteron becomes elongated posteriorly (fig. 20).

Now the larva increases slightly in length (fig. 21), the blastopore assumes the form of a transverse slit, the anterior end bends farther ventrally, and the posterior end of the enteron becomes applied to the ectoderm at the posterior end of the larva (fig. 21).

Our observations on *Phoronis architecta* agree with the description of Masterman (16), Ikeda (9), and Longchamps (12) in regard to the closure of the lips of the blastopore and the resulting change in the shape of the latter, but in *Phoronis architecta* the definitive blastopore does not seem to be pushed farther anteriorly by the special activity in the posterior region of the blastopore, as Ikeda has found to be the case for *Phoronis ijimai*. The definitive blastopore seems to be represented by the anterior part of the wide circular blastopore of the young gastrula. Its change in position with reference to the anterior end is due to an elongation of the posterior portion of the embryo and the ventral flexure of its anterior end.

Our studies on the development of *Phoronis architecta* lead us to agree with Ikeda and Longchamps as to the fate of the cells in the posterior part of the blastopore and as to the ectodermal origin of the "posterior pit." The cells of the posterior part of the blastopore become invaginated by the closure of the blastopore lips and form part of the ventral wall of the enteron, while the "posterior pit," which appears in *Phoronis architecta* shortly before the definitive blastopore is formed, is of ectodermal origin and has no apparent relation to the ventral groove. As Ikeda (9) has stated, the pit is the beginning of the nephridium of the *Actinotrocha*. In a recent paper Masterman (16*a*) says that he has found the "posterior diverticulum" both in larvæ of *P. buskii* and *P. hippocrepia* and that he considers them to be the anlagen of the nephridia.

FORMATION OF THE MESODERM.

There is considerable difference of opinion among those who have investigated the embryology of *Phoronis* as to the origin of the mesoderm, and there seem to be no two whose descriptions agree, although Ikeda (9) and Longchamps (12), in their recent papers, arrive at the same conclusions, generally speaking.

The study of the eggs and larvæ of *Phoronis architecta* and those of *Phoronis australis* show that the great difference in the origin of the mesoderm, as Roule (20) and Masterman (16) see it, may be due, in a great part, to difference in the larvæ themselves.

The eggs and embryos of *Phoronis australis*, for which we are indebted to Mr. Ikeda, are very similar in appearance to those of *Phoronis buskii*, judging from Masterman's figures (16). Sections of the eggs and larvæ of the former show the development to be of the same general type as that of *Phoronis ijimai*, which Ikeda (9) has described.

The eggs and larvæ of *Phoronis architecta* are considerably different from those mentioned above. They are more regular in form, the blastocœle is much more spacious and the cells themselves are more regular in shape and arrangement. They are most similar in appearance to the early stages of *Phoronis sabatieri* studied and figured by Roule (20) and those of "*Phoronis d'Helgoland*" figured by Longchamps (12).

The formation of the mesoderm begins in *Phoronis architecta* as soon as the flattened side of the blastula begins to gastrulate. In a few cases round blastulæ are found, within the blastocœle of which are rather large granular spherical bodies much larger than the plasmic corpuscles described above. Each of these contains an opaque body which takes saffranin stain with readiness. A comparison of these bodies with the nuclei of the cells of the blastula wall convinces one at once that they are not nuclei. In fig. 14*a* a section through such a blastula is shown in which these bodies are seen within the wall of the blastula as well as inside the blastocœle. They are embedded in the wall without reference to the limits of the cell and usually occupy the width of two cells. The cells inclosing these peculiar bodies do not differ from the cells surrounding them in that region and each has its own nucleus. These bodies are not the cut ends of amœboid processes which Caldwell (3*a*) and Roule (20) observed, for such processes do not occur in the blastulæ of *Phoronis architecta*. We are unable to make any positive statement as to their fate, but it is very probable that they break up into the smaller plasmic corpuscles. Such bodies as the former might easily be mistaken for mesoderm cells, and we suspect that the "mesoderm cells" observed by Foettinger (5), Metschnikoff (18), and E. Schultz (21) in the round blastulæ were of the same character.

The work on *Phoronis architecta* indicates that the mesoderm which forms the lining of the preoral lobe and the collar cavities of the *Actinotrocha* arises from the lips of the blastopore. As to the origin of the lining of the trunk segment, we are still in some doubt, but we are inclined toward Longchamps's suggestion that some of the cells of the nephridial pit give rise to it. Caldwell (3*a*) also holds that the mesoderm arises from the endoderm, assuming that the "posterior pit" (nephridial diverticulum), which he considers to be one point of origin of the mesoderm, is of endodermal origin. Roule (20) derives most of the mesoderm from the endoderm, but also considers the "bandelettes mésoblastiques," which Schultz (21) first pointed out to be the same as the posterior diverticulum of Caldwell, as giving rise to mesoderm.

As is seen on referring to fig. 15, the flattened part of the wall of the blastula has become more than one cell thick. In fact active cell division has taken place. Yet most of these cells are destined to become the wall of the archenteron, and only a few are to give rise to mesoderm. Careful examination of many sections fails to show that mesoderm cells ever have their origin from the dorsal surface of the archenteron. In this respect the development of *Phoronis architecta* seems to agree with that of *Phoronis kowalevskii* as described by Caldwell (3*a*) and Longchamps (12), and that of *Phoronis buskii*, which Masterman (16) investigated. In *Phoronis architecta*, as in the form studied by Longchamps (12), the anterior and lateral borders of the blastopore are most active in giving rise to mesoderm (figs. 16 *a*, *b*, *c*, *d*, *e*, *f*). Most of it is proliferated from the anterior end of the archenteron, and the power of producing the same seems to diminish gradually toward the posterior end of the blastopore lips in those gastrulæ where the round blastopore is just beginning to close up (figs. 16 *a*, *b*, *c*, *d*, *e*, *f*).

The mesoderm cells are very amœboid in character and are often seen in living specimens and sometimes in sections sending out long pseudopod-like prolongations, which become attached to the walls of the gastrula. By means of these amœboid movements they are able to crawl up the walls of the blastocœle.

We were unable to make out any structure in *Phoronis architecta* which could be interpreted as "archenteric diverticula," such as figured by Caldwell (3*a*) and Ikeda (9). Fig. 16*e* might be interpreted as showing these diverticula, but the condition there is hardly different from the arrangement of the mesoderm cells, which are being pushed out into the blastocœle in front of the blastopore (figs. 16, 16*b*). Caldwell first observed these structures in the gastrulæ of *Phoronis kowalevskii*, but Longchamps (12), who has recently carefully studied the same species, has been unable to find them. Ikeda (9), however, finds very definite diverticula in the gastrulæ of *Phoronis ijimai*, but he figures them as being in the region of the blastopore, while, according to Caldwell's (3*a*) figures, they are found posterior to the blastopore.

Let us return again to the mesoderm cells which lie anteriorly to the blastopore. These amœboid cells undoubtedly multiply while in the blastocœle, and in a gastrula where the blastopore lips have closed up somewhat so as to give an oval outline to the blastopore (fig. 18*f*) these cells have become arranged into a definite sac (figs. 19, 20*a*), which is later to form the lining of the preoral lobe. In no case were we able to find the least indication of an anterior unpaired diverticulum, which Masterman (16) says exists in the gastrula of *Phoronis buskii*. At this stage the cavity of the sac is small and is present only in front of the blastopore. The walls, however, are extended on each side into a lateral cord of mesoderm cells, which lies in the blastocœle at the side of the blastopore (fig. 18*f*). Some of the cells of the dorsal wall of the sac send out pseudopodia, which attach themselves to an ectodermal thickening, and this thickening will become the ganglion of the *Actinotrocha* (fig. 19).

The above condition continues until the oval blastopore becomes smaller and round in outline (figs. 20, 20*c*), which change is also accompanied by further growth of the enteron in a posterior direction until it almost touches the end of the larva. The cells of the two lateral cords of mesoderm have now increased in number, have arranged themselves so as to inclose a cavity, continuous with the cavity of the anterior one described above, and have become attached both to the lateral ectodermal wall and the lateral endodermal wall (fig. 20*b*). Anteriorly this sac, which is now horseshoe shape (fig. 20*c*), is still only attached to the ganglionic thickening and the ventral ectodermal wall (fig. 20). The conditions just described are not due to the shrinkage of the mesodermal lining away from the wall of the larva, for the transparency of the living larva makes it possible to see the formation of the mesodermal sac. We have followed this formation step by step many times in the living gastrula and larva, as well as in sections and surface mounts.

As the anterior end of the larva bends farther ventrally and becomes a definite preoral lobe, the round blastopore assumes the shape of an oval with its major axis transverse to the long axis of the larva (fig. 21). The posterior part of the larva increases in length and the enteron sends out a posterior diverticulum, the beginning of the intestinal canal, whose blind end fuses with the ectoderm of the posterior end of the larva. The walls of the mesodermal sac become applied to the walls of the preoral lobe more generally, thus forming a definite mesodermal epithelium for the cavity of the preoral lobe (figs. 23, 21, 22). Posteriorly, as Masterman (15) has described for the fully developed *Actinotrocha*, the cavity is produced "into two horns running back laterally" (fig. 22*a*), but as yet there is no complete mesodermal lining in the cavity back of this (figs. 22 *b*, *c*). The posterior wall of the mesodermal lining of the preoral lobe forms a definite septum (figs. 21, 21*a*), but it is not as yet, at least, composed of two layers, as Masterman finds in the older *Actinotrocha*.

While the above changes have been taking place in the preoral end of the larva there has also been some change in the postoral region. It is seen from figs. 16 *c, d, e, f* that in the young gastrula with the large circular blastopore mesoderm cells are being pushed out into the blastocœle along both sides of the archenteric wall back almost to the posterior border of the blastopore. At this stage large spherical cells with rather small, deeply staining nuclei are sometimes seen floating freely in the blastocœle (fig. 17*a*). These cells have their origin in the wall of the archenteron (fig. 17) and are quite different from the bodies found in the blastocœle of the blastula. They have a definite nucleus and they seem to be similar cells to those found by Ikeda in the larva with one pair of tentacles. They certainly do resemble the blood corpuscles found in the older larvæ, only they are considerably larger. Ikeda (9) came to the conclusion that these cells were the "mother cells of blood corpuscles which are found as corpuscle masses in the collar cavity of the *Actinotrocha*." Since the publication of his paper Mr. Ikeda has written that he considers his theory concerning the fate of these cells to be incorrect. They are easily distinguishable from all other cells by the fact that they are larger and that the cytoplasm does not stain. They have a nucleus which is rather small. We shall return to a consideration of these cells when we describe the blood corpuscles of the *Actinotrocha*.

As the blastopore lips begin to close up posteriorly (figs. 18 *d, e*) the endoderm cells in that region lose the power of giving rise to mesoderm cells, but they are still found arising in a more anterior region.

At a little later stage, in which the blastopore has become circular again after the fusion of the blastopore lips and the enteron has almost reached the posterior end, a few mesoderm cells are seen lining the ventral ectoderm in the posterior region (fig. 20*d*). These cells, however, do not have their origin from the wall of the posterior part of the enteron nor from the ventral ectoderm which Caldwell (3*a*) would call the "primitive streak." The cells forming the ventral ectoderm are very regularly arranged into a layer one cell thick and all the nuclei are in a resting state. The mesoderm cells have either migrated from the cells of the lateral cords which are prolongations of the sac, forming the lining of the preoral lobe (fig. 20*e*), or from the region of the blastopore, where some mesoderm cells are still arising. In general, our interpretation of the facts bearing on the origin of the mesoderm in the posterior region of the larva agrees with that of Longchamps (12) for *Phoronis kowalevskii*.

When the larva reaches the stage shown in fig. 21 where the blastopore is transverse and the archenteron fuzes with the posterior ectoderm, the mesoderm cells are found to be more numerous in the posterior region, and in nearly all cases they are applied to the ventral suface of the blastocœle. At this time the proliferation of mesoderm cells from the endoderm has ceased in the anterior region and there is no indication of any mesoderm cells being given off from most of the posterior region. At the extreme posterior end of the enteron, however, a transverse section across the larva (fig. 22*d*) shows a mass of cells which might be taken for proliferating mesoderm cells. Traced farther back, this mass of cells is found to be part of the wall of the "posterior pit," or, as Ikeda (9) has called it, "the nephridial pit" (figs. 22 *e, f, g*). The fate of the cells of the nephridial pit will be discussed in the description of the larva with two tentacles.

Larvæ like the one just described do not show the least trace of a mesentery between the collar and trunk. In fact, one could hardly say that a trunk existed at this time. The oblique strongly ciliated tract of ectoderm which indicates the line of origin of the larval tentacles has not appeared.

FURTHER GROWTH OF THE YOUNG LARVA.

The flexure of the preoral lobe continues as the larva grows older (fig. 24). In this way a vestibule is formed and the original blastopore becomes the part which connects the vestibule and archenteron (fig. 24). This relation between the vestibule and blastopore has been recognized by Masterman (16), Roule (20), Ikeda (9), and Longchamps (12). Longchamps speaks of it as a "stomodæum," and Masterman does also, but the latter adds "œsophagus" after it. (If our idea that a stomodæum is a pitting in of the ectoderm which finally breaks through into the enteric cavity is correct, then Masterman's and Longchamps's use of the word is incorrect.)

Masterman speaks of a "slight ridge" running around the edge of the preoral hood and then "downwards till it is lost on the surface of the tentacles." Such a ridge is not present in the larva of *Phoronis architecta* and there is no connection between the ciliated tract along the line of which the larval tentacles arise and the ciliated edge of the preoral hood.

At this stage (fig. 24) a definite intestinal canal is seen which, however, does not open yet to the exterior. The intestine, as described above, is not of ectodermal origin in the larva of *Phoronis architecta*. There is no proctodæum. On this point our observations agree with those of Masterman, Longchamps, and Ikeda.

Roule (20) says: "Un anus et rectum se façonnent, aux dépens de l'ectoderm, sur l'extrémité postérieure du corps" (p. 102), and Caldwell (3*a*) derives the intestine from the remains of the "primitive streak."

As yet the anal papilla is not at all definite, but the ciliated band along which the larval tentacles are to arise has now appeared. This is indicated in the sagittal section (fig. 24) by a thickening of the ectoderm.

The mesoderm cells which in fig. 21 are seen applied to the ventral ectoderm of the larva have now increased considerably in number and have become arranged at quite definite intervals (fig. 24). If the ventral surface of the larva is examined, while the larva is alive, it will be seen that these cells have become simple muscle cells made up of two rather delicate fibres which extend from a large nucleus situated near the mid-ventral line. These fibres run parallel to one another around the wall of the larva (fig. 25).

The whole body cavity back of the mesentery between the cavities of the collar and lobe represents the larval collar cavity of the *Actinotrocha*, and although its somatic walls are not lined by a perfectly continuous mesodermal epithelium, yet there are indications that such a lining is being formed. The ventral and lateral walls of the stomach, however, are perfectly free from any epithelial covering. In fact, in all the Actinotrochæ examined no mesodermal epithelium covering the ventral and lateral walls of the stomach in the collar region could be found. We have never seen any sign of mesodermal sac-like formation such as occurs in the preoral lobe.

Roule (20, p. 112) has described in a considerably older larva than the one with which we are dealing certain mesodermal cells to which he has given the name "conjunctivo-musculaires elements." These he represents as spindle-shaped cells terminated by long fibre-like prolongations and he has figured them as being quite numerous in the "plasma, transparent et consistant," of the coelomic cavity. While the young larva of *Phoronis architecta* bears a close resemblance to that of *Phoronis sabatieri* described by Roule (20), yet at no time during the life of the larva have we seen these cells suspended in the body cavity in such numbers as he has shown. Spindle-shaped cells with long prolongations are quite numerous, but they are usually found applied to the somatic walls of the larva.

Although recent investigators have thrown some doubt on the existence of the lobe-collar septum, yet such a septum unquestionably exists in the larva of *Phoronis architecta*. Ikeda (9) has shown that it is incomplete in the old actinotrocha and our observations agree with his, but it is a fact, nevertheless, that the septum is continually present throughout the larval life of *Phoronis architecta* and that it makes its appearance at a very early stage in the life history.

Longchamps (12) says: "Si une subdivisions plus ou moins complète s'établissait, entre ces deux regiones, elle ne seriat en tout cas que secondaire, et la cloison s'édifierait aux dépends de mésenchyme." It is plain from what has been said that we can not agree with Longchamps in his statement that the septum is secondary. It must be admitted, however, that the septum between the lobe and the collar is often considerably thinner than that between the collar and the trunk. If its origin had not been followed from the earliest stages by means of sections in three different planes, whole mounts and live material, we should not have been inclined to consider it a primary and constant organ of the larva.

We had confidently expected to find in the larva of the stage represented in fig. 24 some indication of the mesentery between the collar and the trunk, but were disappointed. Although the ciliated tract along which the tentacles are to arise has made its appearance and extends obliquely around the body proper of the larva, indicating a line just a little above the line of separation of the cavities of the trunk and collar in the older actinotrocha, yet examination of sections does not show the least sign of the mesentery or its fundament.

Ikeda (9) has found mesoderm cells connecting the nephridial canals with the splanchnic walls, and he thinks they are the first indication of the septum between the collar and trunk cavities. We have not been able to find the paired masses of "hypoblast cells" which Masterman (16) says give rise to the trunk cavities, although it is true that mesoderm cells were found lying on the dorsal wall of the intestine. Masterman does not follow the fate of these masses, but in the larva with three pairs of tentacles he speaks of "the two mesocœles pushing dorsally, their walls forming a pair of conspicuous mesenteries with the walls of the metacœles" (p. 395).

As has been said, the masses of cells that Masterman (16) speaks of have not been found, but we do not deny that the condition which he describes may exist in the larva of *Phoronis buskii* with three pairs of tentacles.

"*Nephridial pit*" (Ikeda).—A structure of the larva of *Phoronis* which has given rise to considerable controversy is the "nephridial pit" ("posterior, anal, ectoblastic pit," "posterior diverticulum"). It seems safe to assume that such a structure exists in the young larvæ of all species of *Phoronis*. It has been seen by Caldwell (3*a*) in *P. kowalevskii*, by Ikeda (9) in *P. ijimai*, by Longchamps (12) in *P. kowalevskii*, by Masterman (16*a*) in *P. buskii* and *P. hippocrepia*, and by us in *P. architecta*. Although Roule (20) has not observed the pit in *P. sabatieri*, it seems probable that such a structure will be found there on further investigation. It is difficult to believe that Roule's understanding of the origin of the nephridia from two cell masses of somatopleure symmetrically placed at the sides of the larva is correct. As stated above, we consider the pit to be of ectodermal origin (fig. 24). Further study of the structure leads us to agree with Ikeda that it divides into two lateral branches, each of which becomes a nephridial canal of the actinotrocha (figs. 25, 26, 27, 28). In fig. 25, which is a drawing made from a living larva, the canals, which in a little younger stage were practically the same diameter throughout their length, have become tipped at their distal ends with a bunch of cells which, we believe, are later to form the excretory cells of the nephridium.

No positive statement concerning the origin of these cells can be made, since it is difficult to obtain many larvæ of *P. architecta* which are old enough to show these bunches of cells in the process of formation. The sections examined afford no evidence that they are formed by free mesoderm cells attaching themselves to the internal ends of the nephridial canals, and we are rather inclined to consider them as arising from the cells of the internal blind ends of the nephridial canals (figs. 25–28). Ikeda's description (9) of the way the nephridial tubes arise from the ectodermal pit—i. e., by the "reevagination of the distal unpaired portion of the nephridial pit"—seems to be correct. Longchamps's (12) interpretation of the change in form of the "ectodermal pit" agrees quite closely with Ikeda's description.

"*Medullary plate*" (Roule).—When the young larva of *Phoronis architecta* has reached the two-tentacle stage cross sections show that there is a definite ventral ciliated band extending from the mouth to the ciliated tentacular band (figs. 29, *b*, *c*, *d*, *e*). This ventral ciliated band has been observed by Roule (20) in the larva of *P. sabatieri*, but it has not been described for any other species. Roule has homologized it with the medullary plate or medullary groove of the annelid larva.

"*Trunk cavity*."—Longchamps has drawn attention to a figure of an *Actinotrocha* published in Hatschek's "Lehrbuch der Zoologie." In this figure are represented two cœlomic sacs surrounding the intestine. Hatschek does not describe the origin of these sacs, but Longchamps (p. 555) proposes the question, "Si les canaux ne derivaient pas des expansions latérals du diverticule ectoblastique, chacun des canaux restant en rapport avec l'extérieur par un orifice résultant du dedoublement de l'orifice primitif et médian, tandis que le restant du diverticule ectoblastique deviendrait la cavité postérieure du corps."

Such an origin for this posterior cavity would seem to be a possible one and would give an easy explanation for the origin of the collar trunk and ventral mesenteries.

We believe that the cavity of the trunk is formed in the following manner: As the tentacles grow out and increase in number the posterior region of the larva about the rectum increases greatly in length. In doing the latter the mesodermal lining of the collar is drawn away from the somatic wall in the region back of the tentacular band, and a cavity is left containing the rectum, part of the stomach, and the proximal part of the nephridial diverticula. At the same time this is taking place certain cells which seem to arise from the base of the nephridial diverticula give rise to the lining of the cavity of the trunk. As to the manner of origin of these cells we are still in doubt. We have not found two cœlomic sacs which Hatschek (8) seems to have figured (it is possible that his figure is meant to represent a single sac cut at two places), and we have hunted for them in larvæ where the diverticula are just beginning to form and also in larvæ with two, four, and six tentacles. In one specimen with two tentacles, however (fig. 30), an arrangement of mesodermal cells on the dorsal side of the intestine which seems to be the beginning of a sac is found; this, however, is not paired. Whether or not this sac and its cavity give rise to the lining and cavity of the trunk we can not say, for we have found but one specimen in which this condition exists.

One thing is certain, the fully developed trunk cavity of the *Actinotrocha* has a distinct mesodermal lining, consisting of a somatic and a splanchnic layer. As far as we know all *Actinotrochæ* have a ventral mesentery, which tends to support the view that the lining of the cavity of the trunk has its origin in a sac which grows around the rectum and posterior part of the stomach. Whether or not the fact that there is an indication of a dorsal mesentery in the posterior region of some of the fully developed *Actinotrochæ*, Species B., has any bearing on the double origin of the cavity of the trunk we can not say, for we have never seen the very young larvæ of this form.

The youngest larva taken from the tow had three pairs of tentacles, with beginnings of the fourth pair. In this larva the tentacles had grown considerably in length, and the posterior region had become somewhat elongated (fig. 31). Only one specimen of this age was obtained, and it was only studied while alive. The mesentery between the collar and lobe was plainly seen, and there seemed to be a thin mesentery between the region of the collar and the younger trunk region. The nephridial canals were seen with difficulty, but the rounded bunches of excretory cells forming the internal ends of the canals were plainly visible.

When the larva of *Phoronis architecta* has five pairs of tentacles (fig. 32) the trunk region is elongated considerably and constitutes about one-half the length of the larva. In fact, the larva at this stage looks much like the fully developed *Actinotrocha*. The "retractors" described by Ikeda (9) are now present and the body wall in the anal region shows a thickening which is to become the perianal ciliated band. This larva shows clearly the presence of two mesenteries.

In the larva with six pairs of tentacles (fig. 33) all of the organs of the fully developed *Actinotrocha* are present. The ventral pouch begins to invaginate (fig. 33) and sections usually show that the blood corpuscle masses are forming.

FULLY DEVELOPED ACTINOTROCHA.

There are two species of *Actinotrochæ* found in the waters of Beaufort Harbor, and they are very similar, if not identical, with the two species that E. B. Wilson (24) observed in Chesapeake Bay. From the latter part of May until the latter part of September both species are fairly abundant in the tow.

Wilson has designated the two species found in Chesapeake Bay as Species A. and Species B., and because of the general agreement between our observations and his descriptions the Beaufort *Actinotrochæ* will be designated as Species A. and B., although we are satisfied that Species A. is the larva of *P. architecta*.

Species A.—Species A. (fig. 34) is somewhat smaller than Species B. and its average length is 1.03 mm. The trunk is quite stout, the intestine is short, and the posterior end of the stomach reaches as far as two-thirds of the length of the trunk cavity. When about ready to metamorphose, this larva usually has 18 larval tentacles and an equal number of young adult tentacles. The adult tentacles do not usually appear until the larva has 18 larval tentacles (its full number) and they arise as thickenings on the under side of the bases of the larval tentacles. In this respect the larva resembles one of the actinotrochæ which Ikeda (9) has described. The blood corpuscles are found in two masses usually applied to the ventro-lateral surface of the stomach, and they make their appearance in the larva with 12 or 14 tentacles. A pair of muscles which Ikeda has been the first to describe, and which he has called "retractor muscles," are always present; although they have not been made out in younger larvæ than those with 10 tentacles. This species is without the so-called "stomach diverticula." Pigment cells are found rather irregularly scattered on the wall of the body cavity. There are definite aggregations of these at the bases of the tentacles, and a few pigment cells are seen on the surface of the blood corpuscle masses. Usually there are quite a number in the wall of the posterior portion of the trunk.

This *Actinotrocha* is not as active as Species B. and it does not, as a rule, turn up its preoral hood when irritated. Its metamorphosis usually takes place quickly, fifteen or twenty minutes being required for its completion. *Actinotrocha* Species A. is, no doubt, the actinotrocha of *P. architecta.*

Species B. (*fig. 35*).—This *Actinotrocha* is larger than Species A., and when about ready to metamorphose it has an average length of 1.22 mm., and has at least 26 tentacles. (Wilson (24) figures the *Actinotrocha* Species B., ready to metamorphose, with 22 tentacles.) The difference in appearance between this larva and Species A. is rather striking. Beside being somewhat longer, it is slightly narrower in the collar region and decidedly so in the trunk region, which gives it a much more graceful appearance than that of Species A. The intestine is quite long, extending throughout the posterioı two-thirds of the trunk cavity.

M. Longchamps has kindly pointed out to me that the "adult tentacles appear bilaterally, the mid-ventral line being, at first, free of the buds." They do not arise, however, as thickenings on the under side of the bases of the larval tentacles as in Species A. They have their origin at the base of the larval tentacles, but they are separate from them, and they appear first in the larva with 24 tentacles.

This *Actinotrocha* differs in three important respects from *Actinotrocha* Species A. In the first place it has its blood corpuscles aggregated into four masses, two of which are usually in the same position as the pair in the smaller species. The other two, however, are found, as a rule, more anteriorly in the collar cavity, and are applied to the dorso-lateral walls of the stomach. The posterior pair lying on the ventro-lateral sides of the stomach make their appearance during the 18 or 20 tentacle stage, but the other pair do not appear until about the 22-tentacle stage. This larva also has retractors extending from the ganglion to the region of the first and second pair of tentacles.

A second point of difference is the fact that *Actinotrocha* Species B. possesses a pair of diverticula at the anterior end of the stomach. These are present as early as the 22-tentacle stage. This larva can further be distinguished from the other species by the fact that there is found in the older larvæ a sensory papilla on the mid-dorsal surface of the preoral lobe.

Actinotrocha Species B. is much more active when irritated than the other species. The least irritation causes it to turn up its hood and to assume attitudes like those figured by Masterman (15). In fact, judging by the figures and text of Masterman's paper, it seems that there is considerable similarity between this larva and the one he has described. The two larvæ are very much alike in shape and both have the lateral stomach diverticula, but the form that Masterman describes has only two masses of blood corpuscles. The two species are not identical, nor is *Actinotrocha* Species B identical with *Actinotrocha branchiata* from the North Sea, for, as Longchamps has pointed out to us, the latter has but two blood corpuscle masses. Longchamps has informed us that in *Actinotrocha* Species B. the adult tentacles make their appearance in the same special way that they do in *Actinotrocha branchiata* (found near Helgoland and described by J. Müller (19); and Masterman (15) says in his paper that the form he worked on "does not appear to differ in any essential respect" from *Actinotrocha branchiata*. There seems, however, to be considerable difference in size between *Actinotrocha branchiata* and *Actinotrocha* Species B., for, according to Longchamps, the best-developed specimen that he obtained of this species measured 2 mm., while the length of *Actinotrocha* Species B. averages 1.22 mm.

Although *Actinotrocha* Species A. seems to metamorphose without any difficulty when brought into the laboratory, yet we have never been able to induce *Actinotrocha* Species B. to do so. Specimens have been kept for ten days or more (the pouch and blood corpuscles being well developed) and in some cases they succeeded in evaginating the ventral pouch, but they were never able to complete the metamorphosis.

As far as we know, the adult of this *Actinotrocha* has never been found, but probably it lives under quite different conditions from *Phoronis architecta*, and it is not improbable that it may be found as a deep-water form.

INTERNAL ORGANIZATION OF THE FULLY DEVELOPED ACTINOTROCHA.

"*Subneural gland*" (Masterman).—Masterman (15) has described a depression in the dorsal wall of the buccal cavity which he terms a "subneural gland" and which he compares with the gland of the same name in the Tunicata and also possibly with the hypophysis of the Vertebrata.

Roule (20) and Ikeda (9) are of the opinion that this depression is a product of the fixing method.

Longchamps (12) does not consider it to be an accidental structure, but he does not agree with Masterman's view as to its theoretical significance.

Menon (17) says that the "subneural gland" first appears in connection with the collar and that during development it shifts forward into the preoral lobe, but in another part of his paper he says the œsophagus is often folded transversely (this also the case in the young *Phoronis*) into pouches and the "subneural gland" is a diverticulum of its dorsal wall.

While in examining sections we have frequently found a depression in the region that Masterman (15) indicates, we have never found it in the living larva. Only in very poorly killed larvæ have we found the depression to be as deep as Masterman has shown, and in all cases the structure of the wall is practically like that of the œsophagus.

In the *Actinotrochæ* Species A. and B. there is no depression in the living larva which might be homologized to the subneural gland of higher animals, and we are forced to agree with Roule and Ikeda in their belief that the so-called "subneural gland" which Masterman describes is a product of fixation.

"*Oral and atrial grooves*" (Masterman).—Masterman (15) has observed a mid-ventral ciliated area leading into the mouth from the preoral lobe in front and a broad ciliated area depressed into two oral grooves leading into it from the ventral surface of the collar area. He has also seen two so-called "atrial grooves" leading into the dorso-lateral corners of the mouth. Masterman says he does not find gill-slits in the *Actinotrocha*, nor does he find structures that he considers to be their homologues. "The atrial grooves" of the *Actinotrocha*, he says, however, are the analogues of gill-slits (15, p. 319). On page 358 (15), however, he says that "tentatively, I would regard the atrial grooves of the *Actinotrocha* as the early rudiments of pharyngeal clefts as found in Cephalodiscus."

His "oral grooves," he says, correspond to the oral grooves in *Cephalodiscus*.

Roule (20) does not find the "atrial grooves," but finds two lateral grooves, which he considers to be formed by the insertion of the hood on to the collar wall.

Ikeda (9) and Longchamps (12) are of the opinion that these grooves do not normally exist.

We have made a careful study of the live *Actinotrocha* and of surface mounts, but have not been able to make out these grooves in either Species A. or Species B. Sections, however, show that the "oral grooves" are present, and that in most preparations where the preoral hood has been turned upward by violent contraction (due to the fixing agent) there are two short grooves in the position in which Masterman finds the "atrial grooves." In those cases in which the hood remains in its normal position we have seldom found Masterman's so-called "atrial grooves," and even in a few cases where the hood is turned upward they have been absent.

The ventral wall of the hood just as it passes into the wall of the œsophagus not infrequently shows a pair of bilaterally situated grooves which are similar to those found on the ventral collar wall.

"*Neuropore*" (Masterman).—See section on the nervous system.

"*Subneural sinus*" (Masterman).—Another organ which Masterman (15) has described is a sinus immediately below the nerve ganglion, caused by the want of contiguity between the mesoblastic walls of the preoral cavity and the collar cavity. This sinus, he claims, is closed except for a fissure which leads eventually into the dorsal blood vessel. He compares this sinus to the heart of Balanoglossus.

Menon (19), as far as we know, is the only other worker on the *Actinotrocha* who claims that there is a definite vesicle beneath the ganglion and he has discovered no connection between its cavity and the dorsal blood vessel.

Roule, Longchamps, and Ikeda do not find this organ, but the latter recognizes the existence of a space ("posterior recess") free from mesenchymatous fibres, which is the posterior part of the preoral lobe. This, however, he says, does not connect with the dorsal blood vessel.

From the study of the early development of *Phoronis architecta* and the origin of the mesentery between the hood and the collar, we have come to the conclusion that no vesicle is formed in that species between the two layers of the mesentery (if two layers exist). The mesentery which forms the posterior wall of the preoral lobe cavity is found attached just back of the ganglion in the median line and there is not the least sign of a vesicle other than the cavity of the preoral lobe (fig. 24).

In neither *Actinotrocha* Species A. nor *Actinotrocha* Species B. have we found a vesicle below the ganglion, although in both cases there is a space such as Ikeda (9) has seen, free from mesenchymatous fibres. The anterior boundary of this space is rather sharply defined and occasionally among longitudinal sections a fibre with a nucleus is seen running vertically from the dorsal to the ventral wall of the hood, giving the appearance of an anterior wall to the space. These fibres, however, are very much more delicate than the wall of the collar lobe septum, and what is more, they occur only occasionally and are evidently not sections through a membrane.

In the *Actinotrochæ*, which we have examined, there does not exist any vesicle beneath the nerve ganglion nor any structure which could be likened to the heart vesicle of *Balanoglossus*. For the supposed relation of the dorsal blood vessel to the "subneural sinus," see Blood system.

"*Stomach Diverticula*" (Ikeda, Longchamps, and Menon).

"*Notochords*" (Masterman and Roule).

Ever since Johannes Müller (19) saw the paired "blinddarme" in *Actinotrocha branchiata* nearly all of those who have studied *Actinotrochæ* have observed the same structures. Some have considered them to be liver diverticula, others have described them as dark masses with globules and as brown specks. Wilson calls them "glandular lobes of the stomach."

Ikeda (9), Longchamps (12), and Menon (17) speak of them as "stomach diverticula," but they do not ascribe any function to them. Masterman (15) and Roule (20) look upon them as rudimentary notochords. Roule, Ikeda, and Longchamps have studied larvæ in which the diverticulum was not paired and lateral, but unpaired and medio-ventral. The latter investigator has observed larvæ of both types.

We find that in Species A. the diverticulum is undeveloped even at the time of metamorphosis, while in Species B. the diverticulum is paired, well developed, and ventro-lateral.

Longchamps has very justly objected to Masterman's use of the name "*Diplochorda*," under which the latter includes the Phoronidæ and *Cephalodiscus*.

The diverticula of Species B. do not show the regularly arranged vacuoles which Masterman has described for the *Actinotrocha* from St. Andrews Bay. In fact, we agree with Longchamps's (12) observations in finding the histological characters absolutely different in Species A. and B. from the histology of notochords, and there is not the least indication of supporting tissue.

However, larvæ which we have examined, fixed in Flemming's fluid, have not shown the vacuoles to be filled with fat droplets as Longchamps states.

Sections through the diverticula of quite old larvæ (fig. 35) stained with iron hæmatoxylin show columnar cells, nearly every one of which contains a deeply staining body about one-quarter the size of the nucleus. The bodies are not found in the wall of the stomach proper, and we believe that they give the yellowish-brown color to the diverticula of the live *Actinotrocha*.

In some cases we have found old larvæ in which the cells of the diverticula were vacuolated, but in these cases we have also found that the entire stomach wall was vacuolated. The vacuoles were never large enough or numerous enough to alter the natural position of the nuclei.

According to Masterman's description, the first vacuoles are formed at the distal ends of the cells and more vacuoles arise later between these and the inner ends of the cells. As far as we know, the origin of vacuolated tissue in vertebrates is the reverse of this, the vacuolization beginning at the center of the cord and traveling outward.

The specimens of *Actinotrochæ* of *Phoronis sabatieri* which we have examined show the structure of the stomach diverticulum to be very similar to that of the diverticulum in the *Actinotrocha* Species B. The diverticulum, however, is somewhat more vacuolated in the former than in the latter, but it does not show the peculiar structure which Masterman has described for the "notochord" of the species from St. Andrews Bay.

It is hard to see what use the *Actinotrocha* has for any organ of support in the region where the diverticula are found and it seems much more probable that they have a glandular function.

Nervous system.—It is generally admitted among investigators who have studied the anatomy of the *Actinotrocha* carefully, that the creature has a subepidermal layer of nervous tissue throughout the body which is fibrillar in character. This nervous tissue assumes the form of quite definite tracts in certain parts of the body in *Actinotrocha* Species B, and fairly well-developed nerves can be said to exist. The most conspicuous ones are found in the median dorsal line of the preoral hood as three distinct longitudinal bundles of nerve fibres extending from the ganglion to the anterior edge of the hood. There are other tracts which, though they are not as definitely marked out as the above, are undoubtedly nerves.

Masterman (15) in his work on the anatomy of the *Actinotrocha* from St. Andrews Bay has described a complicated nervous system, but the investigations of Roule (20), Ikeda (9), and Longchamps (12) have thrown considerable doubt on the correctness of his observations. Whether these differences have been due to differences in the *Actinotrochæ* studied by these workers or whether they are due to the technique it is impossible to say, but, judging from the difference in the degree of development between the nervous system in Species A. and Species B., we are led to believe that the disagreements are due partly to the fact that no two of these investigators have studied the same species of *Actinotrocha*.

While the nervous system of Species A. can with careful study be shown to be very similar to that of Species B., yet it is so feebly developed that without first having studied *Actinotrocha* Species B. we should not have been able to see the similarity in the disposition of the different nervous tracts. The ganglion with its three dorsal longitudinal nerves running along the median line of the hood is easily seen in the live larva of Species A., but in sections we have found it impossible to trace the latter. The sensory papilla mentioned in the description of the *Actinotrocha* Species B. is absent in this species.

We are pleased to be able to confirm, to some extent, Masterman's (15) description of the nervous system of the *Actinotrocha*, especially since a shadow of doubt has been cast upon his work by some who have studied the *Actinotrocha*.

Partly because Species B. seems to be a much more highly developed *Actinotrocha* than Species A., and partly because of its similarity to the one that Masterman studied (which is of so much theoretical interest), we shall confine the description and figures to the nervous system of Species B., although we are convinced that this *Actinotrocha* is not that of *Phoronis architecta*, but of an adult that has not been discovered.

We must admit that we have been very unsuccessful in the attempt to study the nervous system of the *Actinotrocha* by means of methylene blue and ammonium molybdate. Gold chloride has given no better results than staining with iron hæmatoxylin.

If the dorsal surface of the hood of a live *Actinotrocha* Species B. be examined, one will find that there are a great many fibres which run in more or less definite tracts (fig. 36). Many of these fibres have nuclei along their course and are undoubtedly muscle fibres, while others run to the edge of the hood and there seem to be continuations of certain cell-like bodies which Ikeda was the first to describe (fig. 37). Although we have seen these bodies on all occasions in surface views stained with methylene blue, yet in sections we have never been able to make them out, if they are nerve cells. It must be mentioned, however, that in transverse sections through the edge of the hood every 3 μ section shows at least one nucleus closely applied to the ring of nervous tissue running round the edge of the hood (fig. 43). These occupy the same position with reference to the edge of the hood that the cell-like bodies do which are seen in surface views, but we take them to be the nuclei of muscle cells, and frequently we have traced deeply stained muscle fibres arising from them (fig. 43). Within the nervous tissue of the preoral ring we have found no structures which we could consider to be the cell-like bodies mentioned by Ikeda (9).

Ikeda has figured a great many fibres arising from the ganglion, but in the *Actinotrochæ* that we have examined we have not been able to see the connections; however, we do not wish to deny that they exist.

The three median nerves arising from the anterior side of the ganglion and running forward to the edge of the hood, and two longitudinal tracts of nerve fibres arising from the posterior side of the ganglion, can be easily made out, but the large majority of fibres which compose the broad tract shown in fig. 36 are not connected with the nerve ganglion. There are some individual differences in the arrangement of the above tracts, but in general they are about as shown in fig. 36.

On each side of the medio-dorsal line in the region of the youngest tentacles a tract of fibres can be seen running longitudinally. In the region where the edge of the preoral hood is inserted into the collar a small tract made up of a few fibres branches off from the dorsal longitudinal tract and passes into the edge of the preoral lobe. Somewhat farther forward each dorsal longitudinal trunk spreads out sometimes into three rather indefinite tracts, most of whose fibres seem to reach the edge of the hood. Many of the fibres of the anterior branch appear to end in the region at the sides of the ganglion, but no connection with the latter could be found.

Immediately posterior to the ganglion a tract of fibres (fig. 36) is seen which runs for a short distance transversely to the long axis of the *Actinotrocha*. On both sides the fibres of this tract soon diverge from one another and in this way distribute themselves over the anterior part of the hood, ending at the edge of the latter (fig. 36).

Masterman (15) has figured (Pl. XVIII, fig. 2) certain nerve tracts to the right and left of the three nerves arising from the anterior end of the ganglion and finds that these "run forward and outward and then bend backward and take a course to the posterior corner of the hood."

A lateral view of the hood of *Actinotrocha* Species B. shows sometimes fibres gathered together in trunks, but these never take the direction as shown by Masterman. They diverge rather regularly and end all along the edge of the hood instead of at the posterior corners of the same (fig. 37). They are in no way associated with the ganglion and do not have the appearance of being even when the hood is turned upward out of its usual position.

For several reasons we believe that the complicated tracts of fibres seen in a surface view of a live *Actinotrocha* Species B. are not nerve fibres but muscle fibres. First, many of them show along their course nuclei resembling nuclei of muscle cells. Second, cross sections through the hood show that there is a rather heavy lining of muscle fibres which run in the same general direction as do the fibres shown in the surface view. Third, there is no connection between these fibres and the nerve ganglion.

From the posterior side of the ganglion two tracts of nerve fibres pass out and can be traced backward some little distance, but they are soon lost to view, as Ikeda (9) has found to be the case when studying methylene-blue preparations.

Sections through *Actinotrocha* Species B. bring out quite plainly certain nervous tracts which appear as thickenings of the subepidermal nervous tissue and which correspond in a large part to the principal nerves described by Masterman.

Anterior to the ganglion a section through the hood shows the parallel nerves which run from the anterior side of the ganglion to the anterior edge of the hood. The boundary of these nerves, as shown in fig. 44, is a little too definite. The subepidermal nerve tissue, which forms a thin layer below the ectoderm cells, is not shown in the series of sections to be described.

Following the sections posteriorly we come to the ganglion, which in this specimen has become invaginated, together with the overlying epidermis, so as to form a pit. A cross section through this pit is shown in fig. 44*b*. The cavity of the pit is lined by epidermis, while peripherally the wall of the pit consists of the ganglion cells and the nerve fibres of the ganglion (figs. 38–44*b*). The nuclei of the ganglia are easily made out, but it is only after staining very deeply with iron hæmatoxylin that the cytoplasm can be seen. The invagination in the region of the ganglion is unusual and is brought about by the violent contraction of the hood when immersed in the fixing fluid. This undoubtedly is the same condition that Masterman (15) has described and the same structure that he has homologized to the "neuropore" of the *Chordata*, or that he has compared to the tubular dorsal nervous system of the same type as that of *Balanoglossus*. (Q. J., Vol. XL. page 295, 296.) It should be mentioned, however, that Masterman (16*b*) in his answer to Roule has admitted the error of his rather hasty conclusion.

Menon (17) has recently described a tubular nerve ganglion for a certain *Actinotrocha*, but the structure is probably due to fixation.

Immediately posterior to the ganglion a cross section shows two thickenings of the subepidermal nervous system. These thickenings are what Masterman has described as the dorsal longitudinal nerves and they can be traced from the ganglion. They are almost exactly between the dorsal muscle tract and the epidermis of the dorsal wall. A little farther back these so-called nerves are not quite as distinct, but when the region of the first pair of tentacles is reached they become more prominent again and diverge, passing down the lateral walls along the bases of the tentacles (fig. 41). They meet in the ventral region and thus form a ring-like thickening of the subepidermal nervous system, which is undoubtedly the same that Masterman has described as the "collar nerve ring" (fig. 42). Ganglion cells are demonstrable in this nerve ring by staining deeply with iron hæmatoxylin (fig. 39). As we shall show in the account of the muscular system there is a ring of muscle fibre which follows the nerve ring.

Masterman says that "fibers pass mid dorsally as a pair of tracts, giving off branches to the body wall and terminating in a nervous ring just anterior to the perianal band." In his figures of sections, however, the pair of tracts does not show back of the most dorsal pair of tentacles. In *Actinotrocha* Species B. there are no definite tracts of nerve fibres running longitudinally from the region where the collar nerve ring passes obliquely downward from the dorsal surface of the collar. Nerve fibres are undoubtedly present all along the dorsal wall, but these are not massed together in tracts and are simply the fibres of the ordinary subepidermal nervous tissue. The nervous ring in front of the perianal band is not present in the *Actinotrochæ* that we have studied.

Masterman (15) finds that part of the nerve ring around the edge of the hood passes up to the nerve ganglion when it reaches the insertion of the hood, and that numerous fibres also appear to pass on to the ventral surface of the collar region. Live *Actinotrochæ* (Species A. and Species B.), when examined under the microscope, do not show a branch of the nerve ring of the lobe passing upward to the nerve ganglion. Sections also fail to show this condition, which is very necessary to Masterman's comparison of the nervous system of *Balanoglossus* and the *Actinotrocha*. Fibres from the nerve ring do, however, pass on to the ventral surface of the collar region.

Numerous fibres, which Masterman speaks of as passing down on to the ventral collar wall, are massed in the *Actinotrocha* Species B. into two definite thickenings which are seen in fig. 44*c* and fig. 40. These thickenings of the nervous tissue gradually approach one another as we trace the sections backward and come to run along the same line as do the two ventral muscle tracts of the collar, but before the line of insertion of the ventral tentacles is reached these thickenings are lost in the subepidermal nervous tissue.

We have not been able to make out either in sections or in surface mounts any definite nervous tract running from the collar nerve ring along the ventral region of the trunk, although, as before said, there is a subepidermal network of nervous tissue throughout the wall. It will be remembered, however, that above we have described two longitudinal dorso-lateral tracts of muscle fibres, and there are quite numerous longitudinal muscle fibres in the ventral wall of the trunk. There is also a fairly well-developed layer of circular muscles, and these, together with the longitudinal muscles, give the appearance in surface views of the longitudinal tracts giving off branches.

The nervous system of the *Actinotrocha* of *Phoronis sabatieri* is less highly developed, judging from the specimens we have examined, than that of either Species A. or Species B. The ganglion, or, as Roule (20) calls it, the "plaque céphalique," contains ganglion cells like those we have found in other *Actinotrochæ*, which shows that there is something more present than a simple subepidermal nervous system, such as Roule has described, in the *Actinotrocha* of *Phoronis sabatieri*.

Muscular system.—There is no doubt but that there is some diversity in the arrangement of muscle fibres in the different species of *Actinotrochæ*. A study of the two species, A. and B., as well as the description of different species by other investigators, convinces us of this.

In the study of the muscular system the best results were with material fixed in Flemming's strong solution and stained with Haidenhain's iron hæmatoxylin. These solutions make the muscle fibres stand out very distinctly, whereas material fixed and stained with other fluids shows them so feebly that the muscle tracts might easily be overlooked.

Ikeda (9) has described a pair of bundles of muscle fibres springing from "the hind lateral corners of the ganglion and running divergently downward until they insert themselves in the collar walls between the first and second tentacles." These muscles, to which he has given the name of "retractors," are present in the *Actinotrochæ* Species A. and Species B. (figs. 34, 35, 45, 45*a*).

The "retractors" that Ikeda figures in the trunk cavity of one of the Japanese *Actinotrochæ* were not found in either *Actinotrocha* Species A. or Species B.

Another pair of bundles of muscle fibres is found in Species B. They spring from the wall of the hood at the sides of the ganglion, traverse the cavity of the hood and become inserted on its ventral wall directly under the ganglion (fig. 45*a*).

Certain tracts of muscle fibres are very highly developed in Species B. Transverse sections (stained with iron hæmatoxylin) through the wall of the hood in front of the ganglion show black dots spread over the internal dorsal surface of the hood, and these seem to be embedded in the mesodermal lining. These dots are the cut ends of muscle fibres, and as the sections are followed posteriorly, these dots gradually become massed about halfway between the ganglion and the sensory papilla and represent the sectioned ends of a pair of longitudinal muscle tracts which are bilaterally placed on the right and left of the median dorsal line (fig. 44). These two thick tracts of muscle fibres extend posteriorly in the dorso-lateral regions of the *Actinotrocha* and do not disappear until the perianal ring is reached. They are very characteristic structures in Species B. (figs. 44 to 44*h*), but we have not been able to make them out in Species A.

These muscle bands, no doubt, serve to draw the anal end of the body of the *Actinotrocha* up to the oral end during the metamorphosis. They are the most highly developed muscle tracts in the body of the *Actinotrocha* and their course is almost identical with the course of the "dorsal nerves" that Masterman describes.

Examination of cross sections of Species B. in the region of the vestibule shows the cut ends of numerous muscle fibres which are spread over the ventral surface of the collar. Passing posteriorly, these fibres become massed into definite muscle tracts, about halfway back from the vestibule to the ventral insertion of collar-trunk mesentery (figs. 44*c*, 44*d*). These two ventral longitudinal tracts, which are bilaterally placed one on each side of the ventral median line, become separated, in most cases at least, from the ventral body wall in the region of the posterior pair of blood corpuscle masses and the latter become rather closely associated with them (fig. 46). We could not discover that these fibres were in any way related to the nephridia as has been described for some species.

In the region of the insertion of the ventral tentacles the muscle fibres of the ventral tracts become again applied to the ventral body wall, but definite tracts are no longer present. However, in the trunk region these fibres form a definite tract, which is confined to the ventral body wall, and it does not disappear until the perianal ring is reached (figs. 44 *g*, *h*, *i*).

Another tract of muscle fibres present in species B., which does not seem to be developed in other *Actinotrochæ*, judging from existing descriptions, is that found in the region of the bases of the tentacles. From the dorsal muscle tracts, where the most dorsal and anterior pair of tentacles arises, muscle fibres are given off, which follow the bases of the tentacles and which form a well-developed ring of muscle fibres. In other words, there is a ring of muscle fibres which follows the line of insertion of the mesentery between the collar and trunk cavities (fig. 44*e*).

A tract of muscle fibres, which also seems to occur only in Species B., is one composed of only a few fibres, which are found running around the edge of the hood on the internal wall of the same (figs. 44 *a*, *b*). Where the edge of the hood passes into the wall of the collar cavity these fibres are seen to run on to the internal surface of the lateral wall of the collar and to mingle finally with the fibres of the dorsal tract. The direction these fibres take when they pass on to the wall of the collar reminds one very much of the fibres which Masterman (15) figured as nerve fibres.

On the internal ventral surface of the hood in both species of *Actinotrochæ* there is a system of muscle fibres arranged concentrically. They run almost parallel with one another and with the edge of the hood (figs. 47 and 44*a*).

Beside the tracts of muscle fibres which have been described there are, lining the walls of the collar and trunk, circular muscle fibres lying between the longitudinal muscle fibres and the ectoderm. These have been generally observed by previous workers as have also the muscular covering of the ventral pouch and the muscle cells of the dorsal blood vessels.

Body cavities, mesenteries, etc.—Much difference of opinion exists as to the origin and limits of the body cavities in the *Actinotrocha* and also as to the value of these cavities in determining the phylogenetic history of *Phoronis*.

Roule (20) stands alone in considering the *Actinotrocha* to have but one body cavity, which is lined by an epithelium formed from mesenchymatous cells. He absolutely denies the presence of any mesenteries.

Through the kindness of Mr. Longchamps we have been able to study the *Actinotrocha* of *Phoronis sabatieri*, and have found that the mesentery between the collar and trunk is present, although it is less highly developed than in other species. We are unable, with the material at hand, to give any opinion as to the presence of a mesentery between the preoral lobe and collar cavities.

Caldwell (3) claims that there are but two body cavities, and that these are separated by a mesentery (collar-trunk mesentery of Masterman).

Longchamps (12) is inclined toward the view of Caldwell, while Ikeda (9) finds the mesentery dividing the lobe and collar, which, however, he says, is incomplete. Both of these investigators recognize the presence of the ventral mesentery.

Menon (17) finds three body cavities (preoral, collar, and trunk), a ventral mesentery, and indications of a dorsal mesentery in the trunk.

Masterman (16) considers that the *Actinotrocha* have five body cavities—an unpaired lobe cavity, a paired collar cavity, and a paired trunk cavity. This idea is based on his study of the early development of the body cavities and not on the adult organization of the *Actinotrocha*, for in the collar he finds only a dorsal mesentery (no other investigator has seen this), and in the trunk only a ventral mesentery.

While it is possible that the mesoderm arises as diverticula from the enteron, as Caldwell and Masterman have described, yet Longchamps (12), who has recently reinvestigated the early embryology of the form that Caldwell worked on (*Phoronis kowalevskii*), denies the origin of the cavity in front of the collar trunk mesentery from enteric diverticula. Ikeda (9), who recognizes the "anterior diverticula" of Caldwell in the Japanese species, nevertheless holds that the body cavities do not arise from anterior diverticula, but are simply produced by mesoblast cells applying themselves to and forming the lining of the ectoblastic and entoblastic wall.

In the section on the mesoderm we have stated that in the embryo of *Phoronis architecta* we do not find that the mesoderm arises from enteric diverticula. There can not be the least doubt, however, that the preoral lobe at an early stage becomes lined by a sac of mesoderm cells and that the wall of this sac gives rise to the mesentery. Furthermore, this sac is extended posterolaterally into two horns which are characteristic of the cavity of the preoral lobe, according to Masterman, Ikeda, and Menon. It must be admitted, however, that this sac does not seem to retain its character as a sac, but that the cells become separated and apply themselves here and there to the walls of the preoral lobe. The mesentery remains intact and can not be considered as a secondary structure as has been suggested by Longchamps. Although we agree with Ikeda's statement that the mesentery between the lobe and the collar is incomplete laterally in the fully developed *Actinotrocha*, yet in the *Actinotrocha* of *Phoronis architecta*, at least, it must be considered as a definite mesentery.

The fully formed *Actinotrocha* (Species A. and Species B.) do not show a complete epithelial lining to the preoral lobe, but the mesoderm cells are arranged as described in the young larva.

It is stated above in the part on the mesoderm that we do not find that the lining of the collar cavity is of enterocœlic origin in *Phoronis architecta*. However, in the fully formed *Actinotrocha* there is an undoubted mesodermic ephithelium lining the somatic wall. This layer is very conspicuous immediately before metamorphosis, because it becomes separated from the somatic wall prior to becoming transformed into the ring vessel of the adult (figs. 51*g*, 51*h*).

The splanchnic wall of the collar cavity in the *Actinotrochæ* that we have examined is devoid of a mesodermal lining, and the occurrence of mesoderm cells on the wall is very infrequent. This condition of affairs in the well-developed *Actinotrocha* is what one would expect from the disposition of the mesoderm cells in the very young larvæ of *Phoronis architecta*, where it is only very seldom that any are found on the stomach wall (fig. 24).

The absence of a mesodermal lining on the splanchnic wall of the collar cavity is made all the more evident by the examination of cross sections showing the collar-trunk mesentery (figs. 51*g*, 51*h*). When the mesentery reaches the stomach wall, instead of dividing into two layers, one of which would be continued into the mesodermal lining of the stomach wall of the collar cavity, it turns abruptly upon itself and becomes the lining of the stomach wall of the trunk. We have never found the least indication in the collar cavity of a dorsal mesentery such as Masterman (15) has described in the *Actinotrocha* from St. Andrews Bay. The trunk cavity is lined throughout by a sac of mesodermal epithelium, and the mesentery is plainly seen to be continuous with the lining of the somatic wall and with the lining of the wall of the gut. The ventral mesentery of the trunk is present in Species A. and Species B., and while there is no dorsal mesentery we have found indications of it in two specimens only (Species B.) at the posterior end of the trunk. We can not say, however, that it has any ontogenetic significance (figs. 48, 44*i*, 44*g*). We have also found the ventral mesentery to be present in the *Actinotrocha* of *Phoronis sabatieri*.

The ventral pouch fills a large part of the trunk cavity in the fully formed *Actinotrocha*, and just before metamorphosis it frequently pushes the collar trunk mesentery well forward into the collar cavity, thus making the study of the relation of the different parts quite difficult. Both the external opening of the ventral pouch and the nephridial openings are found on the ventral wall of the trunk just posterior to the insertion of the mesentery as in other species.

Nephridia.—Wagener (23) was the first to observe the "nephridial bouquets," but Caldwell (3) was the first to publish a careful study of the nephridia of the *Actinotrocha*. Goodrich[a] (6) has recently published a paper on the excretory organs of *Amphioxus*, and he adds a note on the nephridium of the *Actinotrocha* which confirms Caldwell's view. The two latter investigators agree that the nephridium ends blindly without funnels; that there are tubular processes, each one containing a lumen and tipped with an excretory cell, and that these processes radiate out from the blind inner end of the nephridial canal.

Longchamps (12) is inclined to accept Caldwell's view of the subject. Roule (20) and Ikeda (9) seem to hold the view that the nephridial canal ends blindly without branching, and that the blind end is tipped with excretory cells, which, however, are not perforate.

Masterman (15) and Menon (17) have another view. They both think that the nephridial canal terminates internally as two (Menon) or more (Masterman) funnels, and they recognize the existence of long processes without lumens attached to the ends of the funnel.

We have not been able to make a study of the nephridia of the living *Actinotrocha*, but we have investigated them by means of sections in Species A. and Species B. For this purpose we have used material fixed in Flemming's fluid and also in corrosive acetic. The sections were stained with iron hæmatoxylin. Our work has been done with very high powers (Zeiss obj. $\frac{1}{12}$ and No. 12 Zeiss compensating occulare).

The nephridia of the two *Actinotrochæ* have much the same structure, but in Species A. we have been unable to find that the internal end of the nephridial canal branches, while in Species B. the internal end divides into two short branches.

Figs. 52, 52*a*, 52*b* represent three transverse sections through the anterior part of the nephridium of Species B. Fig. 52 is through the nephridial canal just posterior to its internal end. Darkly staining dots seen in the lumen represent cross sections of long flagella such as Goodrich (6) has described in the "solenocytes" of *Amphioxus*.

Fig. 52*a* shows a section through the nephridial canal a few sections anterior to that of fig. 52, and at the same time it shows the lower or most posterior branch with a few excretory cells and their processes.

In fig. 52*b*, which is a section through the tip of the upper or anterior branch of the nephridium, the lumen of the nephridial canal is reduced to a very small clear space.

If a section is taken in a longitudinal direction through the nephridial canal and its excretory processes (fig. 52*g*), it is seen that the distinct walls of the nephridial canal disappear when the "bouquet" of excretory cells is reached, but that the end is blind and that it is merely a thin walled bulb from whose surface radiate the processes of the excretory cells. The structure of these processes is the same in both species that we have examined except that in Species A. they are much shorter, which might account for the different descriptions we find in the literature. We are convinced that in both species the excretory processes contain lumens, that these lumens are continuous with the lumen of the nephridial canal, and that they contain flagella.

Each of the excretory processes is tipped by a body the distal end of which is drawn out into a sharp-pointed process. The outline of only one cell could be seen in the body. Sometimes it contains but one nucleus, which may be oval in shape or bent almost at right angles (fig. 52*d*), but in the majority of cases there are undoubtedly two nuclei (fig. 52*e*). Fig. 52*e* shows a cross section through one of these bodies. If a transverse section of the nephridial processes is taken (fig. 52*f*), it is seen that each has a definite wall and that inside there is a definite dot which we take to be a cross section through the flagellum. This flagellum has its origin from the cell body at the end of the process, and the indications are that the flagellum extends throughout the length of the process into the lumen of the nephridial tube.

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[a] Since writing this paper a description of the nephridia of the *Actinotrocha* by Goodrich (6*a*) has come to our notice. Our account agrees to a large extent with his.

We are not prepared to say that the cell bodies at the end of the excretory processes are composed of two cells, but it is a fact that two nuclei exist, and this conclusion is not based on sections through bent nuclei which might lead one to think that there were two when only one existed. It will be seen from this description that the anatomy of the excretory cells and processes of the *Actinotrochæ* which we have studied resembles that of similar structures described by Goodrich for *Amphioxus*.

There is nothing new to add concerning the nephridial canal except that a longitudinal section through it, which has been stained with iron hæmatoxylin, shows long flagella extending some distance from the distal end into its lumen (fig. 52*g*).

Sections of the *Actinotrocha* of *Phoronis sabatieri* show that the nephridia resemble those of other *Actinotrochæ* studied, although they do not seem to be as well developed as those of Species A. and B. The specimens at hand show that the internal opening in the collar cavity is situated at about the same level as in other *Actinotrochæ* and not at the level of the œsophagus, as Roule (20) has indicated.

The course which the canal takes is like that which has been described by other investigators, and we agree with the observation of others in regard to the nephridial canal opening to the exterior at the sides of the ventral pouch opening.

Masterman (15) describes a pair of ciliated pores opening to the exterior on the dorsal surface of the preoral lobe. These, he finds, lead into tubes closely similar in cross section to the cross section of canals of the collar nephridia, and these tubes have an internal opening into the preoral lobe cavity. He compares the external pores to the proboscis pores of *Cephalodiscus*. In the Zoologisher Anzeiger, 1901, Volume XXIV, page 231, he admits that their occurrence is variable. No other investigators have found these organs. Ikeda mentions the fact that flask-shaped glands on the upper face of the preoral lobe occur in one larva studied by him, but he denies that they are such organs as Masterman describes.

Masterman (15) also finds thin-walled organs lying in the hæmocœle space immediately below the anal ciliated band. Speaking of these (15) he says: "A pair of organs which I have not fully made out, but they may be the rudiments of the trunk nephridia." Masterman, however, denies their existence in a later paper, and no one else has seen the organs, as far as we know.

Rudiments of the adult blood vessels in the Actinotrocha.—Many investigators of the *Actinotrocha* have recognized the beginnings of the adult blood vessels, but E. B. Wilson (24) is the first one who clearly states the fact that the cavity containing the blood corpuscle masses gives rise to the ring vessel of the adult, although Metschnikoff seems to have had some such idea. Caldwell (3) and Ikeda (9) confirm the statement of Wilson with reference to the origin of the ring vessel of the adult.

While Masterman (15) describes a much more complicated vascular system for the *Actinotrocha* from St. Andrews Bay than that of all the *Actinotrochæ* examined, yet we agree with him in his view that the cavities of the blood vessels may be considered as vestiges of the segmentation cavity.

Above we have given our opinion that the "subneural sinus" (Masterman) does not exist in the *Actinotrochæ* that we have examined, and that although there is a space beneath the ganglion it has no connection with the dorsal blood vessel.

The blood vessels of the adult are represented in the *Actinotrochæ* Species A. and B. by a dorsal vessel (figs. 34, 35) extending along the median dorsal line of the intestine, from the mesentery between the collar and trunk almost to the posterior end of the stomach, where there are small cæcal outpushings of the splanchnic mesodermal walls of the end of the stomach. This dorsal blood vessel, although it is a completely formed vessel, has arisen from a proliferation of the cells of the splanchnic mesodermal wall along the dorsal median line of the stomach, and its lumen is really a part of the blastocœle— i. e., it is a part of the space between the splanchnic mesodermal lining and the wall of the stomach. Posteriorly, the dorsal blood vessel becomes indefinite and passes into the ordinary splanchnic mesodermal lining, thus really being open posteriorly into the space between the wall of the stomach and the mesodermal lining.

At the time of metamorphosis in the *Actinotrochæ* Species A. and Species B., there is no sign of a ventral blood vessel along the stomach, such as Masterman (15) and Roule (20) describe.

We have been unable to find the "ring sinus" which, according to Masterman, connects the dorsal vessel with the ventral vessel at the end of the stomach, nor have we seen the "postoral ring sinus" connecting the dorsal vessel with the ventral vessel.

Masterman's "postoral ring sinus," "ventral blood vessel," and "ring sinus" (situated at the junction between the stomach and intestine) will be discussed in the section on the metamorphosis.

There is undoubtedly a space between the wall of the perianal ring and its mesodermal lining (fig. 49) in preserved specimens which seems to be what Masterman calls the "hæmal ring," but it does not become any organ of the adult.

As stated above, we believe with Wilson, Caldwell, and Ikeda that the cavity of the collar and its somatic mesodermal lining become the ring vessel of the adult.

We shall continue the discussion of the further development of the dorsal blood vessel into the efferent and afferent vessels of the adult in the section on the metamorphosis.

Masterman speaks of hæmal sinuses passing down the tentacles, but says that they are not very decided. Ikeda has, however, investigated these structures carefully, and we thoroughly agree with his view that the cavity of the collar, together with its somatic lining, extends into the tentacles, and that these prolongations become the tentacular vessels of the adult. This condition is shown very plainly in a dorso-lateral section of the *Actinotrocha* Species A. (fig. 50).

Blood corpuscles and their origin.—E. B. Wilson (24) has touched upon the origin of the blood corpuscles, and according to him they develop in solid masses adhering to the stomach walls near the base of the tentacles. Caldwell (3) finds that the corpuscle masses "arise from the mesoblast cells in front of the septum," but he has nothing further to say about their position or origin. Ikeda (9) describes the blood corpuscles as arising from "gigantic mesoblast cells in the body cavity of the larvæ with one or two pairs of tentacles." Since the publication of this paper, Ikeda has rejected this view, although he has published nothing on the subject. Menon (17) thinks that the blood corpuscles arise from the splanchnopleure covering the stomach and its diverticulum. According to Cori (4), the blood corpuscles in the adult are formed from the endothelium of the blood vessels.

In the *Actinotrocha* Species A. (probably that of *Phoronis architecta*) the blood corpuscles usually make their appearance during the 14-tentacle stage, as in "Type A" described by Ikeda, although we have found larvæ of this stage in which definite blood corpuscles were not present.

Actinotrocha Species A. with 16 tentacles invariably has blood corpuscles, and they are present in the so-called collar cavity as two masses more or less closely applied to the ventro-lateral walls of the stomach (figs. 51 *g*, *h*). In some cases, however, they are separated from the wall by a considerable space.

The transverse section of a larva with 12 tentacles in a plane just posterior to the base of the tentacles, but anterior to the mesentery, always shows two masses of cells bilaterally placed and closely applied to the mesoderm lining the ventro-lateral somatic wall (fig. 53). Occasionally cells are found in these masses, situated very close to the mesodermal lining, which are decidedly spindle-shaped in form and whose nuclei resemble those of the cells of the mesodermal lining, both in shape, size, and internal structure. These cells are not very rich in cytoplasm. Most of the cells, however, are almost three times the size of the cells lining the somatic wall, the cytoplasmic part of the cell having increased in size to a greater extent than the nucleus. Most of the nuclei have large deeply staining nucleoli (fig. 54).

In some specimens parts of these masses of cells are apparently in the act of wandering across the body cavity to the position the blood-corpuscle masses occupy in the fully formed *Actinotrocha*.

Some 15 or 20 larvæ with 12 or 14 tentacles have been sectioned, and with one exception we have found that when the mesodermal masses are present on the ventral body wall there are no blood-corpuscle masses present in the larva, and that when the blood-corpuscle masses are present there are no mesodermal masses. In this exception small blood-corpuscle masses were found applied to the stomach wall, and masses of cells bilaterally placed were found on the ventral somatic wall, but these cells had already taken on the character of blood corpuscles.

Ikeda (9) has described a "mesoblastic cell mass" which he evidently considers as giving rise to the adult body cavity, and its position is very similar to that of the mesoblastic masses described above. They are both products of the mesoblastic lining of the ventral somatic wall and are situated between the plane of the bases of the tentacles and the plane of the somatic insertion of the mesentery between the collar and trunk. Although Ikeda does not touch upon the very early origin of the adult body cavity, yet it seems probable that he considers it as arising from a single mass of cells. The mesoblastic masses described above are paired and bilaterally placed, and they are present only in the young larva of 12 or 14 tentacles. Furthermore, in the larva with 12 or 14 tentacles there is no sign of the beginning of the adult body cavity. Although these mesodermal masses which, according to our observations, give rise to the blood corpuscles have a similar position to the fundament of the young adult body cavity, yet we are convinced that they do not give rise to it.

In Species A. there is no intimate relation between the masses of blood corpuscles and the nephridia, such as has been described by Masterman (15) for the species from St. Andrews Bay, and by Longchamps (12) for *Actinotrocha branchiata*. In the larva of 16 tentacles the blood-corpuscle masses are, however, closely applied to the stomach wall in the region of the digestive area. There is no mesodermal epithelium covering that part of the surface of the stomach which lies within the collar cavity, and the blood corpuscles seem to be so intimately related to the digestive areas that we are inclined to believe that they receive nourishment from them.

While the blood corpuscles vary in size and undoubtedly multiply by karyokinetic division, yet we have never found the "large and somewhat coarsely granular" and the "smaller finely granular" corpuscles that Ikeda (9) speaks of, nor in this species have we found any "gigantic mesoderm cells" in the region of the blood-corpuscle masses. Very large cells in close relation to the blood corpuscle masses are found in some specimens of *Actinotrocha* Species B. (fig. 44*f*). These cells resemble the cells described in the old gastrula of Species A. as arising from the wall of the archenteron, only they are not as coarsely granular as the latter. While in *Actinotrocha* Species B. the cells are found in most cases closely associated with the blood corpuscles, we have never seen them in the process of division and do not believe that they give rise to blood corpuscles. Their occurrence is quite variable, but as far as has been observed they are not present in the *Actinotrochæ* which are ready to metamorphose. They are not phagocytes, nor are they pigment cells, and the only name which we feel justified in giving them is large free mesoderm cells. Frequently they are also found in the posterior end of the trunk cavity (fig. 44*i*).

Roule (20) holds that the nephridia end internally at the level of the œsophagus, and he shows this in a figure. We have made cross sections through this region and have found masses of cells in much the same place as Roule has shown. These cells seem to be blood corpuscles, but very few specimens have been examined, and only one of these showed these masses of cells.

Rudiment of the "adult collar cavity" (Ikeda).—Ikeda has observed a mesodermal cell mass on the ventral somatic wall just under the second tentacle in rather young specimens of all the Japanese *Actinotrochæ*. He has traced the development of this mass of cells and finds that a cavity arises in it which, before metamorphosis, becomes quite spacious and extends into the tentacles. We are able to confirm Ikeda's view that this cavity is the rudiment of the "adult collar cavity," or "supraseptal cavity" of the adult, as it is usually called (figs. 50, 48, 51*h*, 45*b*, 46).

METAMORPHOSIS.

Several investigators have carefully described the external characteristics of the metamorphosis of the *Actinotrocha*, so it is unnecessary to enter into a detailed description.

Wilson (24) studied the metamorphosis of *Actinotrochæ* Species A. and Species B., which are found in Chesapeake Bay, but he did not cut sections of his material. Ikeda (9), however, has investigated the internal changes which take place during metamorphosis and has added a valuable contribution to the subject. The behavior during metamorphosis of *Actinotrochæ* Species A. and Species B. from Beaufort Harbor seems to be quite the same as that of the two *Actinotrochæ* which Wilson has observed, and there is little doubt but that they are of the same species.

As Wilson has stated, the metamorphosis of *Actinotrocha* Species A. (fig. 34) takes place much more quickly than that of Species B. (fig. 35). In fact, we have never obtained a completely metamorphosed specimen of the latter, although many times we have found specimens of this species with the ventral pouch well evaginated (fig. 55). We have tried to make the conditions favorable for the completion of the metamorphosis by covering the bottom of the aquarium with a layer of sand rich in diatoms and also by changing the water frequently. Under these conditions the larvæ (Species B.) would invariably sink to the bottom and move around on the sand apparently in search of a favorable place to finish the metamorphosis. The latter never occurred, however, although sometimes the larvæ would attach the end of the ventral pouch to the bottom of the dish. In this way the creature would often remain for days and although the preoral lobe and larval tentacles would degenerate the anal end of the larva would never become turned upward so as to lie in close proximity to the mouth.

As we have said before, we are inclined to think that the *Actinotrocha* Species B. belongs to an adult which lives under different conditions from that of *Phoronis architecta*, and we should not be surprised if it were found to be the *Actinotrocha* of a deep-water form. Although *Cerianthus* occurs in Beaufort Harbor, we have never found *Phoronis australis* associated with it.

Actinotrocha Species A., as a rule, metamorphoses in about twenty minutes (figs. 56, 56*a*, 56*b*), and usually just before this takes place it sinks to the bottom of the dish, but occasionally metamorphosis occurs on the vertical side of the dish near the surface of the water, the young *Phoronis* remaining fixed where the metamorphosis takes place.

Preoral lobe and tentacles.—Usually the larval or distal part of the tentacles (Species A.) and the preoral lobe are swallowed during metamorphosis. The proximal parts of the tentacles become directed upward and constitute the tentacles of the adult. They always number 18 in the very young *Phoronis* (Species A.) and there is an indication of the horseshoe arrangement which is found in the adult (fig. 56*b*).

The preoral lobe does not give rise to the epistome of the adult, for as Menon (17) has correctly observed, this structure is not present in the very young *Phoronis*. However, the epistome, which is of ectodermal origin, soon makes its appearance, and when the creature has 30 tentacles it is a very conspicuous organ (fig. 57).

Ganglion.—The ganglion on the dorsal surface of the hood is lost when the preoral lobe is swallowed, and hence does not give rise to the so-called brain ganglion of the adult.

Ectodermal wall of collar.—Although the preoral lobe degenerates, the wall of the collar does not, but becomes drawn inside the body of the young *Phoronis* and forms the wall of the oral end of the gut.

Perianal ciliated ring and ectodermal wall of the trunk.—When the critical point in the metamorphosis is reached—that is, when the posterior end becomes drawn up to the region of the mouth—the perianal ciliated ring is usually seen as a protuberance in that region (Wilson's fig. 12), but shortly after this it becomes drawn in, and, together with some of the ectoderm, becomes the lining of that part of the rectum which is near the anal opening. The drawing in takes place to such an extent that most of the ectodermal wall of the trunk of the *Actinotrocha* becomes incorporated in the wall of the rectum, as Caldwell has observed.

This process, together with the drawing in of the ectodermal wall of the collar to form the wall of the oral end of the gut, seems to cause a change in the position of the nephridial canals. (See section on nephridia.)

Cavity of the preoral lobe.—Since the preoral lobe is lost during the metamorphosis, its cavity does not take part in the structure of the adult.

Mesentery between the lobe and collar.—This mesentery does not persist.

Larval collar cavity.—As has been stated by other investigators, and as we have observed, the larval collar cavity with its mesodermal wall becomes the ring vessel of the adult. This organ will be discussed further in the section on the vascular system.

"*Adult collar cavity*" (Ikeda).—This cavity, which is found in the well-developed *Actinotrocha*, undoubtedly becomes the "adult collar cavity" or supraseptal cavity of the adult, as Ikeda says. In the young *Phoronis* it is seen as a cavity which occupies all the region anterior to the transverse septum and which is prolonged into the tentacles. It is lined by a mesodermal epithelium and contains the ring vessel with its tentacular vessel.

Trunk cavity and cavity of the ventral pouch.—These cavities become the infraseptal cavity of the adult.

Ventral mesentery.—The ventral mesentery of the *Actinotrocha* no doubt becomes the mesentery in the adult which Cori calls the "hauptmesenterium" and which Benham names the "œsophageal" and "rectal" mesenteries. Mesenteries are present in the very young *Phoronis* (just after the completion of the metamorphosis), which are found in the exact position that one would expect the ventral mesentery of the *Actinotrocha* to assume after metamorphosis. Ikeda's figures indicate that he considers the longitudinal mesenteries of the very young *Phoronis* to be the same as the ventral mesentery of the *Actinotrocha*, for he gives them the same name.

We can not offer any observation on the origin of the lateral mesenteries of the adult except that they are not present in the very young *Phoronis* that we have examined. They undoubtedly arise later in the life history.

Stomach diverticula.—This structure is not present in the *Actinotrocha* Species A., so we are not able to give any information on the subject. It seems to be the general opinion among those who have studied the metamorphosis that it does not persist as an organ in the adult.

Digestive areas.—While these organs persist for some little time after metamorphosis, they are not evident as organs in the adult *Phoronis architecta*.

Nephridia.—Caldwell (3), Ikeda (9), Longchamps (12), and Menon (17) have all observed the change in position of the larval nephridial canals which is due to the changes taking place during the critical period of the metamorphosis, and it is a quite well-established fact that the external ends of the larval nephridial canals come to be situated near the anal opening.

Just after the critical period a cross section through the anterior end of the young *Phoronis* cuts the transverse septum ("diaphragm," "collar trunk mesentery"), which runs obliquely and passes through the supraseptal and infraseptal cavities. It shows a transverse section through the nephridial canals, which are still attached to the mesentery, as in the *Actinotrocha*. Following the sections anteriorly, the canals are seen to open into the supraseptal cavity ("larval collar cavities," "ring vessel of the adult"), and they are still found in possession of their excretory cells. Posteriorly the sections show that the nephridial canals leave the septum and pass between the wall and the mesodermal lining of the infraseptal cavity (fig. 59). At this time their external openings are situated on the lateral epidermal wall in a transverse plane which is somewhat below the transverse plane of the anus, and they are by no means as near to the latter as they are in the adult *Phoronis*. It is seen from this description that during the critical period there is very little change in the structure of the larval nephridia or in their position, although the evagination of the ventral pouch and the drawing in of the ectoderm of the trunk to form the end of the rectum causes the anus to become rather closely approximated to the external nephridial openings.

Caldwell (3) says that the whole of the larval nephridial canals remains as the paired nephridia of the adult, while Ikeda thinks it probable that only the parts of the nephridial canals lying in the wall of the trunk persist. He assumes that the nephridial funnels of the adult, which both open into the infraseptal cavity, are secondary outgrowths of the above remnants of the nephridial canals.

As the metamorphosis continues, sections show that the excretory cells and that part of the nephridial canals situated in the larval body cavity have become obliterated, together with the portion of the nephridial canals running in the septum. While we do not wish to deny that the remnants of the nephridial canals and their external openings, situated originally in the trunk cavity of the *Actinotrocha*, become part of the nephridia of the adult, yet in the stage under consideration they could not be found. So far as we know, Ikeda is the only investigator who has given us figures illustrating the relation between the larval nephridia and the nephridia of the adult. While his fig. 64*e* shows the larval nephridial canals, his fig. 66, which is a cross section through the anterior end of a young *Phoronis* and which shows a section through the young nephridium of the adult, does not prove that he is dealing with the same structure.

Vascular system.—It will be remembered that the vascular system of the fully developed *Actinotrocha* Species A. consisted of a dorsal blood vessel (figs. 51 *f, g, h*) running along the median line of the stomach from the dorsal insertion of the mesentery, between the collar and trunk, to the posterior end of the stomach, its lumen being a part of the segmentation cavity; a bunch of blood caeca formed at the posterior end of the stomach as evaginations of its splanchnic mesodermal covering and a loose sac of mesodermal tissue arising on the somatic wall of the collar segment and inclosing the larval collar cavity (figs. 50, 51 *f, g, h*). (See below for discussion of the "post-oral ring sinus," ventral vessel and the "ring sinus" at the junction of the stomach and intestine.)

There are several important points in the vascular system of the *Actinotrocha* which must be taken into account in order to understand its metamorphosis into the vascular system of the young *Phoronis*. First, that the dorsal blood vessel, which is formed from the splanchnic mesodermal lining of the trunk cavity, incloses a part of the space between the lining and the wall of the alimentary canal—i. e., the segmentation cavity—second, that this vessel dwindles away posteriorly and opens into the space between the lining and the wall of the alimentary canal; third, that the wall of the stomach in the collar segment is practically free from mesodermal lining (figs. 51 *g, h*), and that the larval collar cavity, with its somatic mesodermal lining, is a blood sinus; fourth, that the larval collar cavity is a part of the segmentation cavity; and, fifth, that during metamorphosis the act of drawing the stomach and intestine into the cavity of the ventral pouch causes pressure to be exerted on the larval collar cavity.

When the critical stage is being passed through, the blood-corpuscle masses break up and they are driven by the pressure on the collar cavity to the points of least resistance. As a rule some of the blood corpuscles are squeezed up into the dorsal region of the collar cavity where the dorsal blood vessel ends, and invariably some of the blood corpuscles pass from the larval collar cavity into the cavity between the wall of the alimentary canal and its mesodermal covering. In fact, as soon as the critical stage occurs, the splanchnic mesodermal lining in all regions becomes separated from the wall of the alimentary canal and thus allows the blood corpuscles to move about between these two layers throughout the extent of the alimentary canal.

The dorsal blood vessel ("mediangefäsz" (Cori), "afferent vessel" (Benham), and the ring vessel with its tentacular vessel are completely formed structures at this stage. The dorsal vessel is still freely open posteriorly into the space or sinus between the stomach wall and its mesodermal covering and blood corpuscles are carried back and forth from it to the sinus by the contraction and expansion of the former. Anteriorly the dorsal vessel can plainly be seen opening into the ring vessel (larval collar cavity.)

The origin of the connection between the dorsal vessel and the ring vessel and the manner in which the blood corpuscles find their way into the former are questions which have not been very satisfactorily elucidated. *Actinotrocha* Species A., does not present any great difficulties in the way of understanding how these processes take place. The dorsal blood vessel opens posteriorly into the sac-like sinus around the loop of the alimentary canal, and it seems probable from an examination of sections of the critical stage that it is also open anteriorly. Assuming that such is the condition, it will open into the space between the mesodermal lining and the wall of the gut. This space, however, is in free communication with the larval collar cavity (adult ring vessel) which contains the blood corpuscles. Under these conditions the blood corpuscles can pass into the dorsal blood vessel from either end.

Masterman (15) and Roule (20) both describe a vessel on the ventral stomach wall of the *Actinotrocha*. We have not found this vessel in the *Actinotrocha*, nor do we find it in sections of the critical stage.

At this time there is but one ring vessel in the supraseptal cavity, but we consider that it represents both the receiving and distributing vessels of the adult *Phoronis*.

Shortly after the critical point in the metamorphosis, the mesodermal lining on the left side of the oral limb of the U-shaped alimentary canal begins to show indications of becoming a blood vessel, and when the metamorphosis is completed a definite vessel is seen, which opens posteriorly into the spacious blood sinus around the loop of the alimentary canal. Anteriorly before reaching the transverse septum, it divides into two branches, which run obliquely upward along the sides of the alimentary canal, almost encircling the same; these finally open into the ring vessel of the supraseptal cavity (fig. 60). The vessel described becomes the efferent vessel of the adult (figs. 78, 77, 75, 66) and its branches become part of the recipient vessel.

As Ikeda has pointed out, the efferent vessel of the adult corresponds to the ventral vessel which Masterman (15) and Roule (20) have found in the *Actinotrochæ* before metamorphosis.

In all the completely metamorphosed *Actinotrochæ* that have been sectioned there is but one ring vessel, but the young *Phoronis*, when it is 12 hours old, possesses both the recipient and distributing vessels; these vessels, we believe, arise from the single ring vessel of the metamorphosing *Actinotrocha* by the fusion of its walls and by the subsequent separation of the two parts along the line of fusion.

Masterman, in his description of the blood system of the *Actinotrocha*, speaks of a "ring sinus" at the anterior end of the intestine which connects the dorsal and ventral vessels. He also says that there are two lateral branches of the dorsal vessel in the region of the pharynx which pass downward around the oesophagus ("post-oral ring sinus") and become continuous with the ventral vessel.

The former undoubtedly represents the sinus surrounding the loop of the alimentary canal in the young *Phoronis*, while the latter, no doubt represents the branches of the efferent vessel which become part of the recipient vessel of the adult. Masterman says that these branches open into the dorsal blood vessel, but such is not the case in the completely metamorphosed *Actinotrocha*.

From a comparison of Masterman's description of the vascular system of the *Actinotrocha* and Ikeda's and our own description of the same before and after metamorphosis, it is seen at once that this system develops more precociously in the form that Masterman studied. This condition, together with the facts that the lumen of the blood vessels are parts of spaces between the wall of the gut and its mesodermal lining and that the mesodermal lining of the alimentary canal fits loosely while the blood system is developing, gives additional weight to Masterman's statement that the dorsal vessel opens into the so-called "subneural sinus." However, in the *Actinotrochæ* that we have examined such a connection does not exist, and, as stated above, a "subneural sinus" or cavity caused by a lack of contiguity between the mesodermal wall of the preoral lobe and that of the collar cavity is not present.

THE ADULT PHORONIS ARCHITECTA.

Phoronis architecta was discovered by Andrews (1) in June, 1885, at Beaufort, N. C., and he described it as a new species, giving it the specific name "architecta," on account, no doubt, of its building a beautiful, straight tube. He finds that the tubes are made up of a clear, firm, chitin-like membrane covered with small, clear grains of sand, and he thinks that these grains are selected by the animal. Specimens collected from different localities in Beaufort Harbor vary considerably in regard to the character of the sand grains and quite often small fragments of dark shells are found mixed in with the latter. Occasionally two tubes occur cemented together; but this condition is rare, for they are usually isolated and embedded perpendicularly in the sand. When the specimens are brought into the laboratory and put into aquaria with sand and water, they usually crawl out of their tubes and begin to form new ones. Longchamps (13) has lately pointed out that the tube is formed by a secretion from the posterior end of the animal and not from the anterior end, as Cori has said. This is the case for *P. architecta*.

Above it is stated that the tubes are straight, but where new tubes are formed in the aquaria they are always twisted to a considerable extent, and they are attached firmly to the bottom of the jar. In its natural habitat, *Phoronis architecta* does not have a firm substratum to which to cement its tube, but it is seen from the above observation that when a solid surface presents itself, the tube may take on the condition found in some of the other species of *Phoronis* which are attached to rocks and shells.

Phoronis architecta lives at about low-water mark on the sand shoals, which are very numerous in Beaufort Harbor, and, as a rule, the individuals occur in patches. Three or four hundred specimens are often found within a radius of 4 or 5 feet, but one is very apt to find isolated specimens while digging in the sand anywhere in the harbor.

Only rarely do the tubes project above the surface of the sand as Andrews (1) has described, and in these cases the condition was due to disturbances of the surface of the sand, such as hollows made by *Callinectes*. Usually the upper end of the tube is from 3 to 5 cm. below the surface of the sand.

The average length of these tubes is 13 cm., and the average width a little over 1 mm. The adult when removed from its tube is about 1 mm. in diameter in the posterior one-third, and slightly less in the anterior two-thirds (fig. 61). The length of specimens taken out of the tubes varies with the amount of contraction from 20 to 25 mm., which figures are considerably lower than the length given by Andrews (about 50 mm.). The specimens which Andrews described must have been considerably more extended than any we have preserved. When the animal is in its natural habitat and undisturbed, however, it is capable of great extension, stretching the whole length of the tube and even considerably farther, so that its lophophoral end may project above the surface of the sand and reach for some considerable distance along its surface. We have not been able to preserve specimens in their extended condition, and they usually contract to from 20 to 25 mm. in length.

The anterior two-thirds of the living specimen has a flesh color, while the posterior one-third is dark-yellowish red and quite opaque, which is due to the fact that the gonads and blood caeca are situated in this region. In preserved specimens, the body wall is annulated (fig. 61), but such is not the case probably in the fully extended individual.

The crown of tentacles is quite simple compared to the crown of tentacles in *P. australis*, *P. buskii*, and *P. pacifica*. A cross section shows that it is crescentric and that the ends are not spirally coiled (figs. 62, 63, 64).

Andrews (1) has given us a description of the principal points in the anatomy of *Phoronis architecta*, which he has undoubtedly made brief because of the resemblance to the anatomy of *Phoronis australis* as described by Benham (2). In general our observations agree with those of Andrews, but there are a few points which merit discussion.

Lophophoral organs.—These peculiar organs (fig. 62) have been observed in several different species of *Phoronis*, and although functions for them have been suggested, the observations do not seem to have extended over a long enough period in the adult life of the worm to warrant a definite statement as to their function.

The lophophoral organs (fig. 62) lie one on each side of the median line within the concavity of the lophophore. They are outgrowths from the base of the inner row of tentacles, and, in some species at least, are quite conspicuous organs, but they do not arise until the *Phoronis* has reached its adult size. Organs located in the above region have been described for eight species, but the size and shape do not seem to be the same in all. Whether these differences are specific or whether the observations have been made at different periods in the adult life it is hard to say. Lophophoral organs like those present in *Phoronis architecta* are found in *P. psammophila*, *P. pacifica*, *P. mülleri*, and, no doubt, in some other species also. It seems, however, probable from the description of the anatomy of *P. buskii* and *P. australis* that in these species the lophophoral organs are much less highly developed than in the smaller species with fewer coils in the lophophoral crown. We have examined several specimens of *P. australis* with and without genital products, but in no case have we seen organs such as are present in *P. architecta*.

Various functions have been assigned to the lophophoral organs. McIntosh (14), working with *P. buskii*, considers that they are sensory in function, while Masterman (16), who has studied the same species, says that they are glandular and that they give rise to mucus which serves to hold the embryos together in masses. In other words, he considers them to be "subsidiary reproductive organs." Benham (2), who worked on *P. australis*, and Cori (4), who investigated *P. psammophila*, both give these organs a glandular function, while Andrews (1) thinks that in *P. architecta* they are used in building the tubes. H. B. Torrey (22) has made the interesting observation that in some specimens of *P. pacifica* the lophophoral organs are like those in *P. australis*, while in others they are like those in *P. architecta*. It is probable that in part of the specimens which Torrey examined the lophophoral organs were not full grown, while in the rest they had reached their full development.

Our observations indicate that Andrews' supposition concerning the tube-building function of the lophophoral organs can not be held. Individuals without the lophophoral organs build new tubes covered with sand grains just as do those with the organs, and young specimens of *Phoronis architecta*, which are in possession of tubes, never have lophophoral organs. These two facts prove quite conclusively that the lophophoral organs of *Phoronis architecta* are not used for tube building.

Masterman's view that the lophophoral organs of *P. buskii* are glandular, and that they furnish mucus to hold the eggs and embryos in masses can not be applied to *P. architecta*, for in this species the eggs and embryos are not held in masses.

Specimens of *Phoronis architecta* have been examined during almost every month in the year in order to discover whether or not there is any relation between the lophophoral organs and the breeding season. During the months of June, July, August, September, and October examination of many specimens of *Phoronis architecta* shows that more than one-half are with lophophoral organs—i. e., with the "carpel-like organs" and the "spherical sense lobes" (Andrews). Examination of specimens taken during these months shows that some contain ovaries and eggs while others do not, and that all contain spermatozoa in the body cavity, but that only those without ovaries contain testes. Occasionally an egg floating freely in the body cavity is found in specimens with testes. These facts are correlated with the presence or the absence of the lophophoral organs, for these organs are present in specimens with testes and without ovaries and absent in specimens with ovaries and without testes.

During the latter part of December and the first part of January specimens of *P. architecta*, some of which were collected in Beaufort Harbor at that time and some of which had been kept alive in the laboratory of Johns Hopkins University since the summer months were examined.

Many of these specimens (30 or 40) were examined by crushing the posterior end and also by cutting sections, but with one exception all of these individuals were found to be without ovaries and testes. In the case of the exception, a few ovarian eggs were present, but the ovaries were still very young. The blood cæca at this time are surrounded by a great abundance of the peculiar peritoneal tissue, which later gives rise to the reproductive organs. Lophophoral organs were absent both in specimens collected at Beaufort during the first part of January and in specimens collected during the summer and kept in the laboratory.

During the months of February, March, and April the specimens in the aquaria at Johns Hopkins University were examined quite frequently, but until March or April there was no sign of lophophoral organs. Then they began gradually to develop in some specimens until by the first of May they were full size. At this time another lot of live material was received from Beaufort which afforded some very interesting observations. The number of individuals with and without lophophoral organs were in about the same ratio as during the summer months. At this time, in specimens with lophophoral organs, the testes are present but the ovaries are not, while specimens without lophophoral organs possess ovaries and contain ovarian eggs. Quite often specimens with lophophoral organs have large bunches of spermatozoa floating freely in the body cavity, and in some cases these occur inside the nephridia. In one individual a large bunch of spermatozoa was found lodged in the end of the lophophoral organ's pocket-like cavity.

Judging from our observations, it seems that the relation of the lophophoral organs to the breeding season is as follows: Some adults are giving rise to eggs throughout the months of May, June, July, August, September, and October. None of the individuals arising from these eggs become sexually mature until March or April of the next year. Those which are the oldest—i. e., those born in the early months of the year before—develop testes and lophophoral organs in March or April. Then they lose their lophophoral organs, the testes disappear and ovaries begin to develop about the first of May. While this is going on, individuals which were born later in the summer of the year before begin to develop testes and lophophoral organs, and thus we have individuals with lophophoral organs and testes occurring at the same time of the year as individuals without lophophoral organs and with ovaries.

While there is no absolute proof, the upper part at least of the lophophoral organs probably functions as a kind of seminal receptacle. We are led to this conclusion by these facts: First, that the organs appear only when the testes are present; second, that large bunches of spermatozoa have been found in the body cavity, in the nephridia, and in the cavity of the lophophoral organs; and, third, that there are ciliated grooves leading from the nephridial pores to the cavities of the lophophoral organs.

Vascular system. Nearly all of the early investigators of the anatomy of *Phoronis* recognize the existence of an efferent and afferent vessel which are in connection with vessels running up into the tentacles.

Caldwell's (3) description, although brief, is complete, and differs very little from later ones. Cori's (4) account seems to be about the same as Caldwell's; however, he recognizes one ring vessel instead of two and describes in more detail the relation between the tentacular vessels and the ring vessel.

In *Phoronis australis*, Benham (2) finds the circulatory system much the same as Caldwell does in the form that he worked on. Practically the only point of difference is that he describes the tentacular vessels as dividing into two branches, one opening into the distributing vessel (inner) and the other into the recipient vessel (outer).

Andrews (1) finds that the vascular system of *P. architecta*, as far as he has determined, is like that of *P. australis*, while Ikeda (9) says that Benham's description holds good for *P. ijimai* and *P. hippocrepia*.

A transverse section through the lophophoral crown of *P. architecta* (fig. 63) shows that the cavity of each tentacle contains a blood vessel which is attached to the inner surface of the wall.

At the base of the tentacles a cross section shows that there are two blood vessels running parallel to one another through most of their course around the cavity of the lophophore (figs. 65 to 71). These vessels are distinct, although closely applied to one another, thus differing from what Cori finds in *P. psammophila*. The outer vessel and inner vessel (figs. 65, 66) are, respectively, the "recipient" and "distributing" vessels which Benham describes. In fig. 83 is shown a cross section through the base of the tentacles. Throughout most of the section the tentacular vessels open into the outer or recipient vessel, but at one end the tentacular vessels open into the inner or distributing vessel. This section, together with sections anterior and posterior to it, show conclusively that the tentacular vessel has two separate openings, one into the distributing vessel, the other into the recipient vessel, and that the distributing and recipient vessels are completely separate. A longitudinal section through the anterior end of *Phoronis architecta* shows conclusively that the tentacular vessel divides into two branches, one opening into the recipient vessel and the other into the distributing vessel.

A little more posteriorly the ring-like distributing vessel opens into a median longitudinal vessel lying between the œsophagus and rectum but close to the wall of the former (figs. 67, 68). This vessel, which is the afferent vessel, pierces the transverse septum (fig. 69) and runs posteriorly (within the rectal or posterior chamber) between the two arms of the alimentary canal. At the point where the vessel passes through the septum there is a thick layer of muscle fibres surrounding the former which undoubtedly has the power of shutting off the blood supply to the tentacles and which may be very necessary to prevent the animal from bleeding to death when the lophophoral crown is cast away (figs. 68 to 71).

The two sides of the ring-like recipient vessel do not pass into a single vessel while they are within the supraseptal cavity (figs. 67 to 71), but after they have pierced the transverse septum the right side of the ring is seen to pass diagonally across the œsophagus and to meet the left side of the ring (figs. 75 to 78). From this point the two become one vessel, the efferent vessel, which runs posteriorly within the left body cavity. In the posterior part of the body, where the alimentary canal makes a loop, the efferent and afferent vessels are continuous and open into a sinus around the stomach. Along most of the course of the efferent vessel blood cæca are given off, and a large bunch also arises from the sinus.

Nervous system.—We have found that the nervous system of the *Actinotrocha* is more highly developed in some species than in others and that it is subepidermal in character. In the different species of the adult we also find that there is considerable difference in the degree of development of the nervous system and that it is largely subepidermal.

Caldwell (3) was the first to give a good description of the nervous system, although Kowalevsky (11) recognized the existence of a lateral nerve and ganglion. Caldwell found the ring nerve, a hollow nerve cord on the left side, and he speaks of two ciliated pits consisting of nerve cells, ganglion, and nerve fibres. The description is so brief, that one can not say whether or not the ganglion that he speaks of represents the ganglion that Kowalevsky (11) and Cori (4) describe.

Benham (2) finds no ganglion in *P. australis*, but describes two small areas which, it seems probable, are the same as Caldwell's "ciliated pits." He is the first to recognize the existence of a lateral nerve on the right side as well as on the left, and he finds a nerve ring with a nerve to each tentacle arising from it.

Cori (4) describes a definite ganglion, a lateral nerve on the left side only and tentacular nerves. He is the only investigator who has published anything on the distribution of the nervous tissue in the lophophoral organ.

Andrews (1), Torrey (22), and Ikeda (9) have given very brief descriptions of the nervous system, but the two former recognize the existence of a short lateral nerve on the right side as well as a long one on the left side, while the latter speaks of a so-called brain ganglion and nerve ring.

The account which Andrews gives of the nervous system of *P. architecta* is very brief, since his paper deals only with the description of a new species. He only speaks of the lateral nerve and makes no mention of a brain ganglion, ring nerve, tentacular nerves, or nerves to the lophophoral organ.

In general our observations on the lateral nerve of *P. architecta* agree with those of Andrews and Torrey. The lateral nerve of the left side is quite conspicuous and extends from the anterior end to a point about one-third from the posterior end of the animal. It runs along the lateral body wall until it is almost in the region of the transverse septum, then it gradually passes obliquely upward in close proximity to the left nephridial canal, and finally is seen embedded in the ectoderm at the side of the anal papilla. From this point it passes around the base of the anal papilla between the anus and the mouth, and then it begins to take the same course close to the nephridial tube on the right side as it did on the left side, but it soon grows much smaller in diameter and finally disappears (figs. 78 to 67). A longitudinal section passing through the mouth and anus shows the relation which the nerve cord bears to the ganglion and nerve ring (fig. 84). Cori (4) figures such a section through *P. psammophila*, but he seems to have overlooked the nerve cord or axis cylinder in this region. It is closely associated with the cells of the ganglion and lies just a little below the latter. In an oral direction from the ganglion is seen a section through the nerve ring.

If a cross section (fig. 85) is taken through the ganglion so as to cut longitudinally through the nerve cord and if the section is stained deeply with iron hæmatoxylin and eosin, it will show plainly that there is no cavity in the cord, but that it is made up of a mass of fibres surrounded by a nucleated sheath. Caldwell (3) considers the structure to be a hollow nerve cord; Benham (2) says that it has semifluid contents and that he has been unable to make out any punctated nerve substance; and Cori (4) states that it is an axis cylinder.

We have endeavored to find some connection between the cord and the ganglion, but have not been very successful. In the region of the ganglion—i. e., between the mouth and the anus—the sheath of the nerve cord does not seem to differ in thickness or character from the same structure in other parts. The cells of the ganglion, however, send out processes which in sections are frequently seen applied to the sheath, but no connection between the fibres of the nerve ring and those of the cord could be made out.

Kowalevsky (11), Cori (4), and Torrey (22) have all found the nerve ganglion, while Benham (2) denies its existence in *P. australis*. It undoubtedly exists in *P. architecta*, is situated at the base of the anal papilla between the anus and the mouth, and lies above the nerve cord between the anal papilla and the nerve ring (fig. 84).

The ganglion consists of nerve fibres and nerve cells and the latter have at least two processes. While it is a definite structure back of the anal papilla, on the sides it diminishes in size until its cells become indistinguishable from those of the nerve ring. In fact, all of the ectoderm forming the sides of the groove between the anal papilla and the base of the lophophore is rich in nerve fibres and cells.

The nerve ring follows the base of the lophophore on the outer side throughout its extent, and in the inner part of the horseshoe it is quite rich in nerve cells whose processes can be seen penetrating into the mass of fibres (figs. 67 to 74). This ring represents the collar nerve ring of the *Actinotrocha*.

There is a definite tract of nervous tissue running up the inner side of the tentacle, but we are not prepared to say that it is a nerve running from the ring, although it is nervous tissue which is undoubtedly continuous with that of the nerve ring.

Cori (4) has carefully studied the anatomy of the lophophoral organ of *P. psammophila* and we have nothing to add to his description at present. We are also unprepared to say whether or not the second layer of the lophophoral organ consists of nerve cells. As he has described, they have long prolongations which extend from the cells of the inner layer to the outer, and these processes form a rather marked layer just below the epidermis on the outer surface of the organ. At the base of the lophophoral organ these prolongations seem to be intimately associated with nerve fibres which can be traced to the nerve ring.

Throughout the body wall of the trunk there is a subepidermal layer of nervous tissue.

Nephridia.—We have nothing new to add concerning the adult nephridia, but our observations on *P. architecta* confirm those of Benham (2) for *P. australis*. The nephridial canals lie embedded in the ectodermal wall in the region of the rectum. Each opens to the exterior through a pore at the side of the anal papilla. Following the canal from the nephridial pore, we see that it passes downward—i. e., posteriorly—for a short distance and then bends upon itself running upward parallel to the descending arm. A short distance above the bend it opens by one funnel into the lateral body cavity (fig. 72) and by another into the rectal body cavity (fig. 70).

Reproductive organs.—Ikeda's recent paper (10) on the reproductive organs of *Phoronis* gives a good account of the anatomy and development so we shall not enter into a description of them. We are able to confirm Andrews's observations that the male organs develop at a different time from those of the female.

Ciliated ridge of the alimentary canal.—Andrews has described a ridge running along the inner wall of the oral branch of the alimentary canal (fig. 81). H. B. Torrey has found the same structure in *P. pacifica*, and we can confirm Andrews's observation for *P. architecta*. This ridge does not seem to have any rudiment in the *Actinotrocha*, and it is not present just after metamorphosis.

SUMMARY.

The male and female reproductive organs do not develop at the same time in *P. architecta*, and the indications are that it is a protandrous animal.

Fertilization is external and the eggs are not held in lophophoral masses by the tentacles.

Segmentation is holoblastic and equal, but cleavage does not occur simultaneously in all the blastomeres. During the division of the four-cell stage into the eight-cell stage, the upper four blastomeres rotate in the direction of the hands of a watch. The sixteen-cell stage arises from the eight-cell stage by a meridional division of each blastomere.

The blastopore is eccentric from the beginning of gastrulation and the ganglion of the *Actinotrocha* makes its appearance at this time. As development proceeds, the blastopore gradually closes up from the posterior end toward the anterior end of the larva until finally it becomes a transverse slit.

The "primitive streak" of Caldwell does not seem to be present in the larva of *P. architecta.*

The "nephridial pit" is of ectodermal origin.

The mesoderm arises, for the most part, from the lips of the blastopore. Archenteric diverticula are not present in the larva of *P. architecta*, but there is a sac-like formation of mesoderm cells in the anterior end which forms the lining of the preoral lobe and which gives rise to a mesentery between the lobe and collar cavities.

The lining of the collar cavity does not arise from a mesodermal sac. It is formed by isolated mesoderm cells which arrange themselves on the somatic wall leaving the splanchnic wall practically without any lining.

In the larva of *P. architecta* the mesodermal lining of the trunk cavity is complete, covering both the somatic and splanchnic walls, and it seems probable that it arises from cells forming the base of the nephridial diverticula. There is a mesentery between the cavities of the trunk and collar.

A stomodæum and proctodæum are not present. The blastopore becomes the mouth, the anus arises quite late in the early life of the embryo, and the rectum is formed as an outgrowth of the blind end of the archenteron.

The nephridial canals, at least, have their origin in a single median pit which soon branches into two intercellular tubes. We have not found any evidence that the excretory cells of the nephridia are formed from free mesoderm cells attaching themselves to the blind end of the nephridial canals.

The "neuropore" and "subneural gland," which Masterman has described, do not exist in the *Actinotrochæ* examined, although imperfectly preserved specimens show unusual structures which might be taken for these organs.

Masterman's "subneural sinus" is not present either, although there is a space below the ganglion which is free from mesodermal strands. The "atrial grooves" which Masterman says exist are present in the larvæ we have studied, but we can not consider that they have the significance that he assigns to them. Occasionally grooves are found which might be comparable to Masterman's "oral grooves," but they are due to imperfect fixation. The stomach diverticula exist in one species that we have examined, but they do not impress us as being of notochordal nature, as Roule and Masterman have claimed.

There is a subepidermal layer of nervous tissue throughout the body. Extending anteriorly from the ganglion, which is situated on the median dorsal surface of the hood, are three longitudinal nerves, which finally become continuous with a nervous ring running around the edge of the hood. From the posterior side of the ganglion two parallel tracts of nerve fibres issue and pass posteriorly along the dorsal collar wall until they reach the circle of tentacles, where most of them follow the line of insertion of the collar trunk mesentery, and give rise to a collar nerve ring. The nerve fibres from the edge of the preoral hood do not pass up to the ganglion from the point of attachment of the hood on to the collar wall, as Masterman has described, but they make a sharp turn, running posteriorly and obliquely along the lateral and ventral wall of the collar, where they form two definite nerve tracts which become lost in the region of the collar nerve ring. While there may be nerve fibres passing from the ganglion out in all directions over the surface of the hood, we have not been able to make them out, nor do we find any definite nervous tract running along the dorsal or ventral wall of the trunk segment.

There is one pair of retractor muscles extending from the region of the ganglion to the collar walls, in the region of the first and second pairs of tentacles, and besides these, in one *Actinotrocha* that we have examined, there is another pair extending from the sides of the ganglion to the ventral wall of the hood. In this latter *Actinotrocha* there is an extensive layer of muscle fibres in the wall of the hood and also a ring of fibres around the edge of the latter. A pair of longitudinal muscle tracts extend from the region of the ganglion, along the dorsal wall of the *Actinotrocha*, to the perianal ring, and there is a similar pair of tracts extending along the ventral wall of the collar and trunk. A ring of muscle fibres run parallel with the ring nerve, between the collar and trunk segments. Beside these muscle tracts there is a layer of circular fibres in the wall of the collar and trunk, lying between the longitudinal fibres and the ectoderm. There is also a covering of muscle cells on the ventral pouch and on the wall of the dorsal blood vessel.

The nephridia have much the same structure as those of *Amphioxus*, as described by Goodrich. In one of the *Actinotrochæ* from Beaufort Harbor the nephridial canal branches, but in the other it does not. Nephridial funnels do not exist, but the ends of the canals open into tubular cells, and the lumen of each cell contains a flagellum. The nephridial canals open to the exterior, at the sides of the orifice of the ventral pouch. The nephridia, which Masterman describes for the preoral hood and trunk, are not present in any *Actinotrochæ* that we have examined.

The blood vessels of the *Actinotrocha* are formed from the splanchnic mesodermal lining and they inclose part of the blastocœle. There is a dorsal blood vessel opening (?) anteriorly into the space between the stomach wall and the splanchnic lining. At the posterior end of the stomach, where the dorsal vessel ends, there are cæcal vessels formed as evaginations of the mesodermal lining of the stomach. The dorsal vessel becomes the afferent vessel of the adult, while the efferent vessel does not arise until just after metamorphosis. The collar cavity, which is a part of the blastocœle, becomes the ring vessels and tentacular vessels of the adult. There is no connection between the dorsal blood vessel and Masterman's "subneural sinus."

The blood corpuscles arise from the somatic mesodermal lining of the ventro-lateral collar wall just in front of the septum. They make their appearance as two masses of cells bilaterally placed, one on each side of the median ventral line, and as they develop they migrate across the collar cavity and become applied to the naked walls of the stomach.

The rudiment of the supraseptal or collar cavity of the adult makes its appearance in about the same region as do the blood corpuscles but a little later in the life history of the *Actinotrocha*.

During metamorphosis the following organs are lost: The preoral lobe, the ganglion, and the larval tentacles. The ectodermal wall of the collar cavity, the stomach diverticula, the digestive areas, and the perianal ciliated ring are not destroyed, but they lose their identity. The subepidermal nervous layer of the trunk and ventral pouch becomes part of the same tissue in the adult, but the larger part of this tissue, as well as the lateral nerve, the ganglion, and the nerves to the lophophoral organs are new formations.

All of the nervous structures of the collar and trunk are lost during metamorphosis, except the collar trunk nerve ring, which persists as the nerve ring of the adult.

The ventral mesentery becomes the œsophageal and rectal mesenteries of the adult, and the cavities of the trunk and ventral pouch are transformed into the infraseptal cavity.

At least the greater part of the nephridia is lost during metamorphosis.

The lophophoral organs arise late in the adult life and are present only in individuals which are with testes and without ovaries. They probably serve as seminal receptacles.

The vascular system of the adult consists of an efferent and afferent vessel, which are continuous posteriorly by means of a sinus around the loop of the alimentary canal; of cæcal vessels as outgrowths from the afferent vessel and the blood sinus; of a distributing and recipient ring vessel, the former opening into the afferent vessel and the latter into the efferent vessel; and of tentacular vessels, each of which divides into two short branches, one opening into the distributing vessel and the other into the recipient vessel.

There is a ciliated ridge extending along part of the inner wall of the alimentary canal.

The nervous system of the adult is to a great extent subepidermal. There is a nerve with a nucleated sheath extending along the left side of the animal. Anteriorly it bends around the anal papilla and continues as a short nerve on the right side. There is a ganglion between the mouth and anus. A nerve ring extends around the base of the lophophore and it gives off nerves to the lophophoral organs. There is nervous tissue in the walls of the tentacles.

The excretory organs are paired and each nephridium consists of a tube bent upon itself. One end opens to the exterior, while the other is continued into two funnels, one communicating with the rectal and the other with the lateral body cavity.

The reproductive organs arise from the lining of the cæcal blood vessels, and the male organs develop at a different time from those of the female.

JOHNS HOPKINS UNIVERSITY, *March, 1904.*

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[a] Received after completion of paper.

REFERENCE LETTERS FOR FIGURES.

a.	anus.
a. c. c	adult collar cavity (Ikeda).
af. v	afferent blood vessel.
al. c	alimentary canal.
a. p	anal papilla.
art	artefact.
a. t	adult tentacle.
a. t. m	transverse septum of adult.
b. c	blood corpuscles.
b. c. m	blood corpuscle masses.
b. t	basement tissue (Benham).
cæ	blood cæcum.
c. c	collar cavity.
c. g	ciliated groove (Andrews).
c. w	collar wall.
d. a	digestive area.
d. m. t	dorsal muscle tract.
d. v	dorsal vessel (afferent).
d. ve	distributing vessel.
ef. v	efferent vessel.
eg	egg.
e. h	edge of hood.
ep	epistome.
ex. c	excretory cell.
fl	flagellum.
g	ganglion.
g. c	ganglion cell.
g. m. c	giant mesoderm cell.
in. c	infraseptal cavity.
int	intestine.
lat. n	lateral nerve.
l. l. c	left lateral cavity.
l. l. m	left lateral mesentery.
l. l. n	lateral longitudinal nerve.
l. m	longitudinal muscle.
l. r. m	ring muscle tract of lobe.
l. r. n	ring nerve tract of lobe.
l. t	larval tentacle.
m	mesoderm.
m.^{1}	mesentery between preoral lobe and collar cavities.
m.^{2}	mesentery between collar and trunk cavities.
m. c. m	mesodermal cell mass giving rise to blood corpuscles.
m. f	muscle fiber.
m. l. n	median longitudinal nerve.
m. s	mesodermal sac of preoral lobe.
n. c	nephridial canal.
neph	nephridium.
neph. o	nephridial opening.
n. f	nerve fiber.
n. f.^{1}	nephridial funnel into rectal body cavity.
n. f.^{2}	nephridial funnel into lateral body cavity.
n. p	nephridial pit.
nu	nuclei of ciliated cells of perianal ring.
œs. m	œsophageal mesentery.
p. an. s	perianal space.
pig	pigment.
p. o. c	preoral body cavity.
p. o. l	preoral lobe.
p. r	perianal ring.
p. re	posterior recess (Ikeda). subneural sinus (Masterman).
r	rectum.
r. b. v	ring blood vessel.
r. c	rectal cavity.
r. d. m	rudimentary dorsal mesentery.
ret	retractor muscle.
r. l. c	right lateral cavity.
r. m	rectal mesentery.
r. n	ring nerve.
r. ve	recipient vessel.
sen. p	sensory papilla.
sp. m	sphincter muscle.
st	stomach.
sup. c	supraseptal cavity.
t	tentacle.
t. b. v	tentacular blood vessel.
t. c	trunk cavity.
th	ventral thickening of ectoderm.
t. m. t	tentacular ring muscle tract.
t. n. t	tentacular ring nerve tract.
t. r	tentacular ridge.
v	vestibule.
ves	glandular vesicles in ectoderm.
v. m	ventral mesentery.
v. m. t	ventral muscle tract.
v. n. t	ventral nerve tract.
v. p	ventral pouch.
v. p. o	ventral pouch opening.
v. v	ventral blood vessel (efferent).
v. w. h	ventral wall of hood.

EXPLANATION OF FIGURES.

The objectives used in this work are the $\frac{2}{3}$ and $\frac{1}{6}$ Spencer and the $\frac{1}{12}$ Zeiss Oil Immersion. The occulares used are the "×4" and "×8" Spencer and the No. 12 Zeiss Compensating.

PLATE I.

PLATE I.

Fig. 1.—Transverse section through nephridium of adult. $\frac{1}{12}$ Ob. × 4 Oc. Camera. × 440.

Fig. 2.—Unsegmented egg with one polar body. (From life.) $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 360.

Fig. 3.—Two-cell stage, showing equal blastomeres. (From life.) $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 360.

Fig. 4.—Two-cell stage, showing unequal blastomeres. (From life.) $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 360.

Fig. 5.—Beginning of two-cell stage. (From life.) $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 360.

Fig. 6.—Section through two-cell stage. Chromosomes have lost their identity and granular vesicles have made their appearance. Granular character of the yolk only shown in part of one blastomere. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 7.—Beginning of four-cell stage. (From life.) $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 360.

Fig. 8.—Four-cell stage, showing polar furrow. (From life.) $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 360.

Fig. *8a.*—Section through four-cell stage, showing granular vesicles which make their appearance after the disappearance of the chromosomes. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 9.—Four-cell stage passing into eighth-cell stage. Seen from above and showing the twisting of the blastomeres. $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 360.

Fig. 10.—Eight-cell stage, showing rotation of blastomeres. (From life.) $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 360.

Fig. 11.—Section of eight-cell stage ready for sixteen-cell stage. Position of mitotic figures indicate meridional division. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 12.—Young blastula showing "blastocœle pore." (From life.) $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 360.

Fig. 13.—Section through young blastula showing blastocœle pore. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

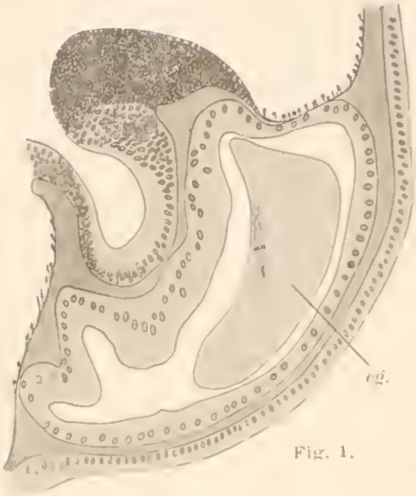


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

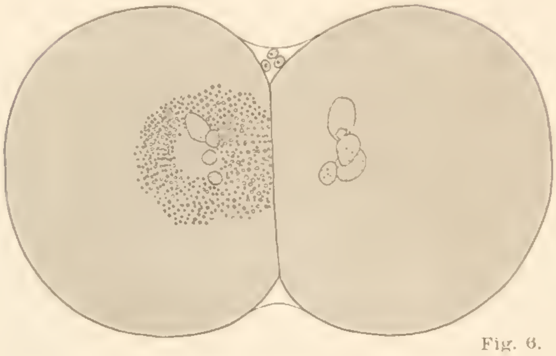
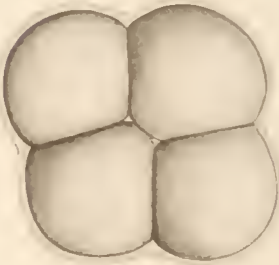


Fig. 6.

Fig. 7.



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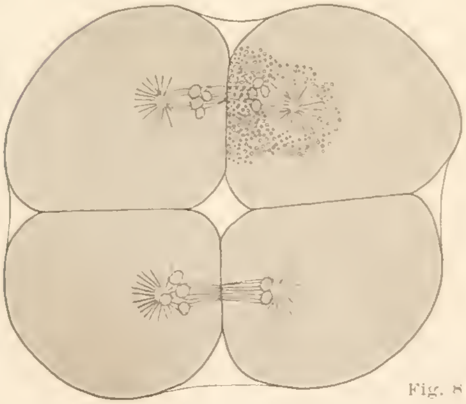

Fig. 8 (*a*)

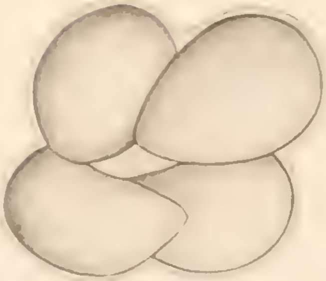

Fig. 9.

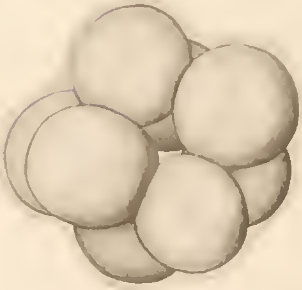

Fig. 10.

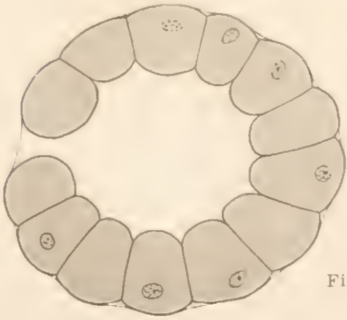

Fig. 13.

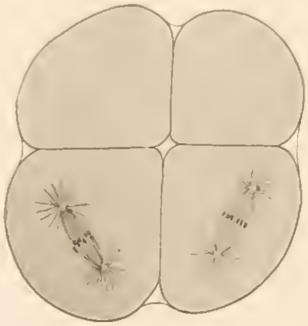

Fig. 11.

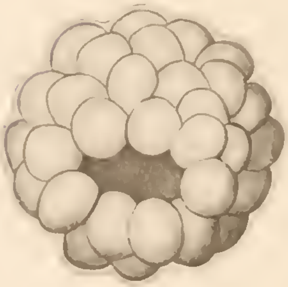

Fig. 12.

PHORONIS ARCHITECTA

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PLATE II.

PLATE II.

Fig. 14.—Optical section of an old blastula. (From life.) $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 360.

Fig. 14*a*.—Section through an old blastula showing endodermal bodies in blastocœle. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 15.—Longitudinal section through older blastula than that of fig. 14*a* showing proliferation of endoderm cells. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 15*a*.—Transverse section through a gastrula which is just beginning to gastrulate. Taken through ganglionic thickening. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 15*b*.—Transverse section through same specimen as that of fig. 15*a*. Taken through the middle of the gastrula. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 16.—Longitudinal section through a gastrula which has begun to elongate. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 16*a*.—Transverse section through anterior end of a gastrula which was a little younger than that of fig. 16. Taken just back of the ganglion. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 16*b*.—Transverse section through same specimen as that of fig. 16*a*. Taken just in front of anterior end of the archenteron. Shows mesoderm arising from the latter. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 16*c*.—Continuation of above series. Taken through anterior part of archenteron. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 16*d*.—Continuation of above series. Taken through middle of archenteron. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 16*e*.—Continuation of above series. Taken through posterior part of archenteron. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 16*f*.—Continuation of above series. Taken through the region where the lips of the blastopore are closing up. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 16*g*.—Horizontal section through a gastrula of the same age as that of fig. 16. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 17.—Transverse section through a gastrula showing peculiar granular cells arising from the endoderm. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

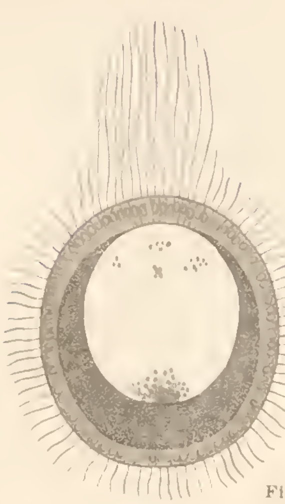

Fig. 14.

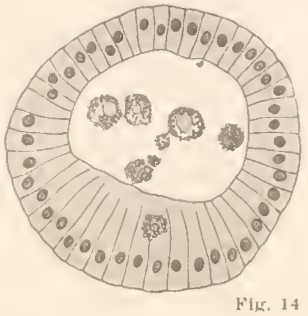

Fig. 14 (*a*)

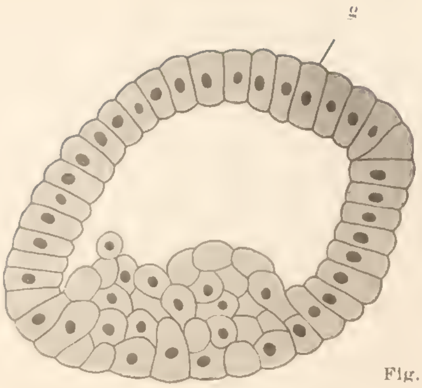

Fig. 15.

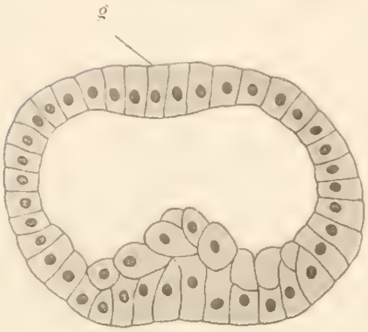

Fig. 15 (*a*)

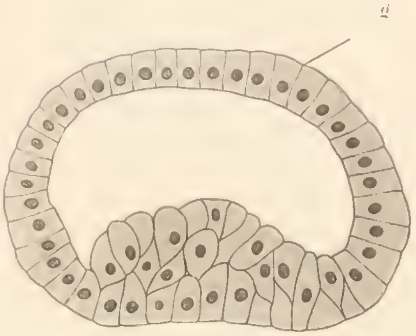

Fig. 15 (*b*)

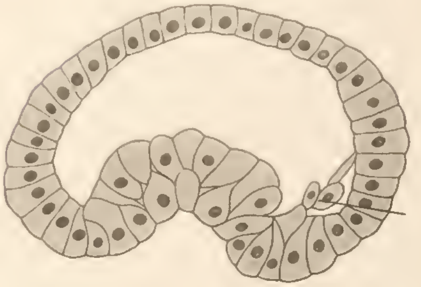

Fig. 16.

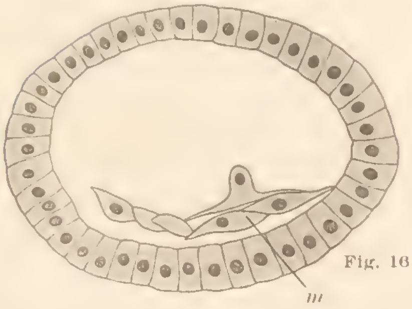

Fig. 16 (*a*)

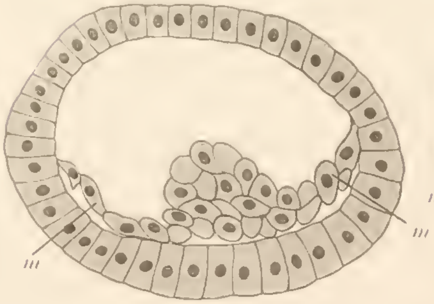

Fig. 16 (*b*)

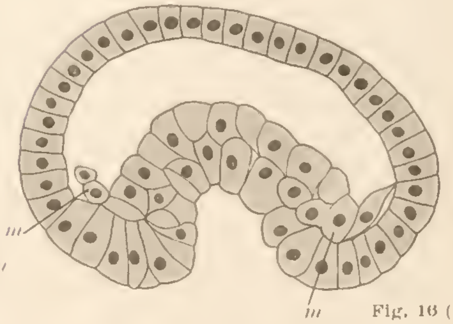

Fig. 16 (*c*)

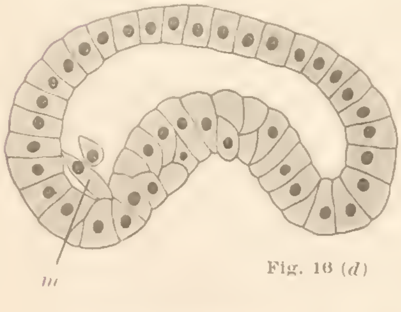

Fig. 16 (*d*)

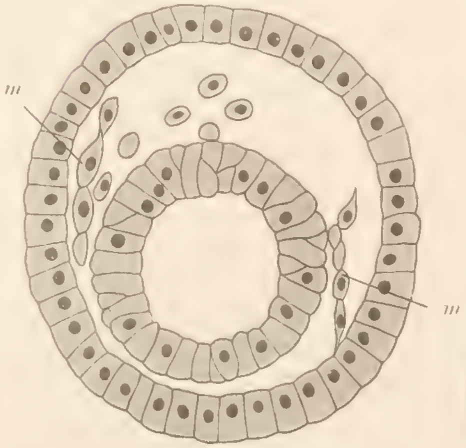

Fig. 16 (*g*)

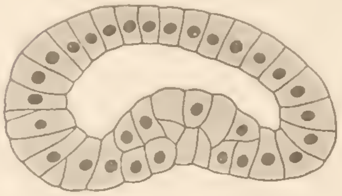

Fig. 16 (*f*)

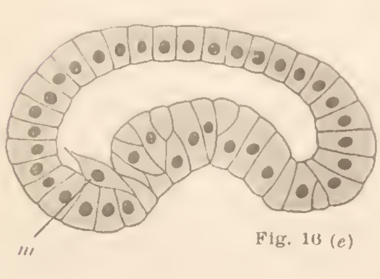

Fig. 16 (*e*)

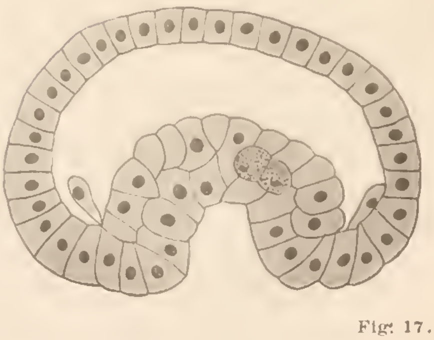

Fig. 17.

PHORONIS ARCHITECTA

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PLATE III.

PLATE III.

Fig. 17*a*.—Same as fig. 17, showing one of the peculiar cells set free in the blastocœle. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 18.—Transverse section through the anterior end of a young larva, which is slightly younger than the specimen of which fig. 19 is a longitudinal section. Blastopore is slightly oval in outline. Taken through the ganglion. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 18*a*.—Continuation of above series. Taken just in front of archenteron. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 18*b*.—Continuation of above series. Taken through anterior part of blastopore. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 18*c*.—Continuation of above series. Taken through posterior part of blastopore. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 18*d*.—Continuation of above series. Taken immediately posterior to the blastopore. Lips have grown together and there is a straight furrow corresponding to Caldwell's "primitive groove." $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 18*e*.—Continuation of above series. Taken posteriorly to section 18*d*. No sign of Caldwell's "primitive groove or streak." $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 18*f*.—Horizontal section through same stage as 18 *a*, *b*, *c*, etc. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 19.—Sagittal section through larva which is a little older than that of series 18 *a*, *b*, *c*, etc. Shows mesodermal preoral sac. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 20.—Sagittal section through a larva somewhat older than that of fig. 19. Blastopore has become circular again, but much smaller than originally. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 20*a*.—Transverse section through larva of same age as that of fig. 20. Taken just posterior to the ganglion. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 20*b*.—Continuation of series. Taken through blastopore. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 20*c*.—Continuation of series. Taken just posterior to the blastopore. Slight indication of groove. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 20*d*.—Continuation of series. Taken near posterior end of larva. No groove. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 20*e*.—Horizontal section through a larva of the same age as that of figs. 20 *a*, *b*, etc. Shows mesodermal sac with posterior prolongations. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

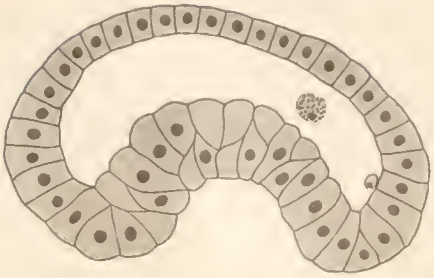

Fig. 17 (*a*)

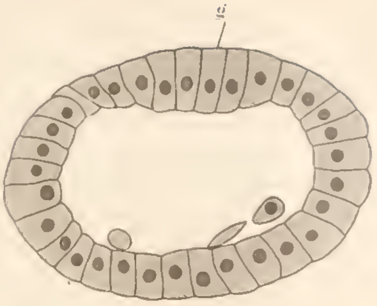

Fig. 18.

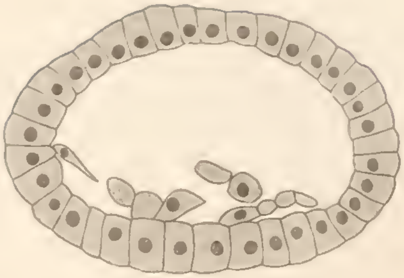

Fig. 18 (*a*)

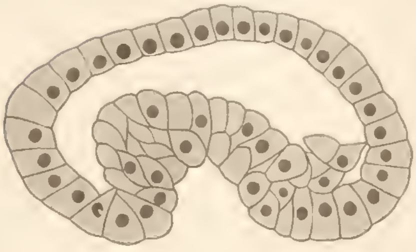

Fig. 18 (*b*)

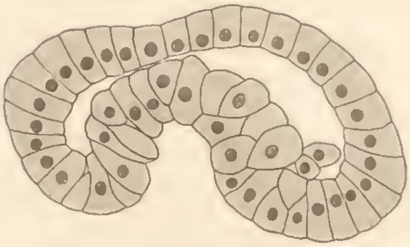

Fig. 18 (*c*)

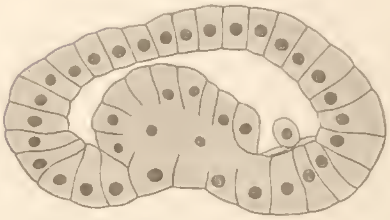

Fig. 18 (*d*)

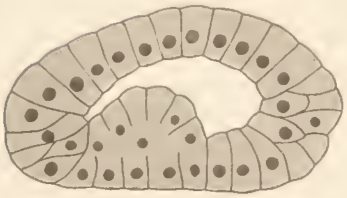

Fig. 18 (*e*)

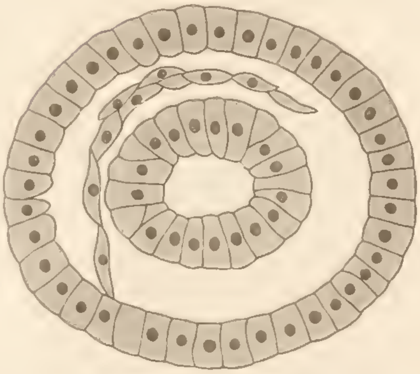

Fig. 18 (*f*)

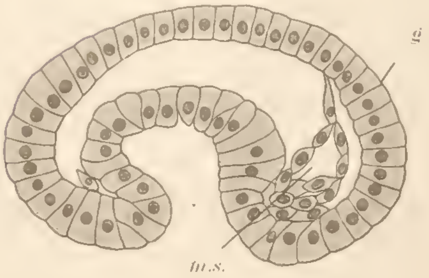

Fig. 19.

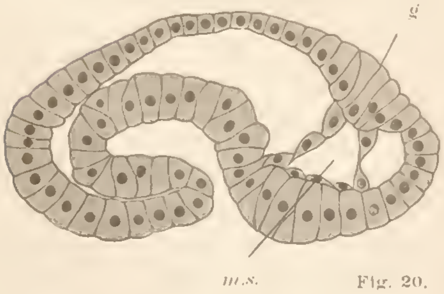

Fig. 20.

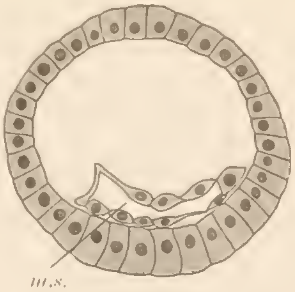

Fig. 20 (*a*)

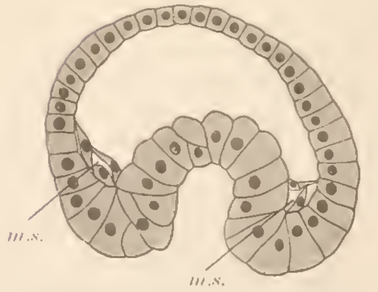

Fig. 20 (*b*)

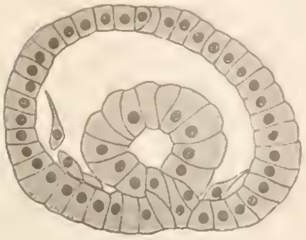

Fig. 20 (*c*)

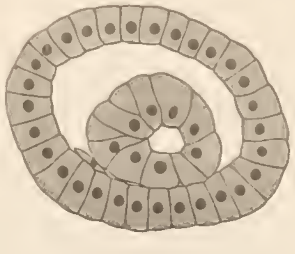

Fig. 20 (*d*)

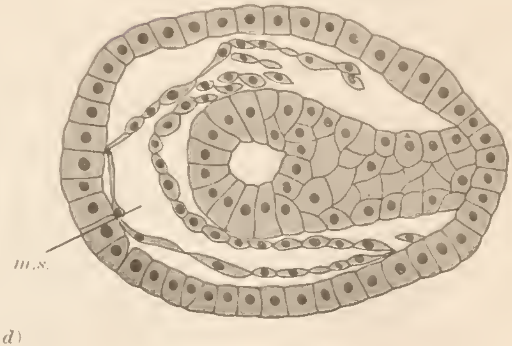

Fig. 20 (*e*)

PHORONIS ARCHITECTA

PLATE IV.

PLATE IV.

Fig. 21.—Sagittal section through a larva somewhat older than that of fig. 20 *a*, *b*, *c*, etc. Blastopore oval and transverse. Nephridial pit present at this stage. Archenteron has fused with posterior ectodermal wall. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 21*a*.—Continuation of above. Taken longitudinally and lateral to that of fig. 21. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 22.—Transverse section through a larva of the same age as the one shown in figs. 21 and 21*a*. Taken just posterior to ganglion. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 22*a*.—Continuation of above series. Taken through blastopore. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 22*b*.—Continuation of above series. Taken just posterior to blastopore. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 22*c*.—Continuation of above series. Taken halfway between the blastopore and the posterior end. Shows the mesoderm cells on the ventral ectoderm. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 22*d*.—Continuation of above series. Taken through rectum. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 22*e*.—Continuation of above series. Next section posterior to that of fig. 22*d*. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 22*f*.—Continuation of above series. Next section posterior to that of fig. 22*e*. Through wall of nephridial pit. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 22*g*.—Continuation of above series. Section through nephridial pit. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 23.—Horizontal section through a larva of the same age as that of fig. 21. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 23*a*.—Same as fig. 23, but more ventral. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 24.—Longitudinal section through a larva somewhat older than that of fig. 21. Not quite sagittal. Anus has just made its appearance. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

Fig. 25.—Larva with two pairs of tentacles. (From life.) $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

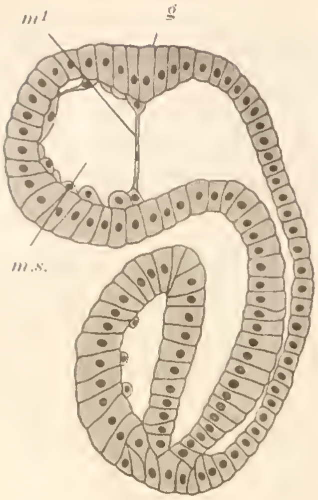

Fig. 21.

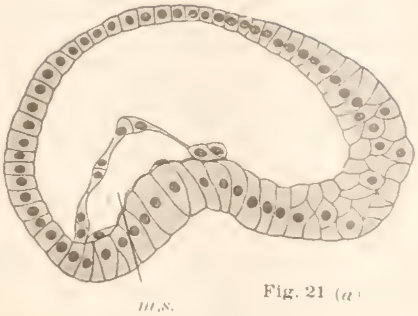

Fig. 21 (a)

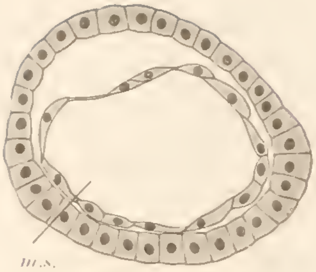

Fig. 22.

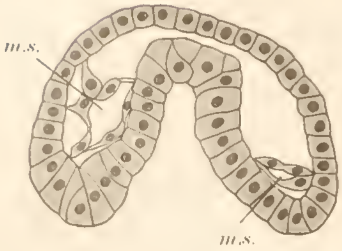

Fig. 22 (a)

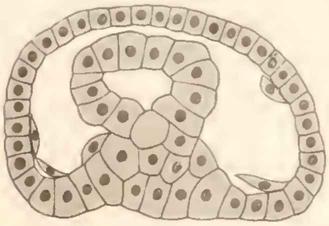

Fig. 22 (b)

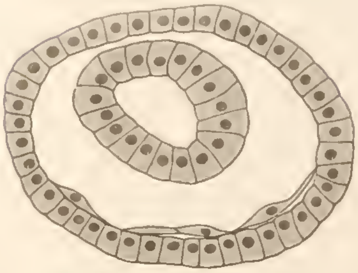

Fig. 22 (c)

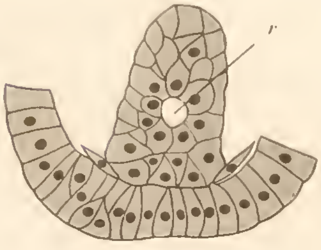

Fig. 22 (d)

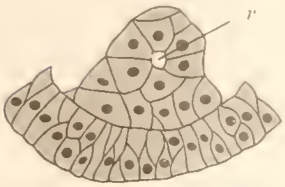

Fig. 22 (e)

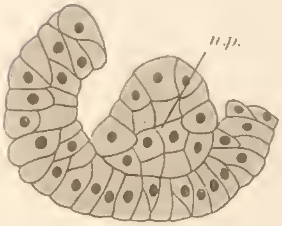

Fig. 22 (f)

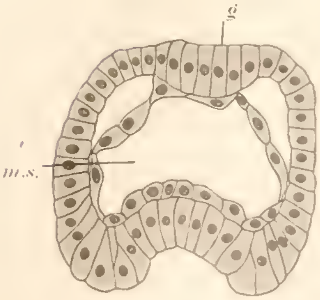

Fig. 23.

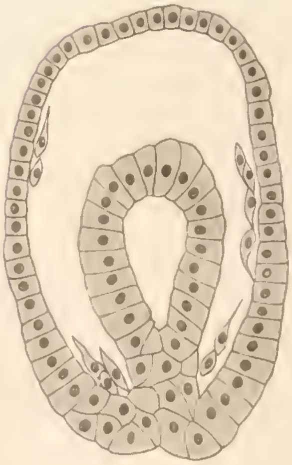

Fig. 23 (a)

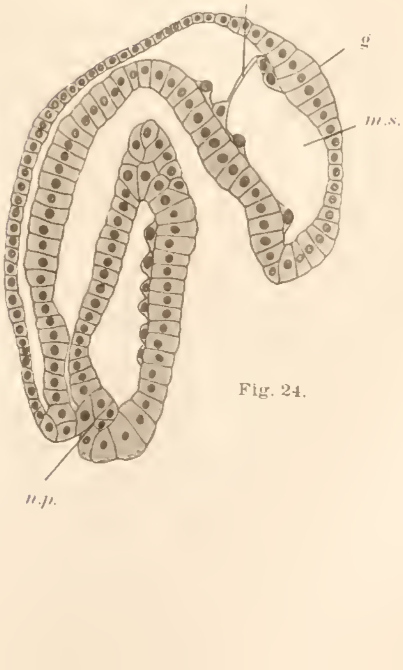

Fig. 24.

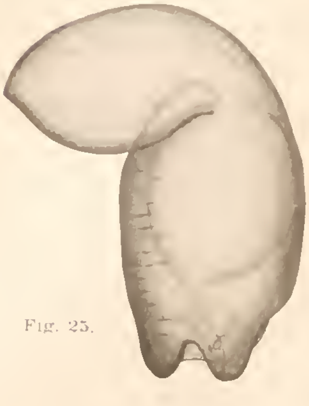

Fig. 25.

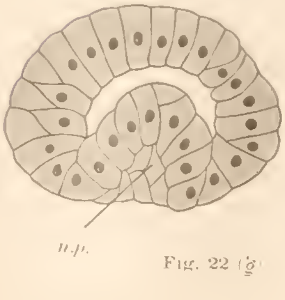

Fig. 22 (g)

PHORONIS ARCHITECTA

PLATE V.

PLATE V.

FIG. 26.—Horizontal section through a larva somewhat older than that of fig. 24, but younger than that of fig. 25. Shows the separation of the cells of the nephridial pit into two wings. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

FIG. 27.—Horizontal section of posterior end showing slightly older stage in the development of the nephridia than that of fig. 26. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

FIG. 28.—Horizontal section through a larva with beginnings of two tentacles. Shows nephridia. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

FIG. 29*a*.—Transverse section through posterior end of a larva with two pairs of tentacles. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

FIG. 29*b*.—Continuation of series 29*a*. Taken through the region of the rectum. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

FIG. 29*c*.—Continuation of series 29*a*. Taken through the middle of the larva. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

FIG. 29*e*.—Continuation of series 29*a*. Taken through the body proper and the lower part of the hood. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

FIG. 29*d*.—Continuation of series 29*a*. Taken through body and hood near the region of the mouth. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

FIG. 30.—Almost a sagittal section through a larva with two tentacles. $\frac{1}{12}$ Oil Immersion. × 8 Oc. Camera. × 704.

FIG. 31.—Larva with three pairs of tentacles. Outline drawing from life. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

FIG. 32.—Larva with five pairs of tentacles. Outline drawing from life. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 202.

FIG. 33.—Larva with six pairs of tentacles. Outline drawing from life. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 202.

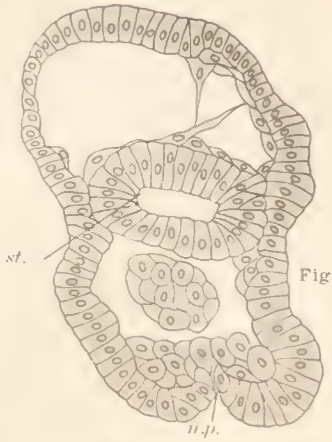

Fig. 26.

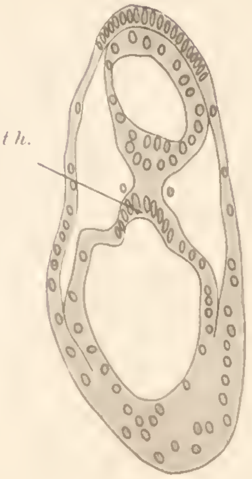

Fig. 29 (d)

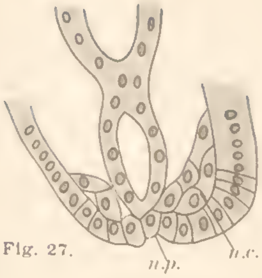

Fig. 27.

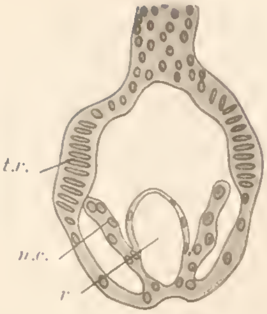

Fig. 28.

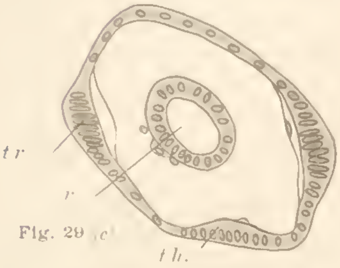

Fig. 29 (c)

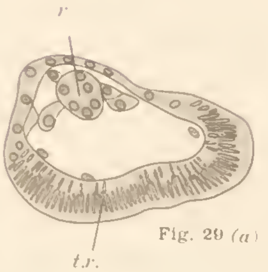

Fig. 29 (a)

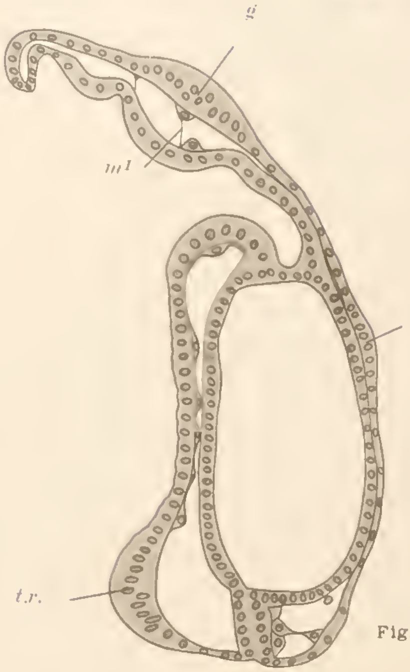

Fig. 30.

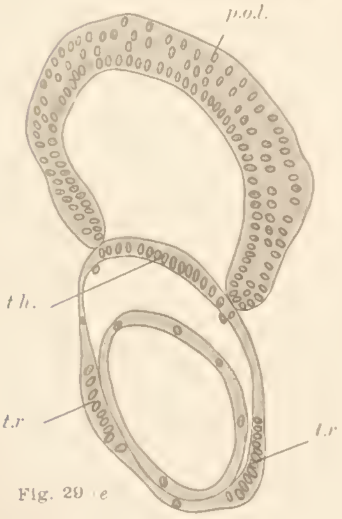

Fig. 29 (e)

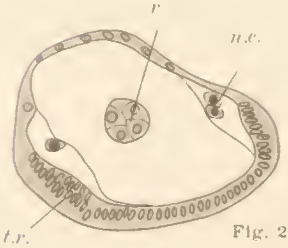

Fig. 29 (b)

Fig. 31.

Fig. 32.

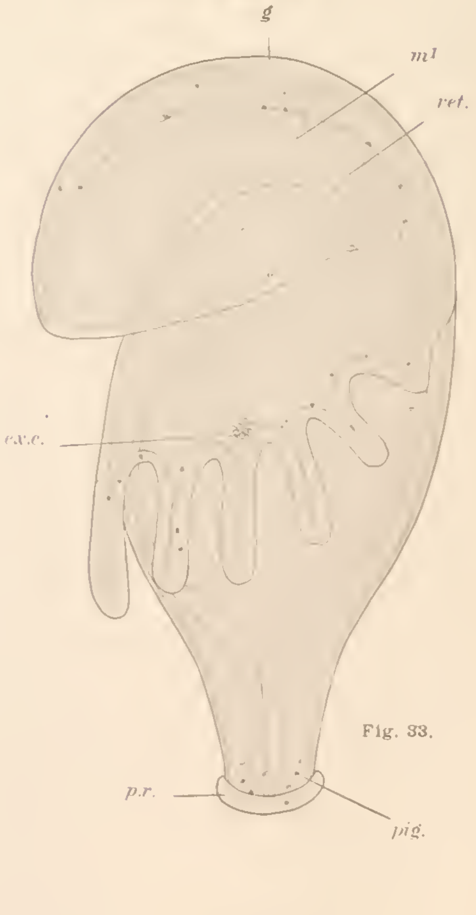

Fig. 33.

PHORONIS ARCHITECTA

WINS, DEL.

PLATE VI.

PLATE VI.

FIG. 34.—*Actinotrocha* Species A. (Drawn from life.) $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 135.
FIG. 35.—*Actinotrocha* Species B. (Drawn from life.) $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 135.

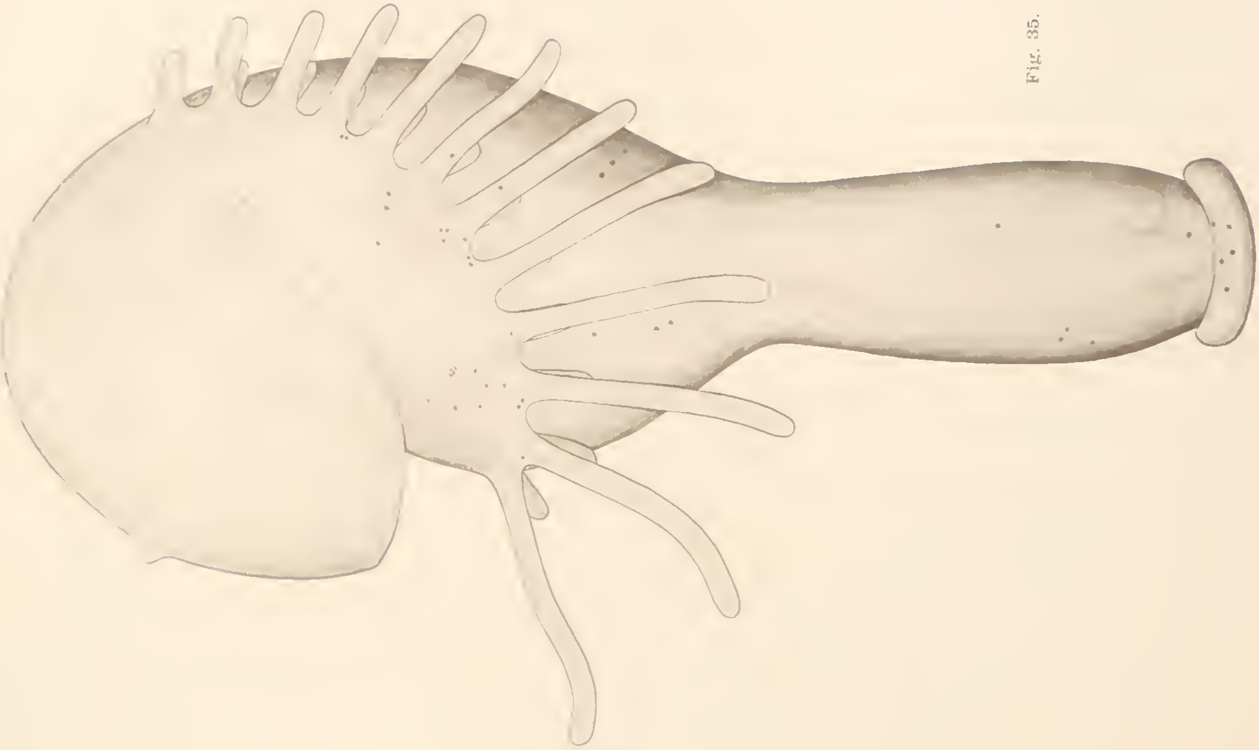

Fig. 35.

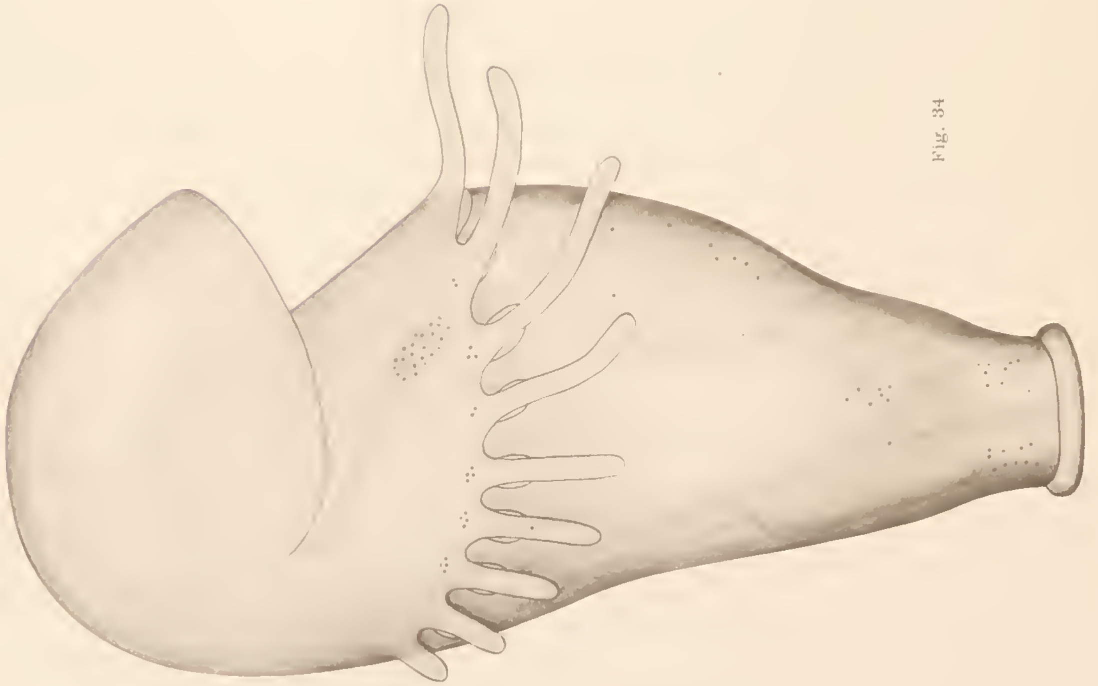

Fig. 34

PHORONIS ARCHITECTA

PLATE VII.

PLATE VII.

FIG. 36.—Nervous and muscular tracts of the dorsal surface of the hood. *Actinotrocha* Species B. (Drawn from living specimen.)

FIG. 37.—Lateral view of anterior part of *Actinotrocha* Species B., showing muscle tracts. (Drawn from living specimen.)

FIG. 38.—Longitudinal section through the ganglion of an *Actinotrocha*. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Occulare. Camera. × 665.

FIG. 39.—Section through a ganglion cell in the collar nerve ring. *Actinotrocha* Species B. $\frac{1}{12}$ Oil Immersion. × 8l Oc. Camera. × 469.

FIG. 40.—Transverse section through the nerve tract of the ventral collar wall. *Actinotrocha* Species B. $\frac{1}{12}$ Oi Immersion. 12 Zeiss Occulare. Camera. × 665.

FIG. 41.—Transverse section through the dorsal nerve tract where it passes down along the bases of the tentacles. *Actinotrocha* Species B. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Occulare. Camera. × 665.

FIG. 42.—Transverse section through the collar nerve ring. *Actinotrocha* Species B. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Occulare. Camera. × 665.

FIG. 43.—Transverse section through the nerve tract around the edge of the hood. *Actinotrocha* Species B. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Occulare. Camera. × 665.

FIG. 44.—Transverse section through the hood of *Actinotrocha* Species B. Taken through the sensory papilla. Hood flattened out. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 300.

FIG. 44*a*.—Continuation of series 44. Taken through the anterior part of the ganglion. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 300.

FIG. 44*b*.—Continuation of series 44. Taken through the ganglion which is invaginated by the action of fixing agents. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 300.

Fig. 36.

Fig. 37.

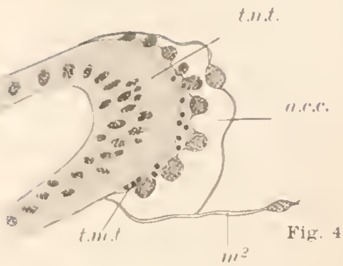

Fig. 42.

Fig. 38.

Fig. 40.

Fig. 41.

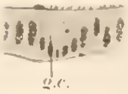

Fig. 39.

Fig. 43.

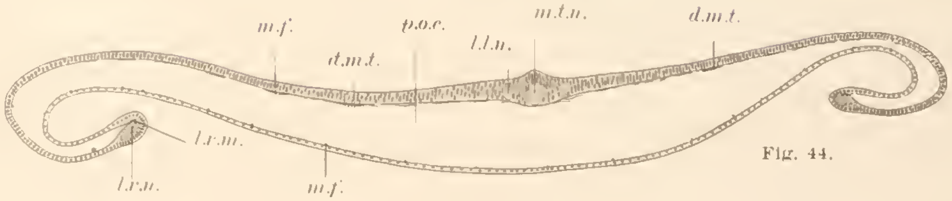

Fig. 44.

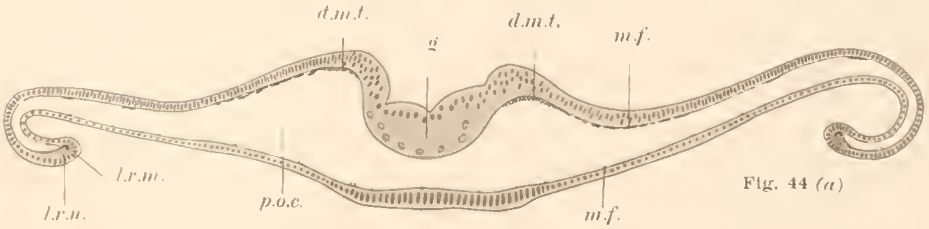

Fig. 44 (*a*)

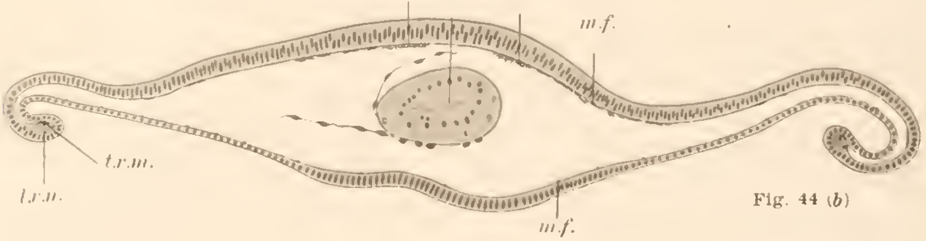

Fig. 44 (*b*)

PHORONIS ARCHITECTA

WLES DEL.

PLATE VIII.

PLATE VIII.

FIG. 44*c*.—Continuation of series 44. Taken through the region where the edge of the hood passes into the collar wall. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 300.

FIG. 44*d*.—Continuation of series 44. Taken through the middle of the collar segment. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 300.

FIG. 44*e*.—Continuation of series 44. Taken through the bases of the ventral tentacles of the collar. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 300.

FIG. 44*f*.—Continuation of series 44. Taken immediately posterior to that of fig. 44*e*. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 300.

FIG. 44*g*.—Continuation of series 44. Taken in the anterior part of the trunk segment. $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 480.

FIG. 44*h*.—Continuation of series 44. Taken through the rectum. $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 480.

FIG. 44*i*.—Continuation of series 44. Taken through the anterior part of the perianal ring. $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 480.

FIG. 44*j*.—Continuation of series 44. Taken through the posterior part of the perianal ring. $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 480.

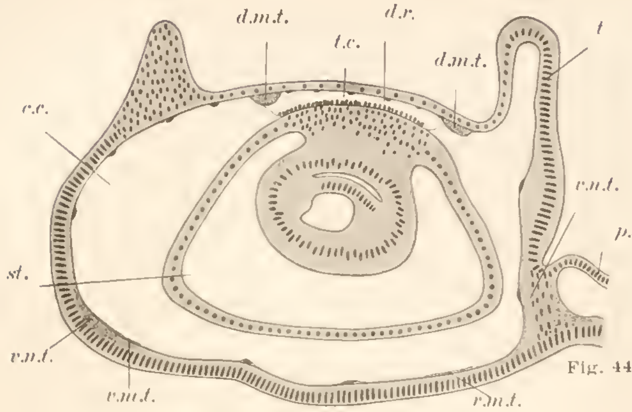

Fig. 44 (c)

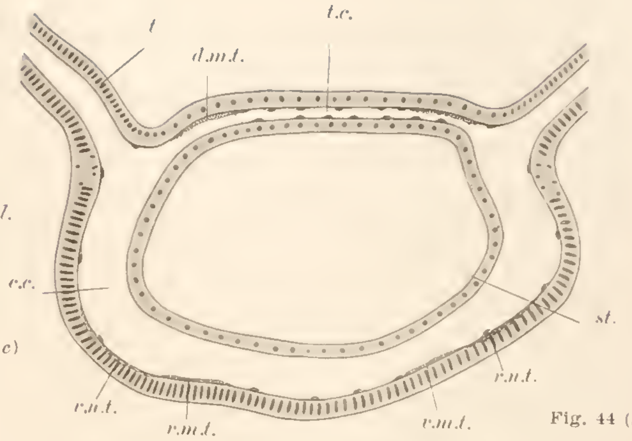

Fig. 44 (d)

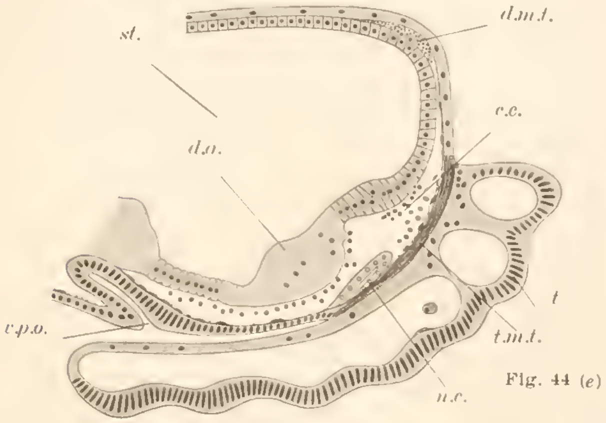

Fig. 44 (e)

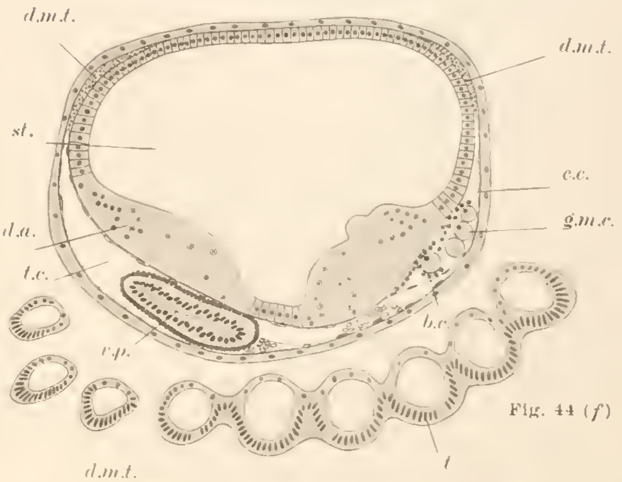

Fig. 44 (f)

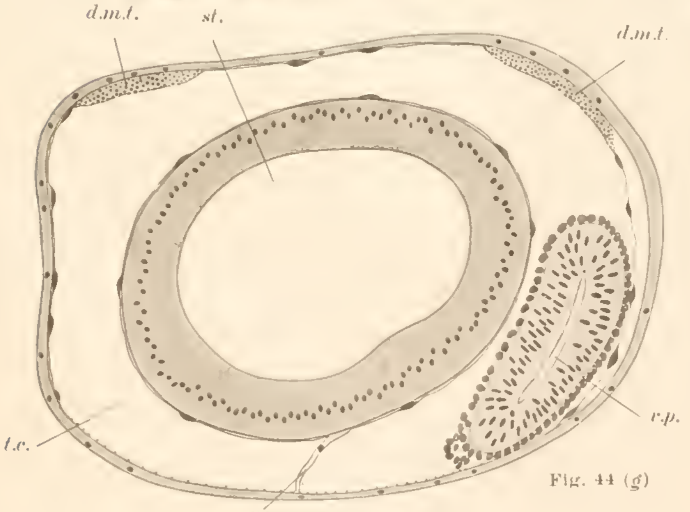

Fig. 44 (g)

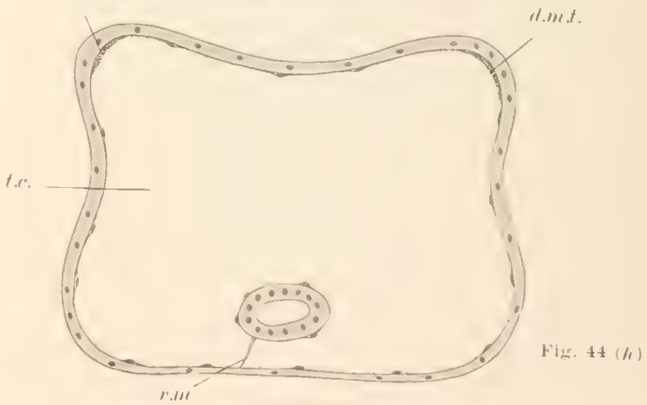

Fig. 44 (h)

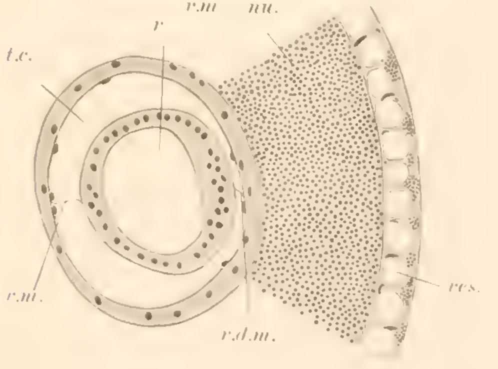

Fig. 44 (j)

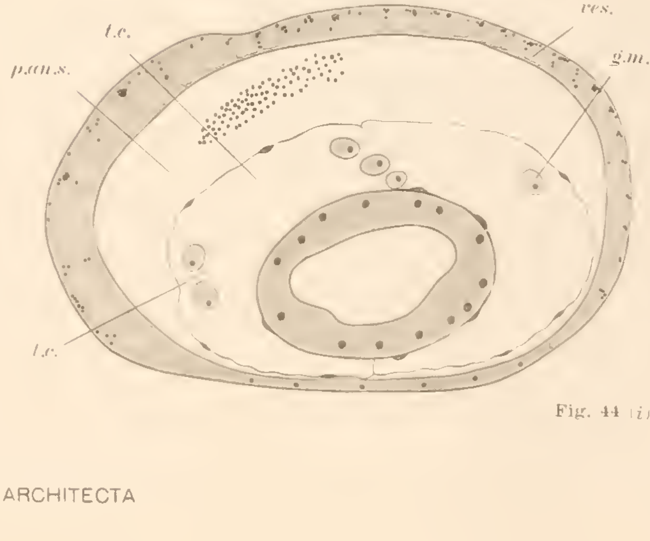

Fig. 44 (i)

PHORONIS ARCHITECTA

PLATE IX.

PLATE IX.

Fig. 45.—Longitudinal section through the ganglion, showing lobe collar mesentery. $\frac{1}{12}$ Oil Immersion. × 4 Oc. Camera. × 293.

Fig. 45*a*.—Longitudinal section through ganglion, showing retractor and mesentery. $\frac{1}{12}$ Oil Immersion. × 4 Oc. Camera. × 293.

Fig. 45*b*.—Longitudinal section through the *Actinotrocha*, showing incomplete part of lobe collar septum. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 200.

Fig. 46.—Horizontal section through *Actinotrocha* Species B. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 200.

Fig. 47.—View showing muscles of inner surface of hood. From living specimen. $\frac{2}{3}$ Ob. × 8 Oc. Camera.

Fig. 48.—Sagittal section through *Actinotrocha* Species B. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 150.

Fig. 49.—Longitudinal section through the posterior end of *Actinotrocha* Species B. $\frac{1}{12}$ Oil Immersion. × 4 Oc. Camera. × 293.

Fig. 50.—Longitudinal section through *Actinotrocha* Species A., showing relations of larval collar cavity and adult collar cavity. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 200.

Fig. 45.

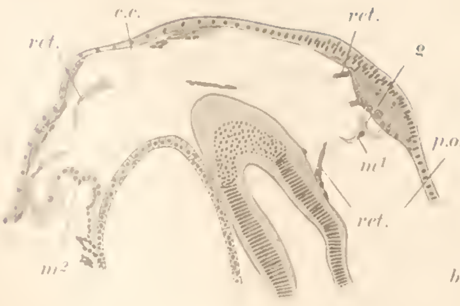

Fig. 45 (a)

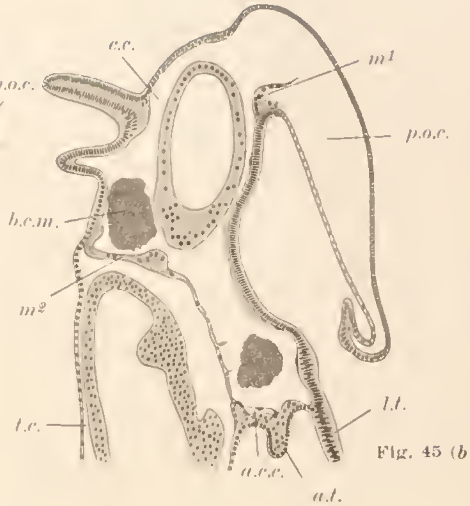

Fig. 45 (b)

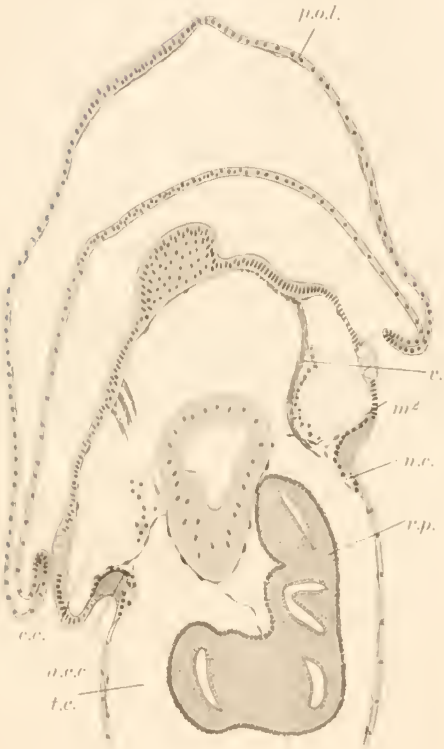

Fig. 46.

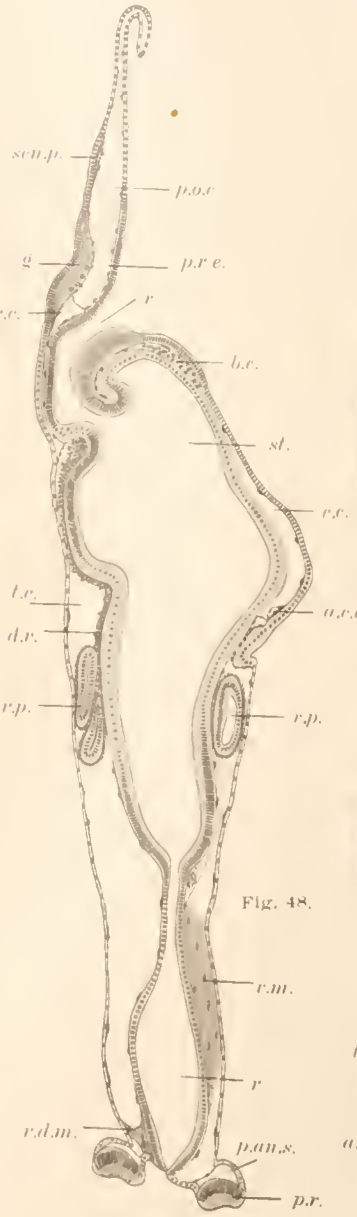

Fig. 48.

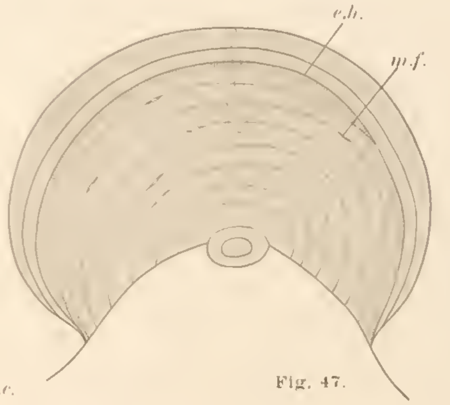

Fig. 47.

Fig. 49.

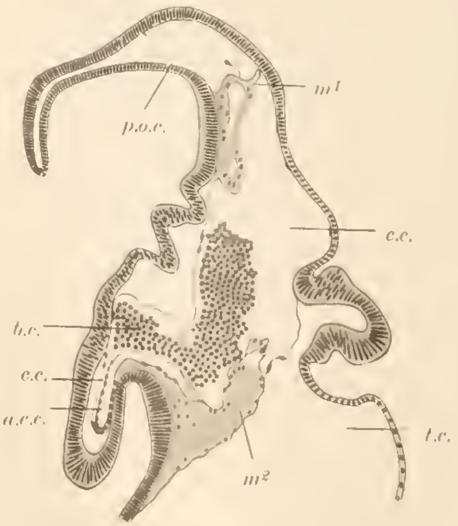

Fig. 50.

PHORONIS ARCHITECTA

PLATE X.

PLATE X.

Fig. 51.—Transverse section through *Actinotrocha* Species A. Taken through ganglion. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

Fig. 51*a*.—Continuation of series 51. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

Fig. 51*b*.—Continuation of series 51. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

Fig. 51*c*.—Continuation of series 51. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

Fig. 51*d*.—Continuation of series 51. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

Fig. 51*e*.—Continuation of series 51. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

Fig. 51*f*.—Continuation of series 51. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

Fig. 51*g*.—Continuation of series 51. Taken through the collar segment. Showing the lining drawn away from the ectodermal wall. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

Fig. 51*h*.—Continuation of series 51. Taken through collar region just anterior to bases of the ventral tentacles. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 225.

Fig. 52.—Transverse section through the nephridial canal. *Actinotrocha* Species B. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Comp. Occulare. Camera. × 1400.

Fig. 52*a*.—Continuation of series 52. Taken through the lower branch of the nephridial canal. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Comp. Occulare. Camera. × 1400.

Fig. 52*b*.—Continuation of series 52. Taken through the end of the upper branch of the nephridial canal. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Comp. Occulare. Camera. × 1000.

Fig. 52*c*.—Longitudinal section through one of the cellular processes at the end of the nephridium. Showing two nuclei. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Comp. Occulare. Camera. × 1000.

Fig. 52*d*.—Same as fig. 52*c*. Showing one nucleus. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Comp. Occulare. Camera. × 1000.

Fig. 52*e*.—Transverse section through the end of a process. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Comp. Occulare. Camera. × 1000.

Fig. 52*f*.—Transverse section through the proximal half of the processes. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Comp. Occulare. Camera. × 1000.

Fig. 52*g*.—Longitudinal section through anterior end of a nephridium. *Actinotrocha* Species B. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Comp. Occulare. Camera. × 1000.

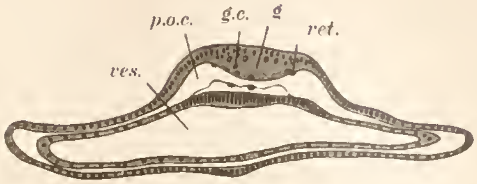

Fig. 51.

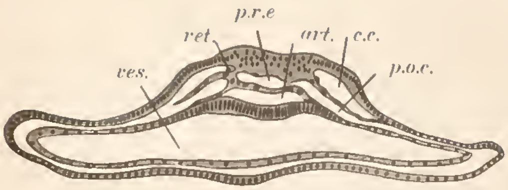

Fig. 51 (*a*)

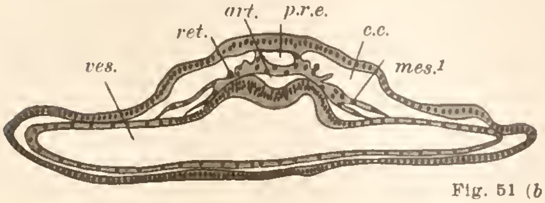

Fig. 51 (*b*)

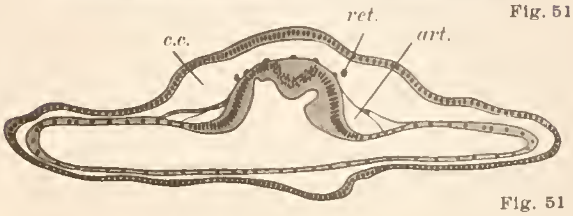

Fig. 51 (*c*)

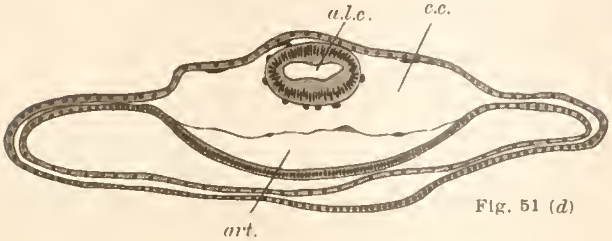

Fig. 51 (*d*)

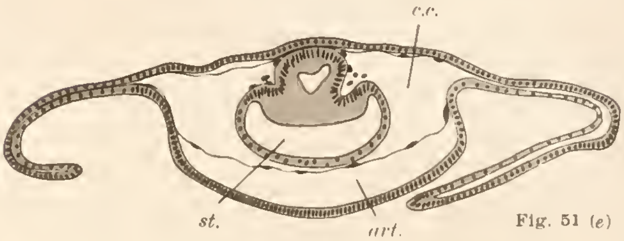

Fig. 51 (*e*)

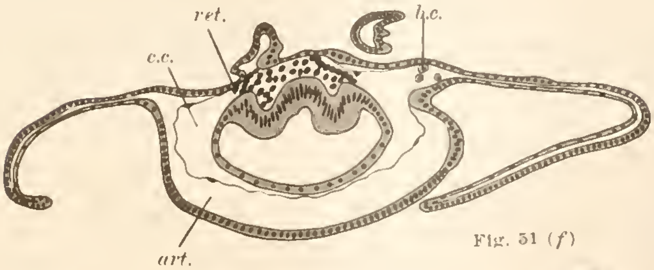

Fig. 51 (*f*)

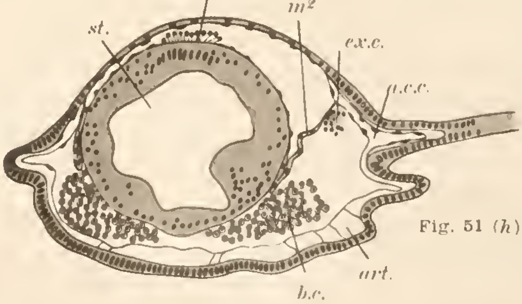

Fig. 51 (*h*)

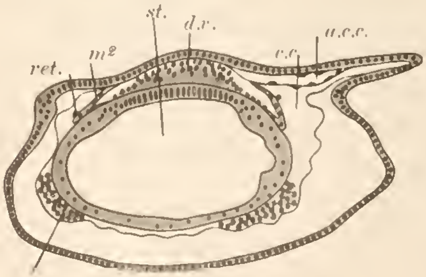

Fig. 51 (*g*)

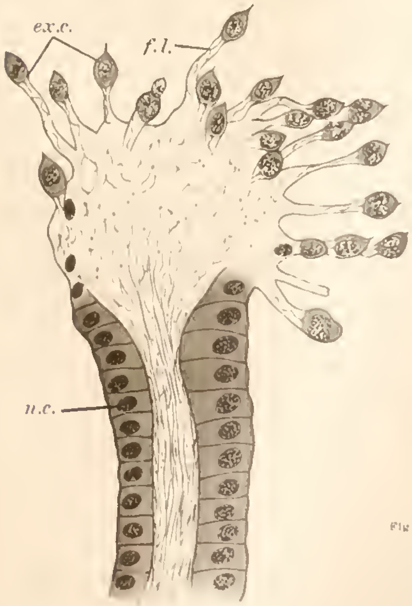

Fig. 52 (*g*)

Fig. 52 (*b*)

Fig. 52.

Fig 52 (c)

Fig 52 (d)

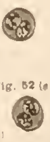

Fig. 52 (e)

Fig. 52 (*f*)

Fig. 52 (*a*)

PHORONIS ARCHITECTA

PLATE XI.

PLATE XI.

Fig. 53.—Transverse oblique section through *Actinotrocha* Species A. Taken through region of origin of blood corpuscles. 14 tentacles. $\frac{1}{12}$ Oil Immersion. × 4 Oc. Camera. × 293.

Fig. 54.—Transverse section through ventral collar wall. Same specimen as that of fig. 53. Showing origin of blood corpuscles. $\frac{1}{12}$ Oil Immersion. 12 Zeiss Comp. Occulare. Camera. × 935.

Fig. 55.—*Actinotrocha* Species B with ventral pouch evaginated. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 45.

Fig. 56.—*Actinotrocha* Species A. Immediately before metamorphosis. $\frac{2}{3}$ Ob. × 4 Oc. Camera. × 56.

Fig. 56*a*.—*Actinotrocha* Species A. Shortly after the beginning of metamorphosis. $\frac{2}{3}$ Ob. × 4 Oc. Camera. × 56.

Fig. 56*b*.—Metamorphosed *Actinotrocha* Species A. $\frac{2}{3}$ Ob. × 4 Oc. Camera. × 56.

Fig. 57.—Young specimen of *Phoronis architecta* (?) with 30 tentacles. $\frac{2}{3}$ Ob. × 4 Oc. Camera. × 28.

Fig. 59.—Metamorphosed *Actinotrocha* Species A. Transverse section through the region of the transverse septum. $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 240.

Fig. 60.—Completely metamorphosed *Actinotrocha* Species A. Transverse section in region of branching of efferent vessel. $\frac{1}{6}$ Ob. × 8 Oc. Camera. × 240.

Fig. 61.—Adult *Phoronis architecta* removed from tube. × 8.

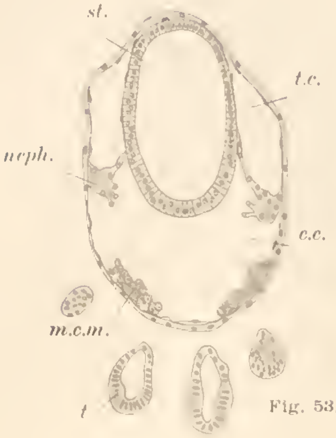

Fig. 53.

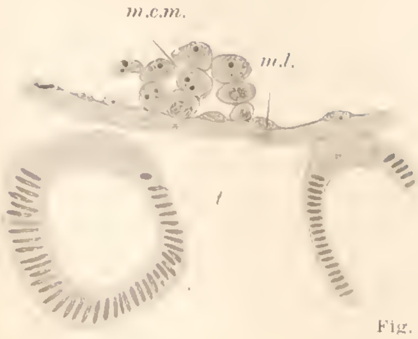

Fig. 54.

Fig. 55.

Fig. 57.


Fig. 61.

Fig. 56.

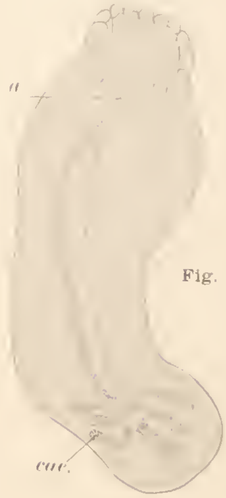

Fig. 56 (b)

Fig. 56 (a)

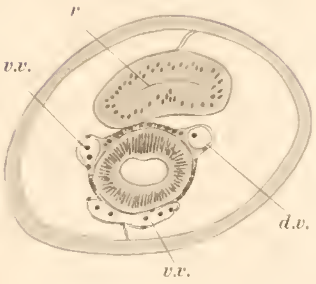

Fig. 60.

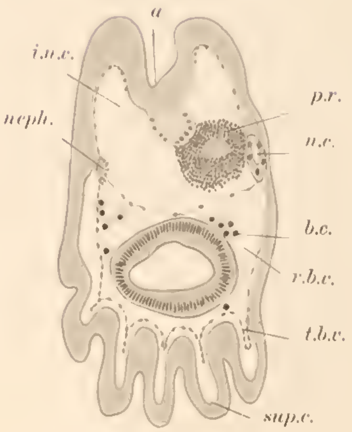

Fig. 59.

PHORONIS ARCHITECTA

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PLATE XII.

PLATE XII.

Fig. 62.—Tentacular crown of *Phoronis architecta.* Showing lophophoral organs, epistome, and mouth. Drawn from a living tentacular crown which had been constricted off from the animal. × 100.

Fig. 62.

PHORONIS ARCHITECTA

PLATE XIII.

PLATE XIII.

Fig. 63.—Transverse section through *Phoronis architecta*. Taken through tentacles. $\frac{2}{3}$ Ob. ×8 Oc. Camera. ×130.

Fig. 64.—Continuation of series 63. Taken near base of tentacles. $\frac{2}{3}$ Ob. ×8 Oc. Camera. ×130.

Fig. 65.—Continuation of series 63. Taken through epistome. $\frac{2}{3}$ Ob. ×8 Oc. Camera. ×130.

Fig. 66.—Continuation of series 63. Taken through anal papilla. $\frac{2}{3}$ Ob. ×8 Oc. Camera. ×130.

Fig. 67.—Continuation of series 63. Taken through nephridial opening. $\frac{2}{3}$ Ob. ×8 Oc. Camera. ×130.

Fig. 68.—Continuation of series 63. Taken through the transverse septum and below the nephridial openings. $\frac{2}{3}$ Ob. ×8 Oc. Camera. ×130.

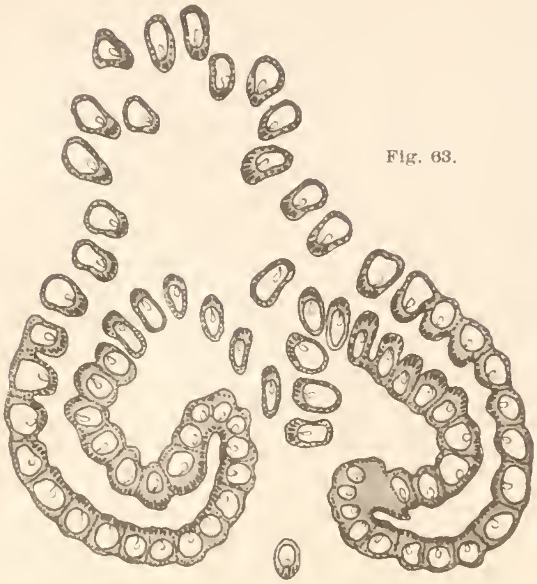
Fig. 63.

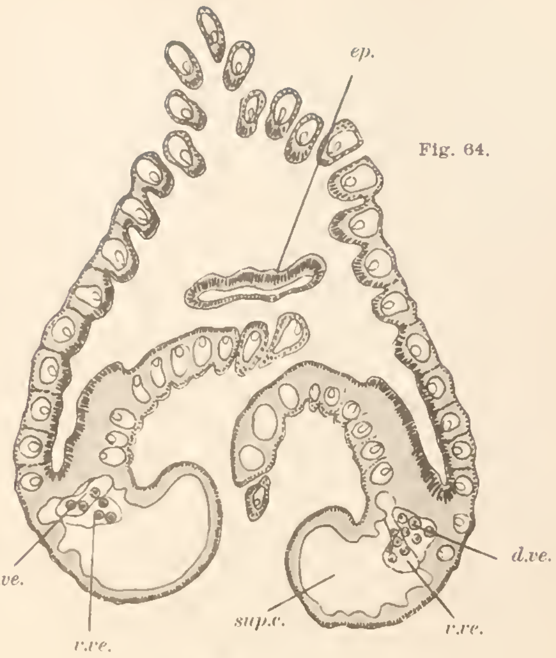
Fig. 64.

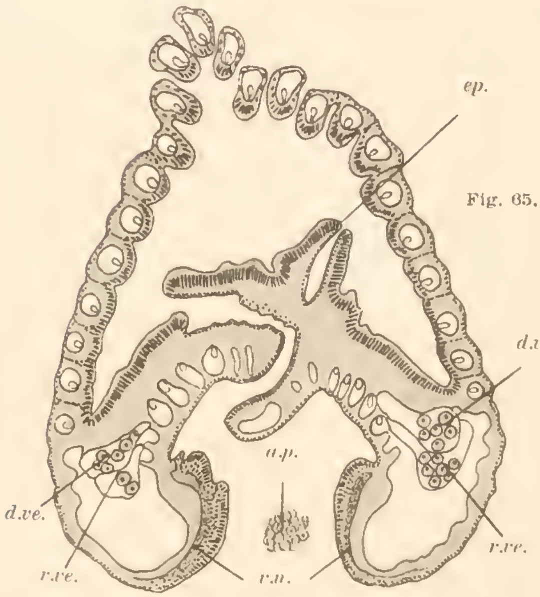
Fig. 65.

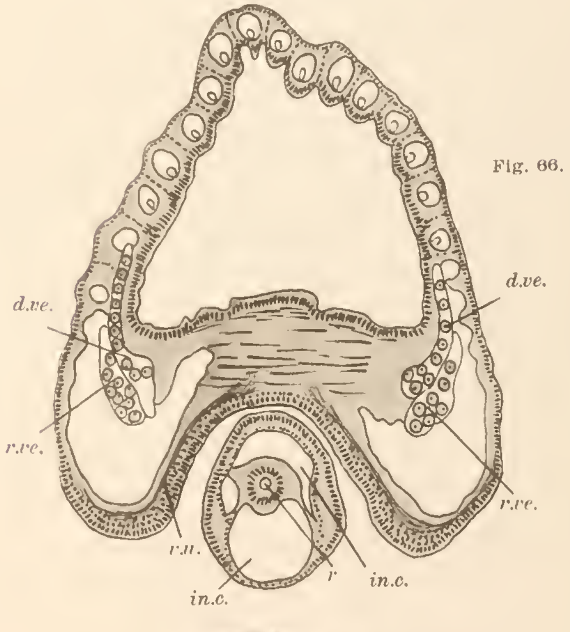
Fig. 66.

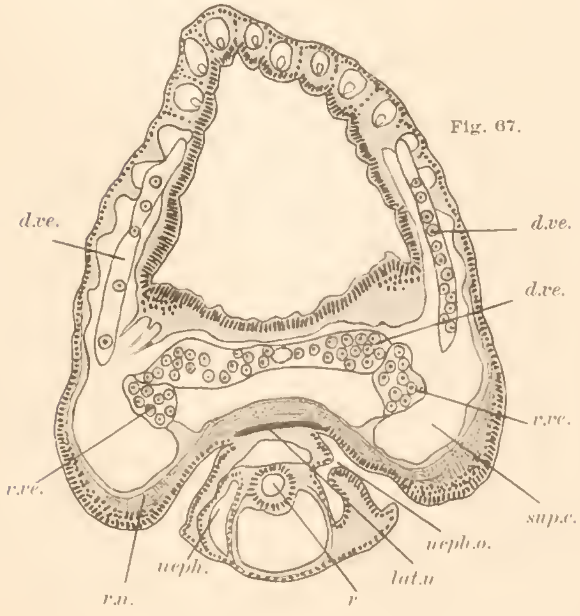
Fig. 67.

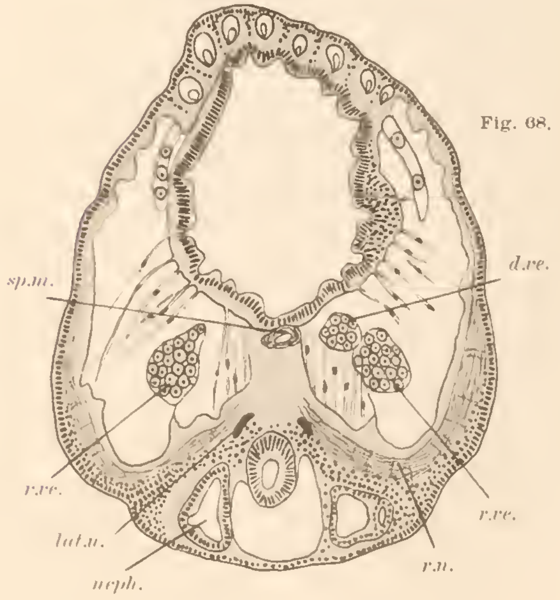
Fig. 68.

PHORONIS ARCHITECTA

PLATE XIV.

PLATE XIV.

Fig. 69.—Continuation of series 63. Taken a little posteriorly to that of fig. 68. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 70.—Continuation of series 63. Taken through the nephridial funnel that opens into the rectal cavity. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 71.—Continuation of series 63. Taken a little posteriorly to that of fig. 70. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 72.—Continuation of series 63. Taken through the funnel opening into the lateral cavity. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 73.—Continuation of series 63. Taken through the loop in the nephridium. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 74.—Continuation of series 63. Taken through the oral side of the nerve ring. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

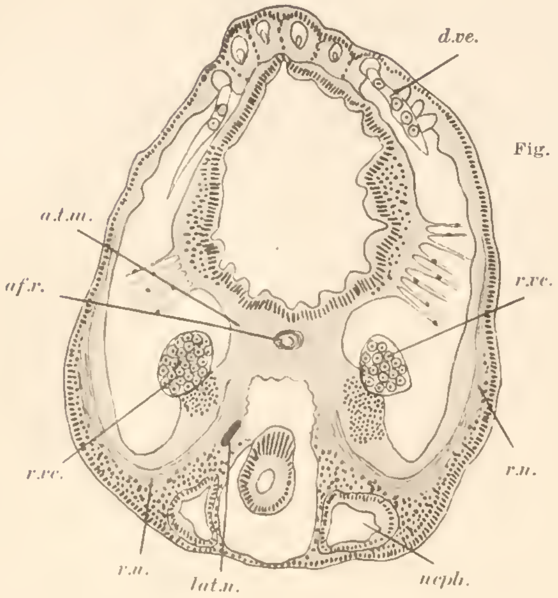

Fig. 69.

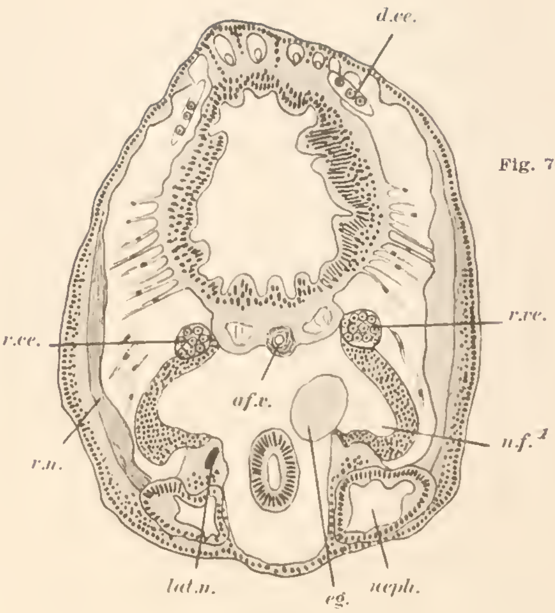

Fig. 70.

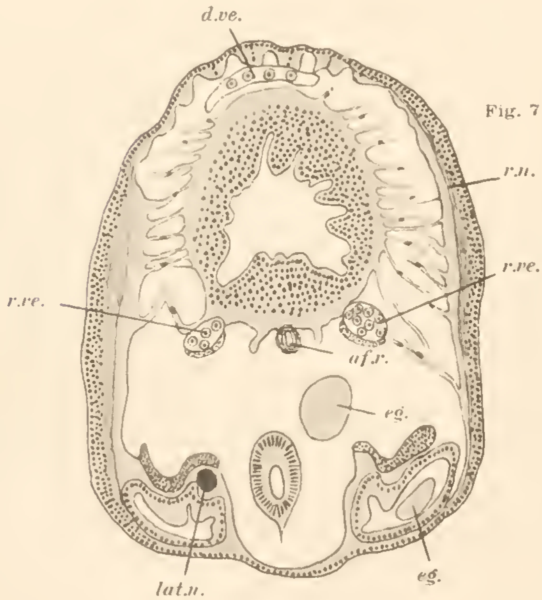

Fig. 71.

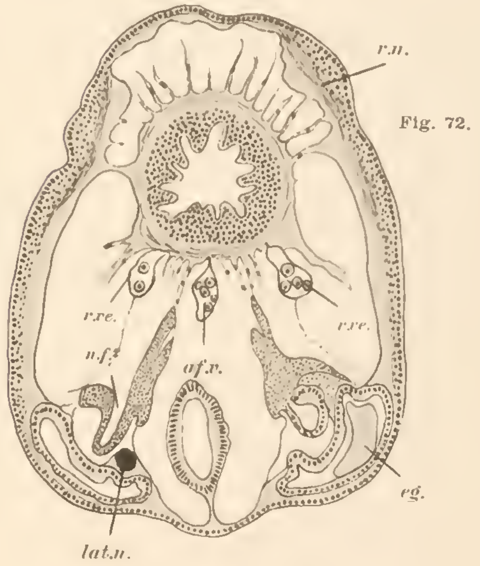

Fig. 72.

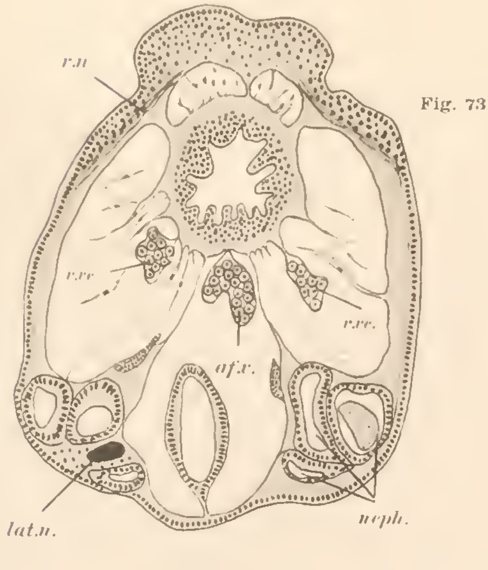

Fig. 73.

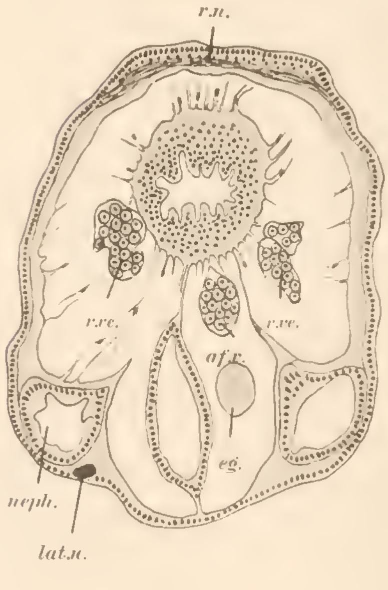

Fig. 74.

PHORONIS ARCHITECTA

PLATE XV.

PLATE XV.

Fig. 75.—Continuation of series 63. Taken a little posteriorly to that of fig. 74. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 76.—Continuation of series 63. Taken through the region where the branches of the efferent blood vessel pass around the œsophagus. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 77.—Continuation of series 63. Taken a little posteriorly to that of fig. 76. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 78.—Continuation of series 63. Taken a little posteriorly to that of fig. 77. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 79.—Continuation of series 63. Longitudinal muscles begin to appear. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 80.—Continuation of series 63. Taken a little posteriorly to that of fig. 79. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

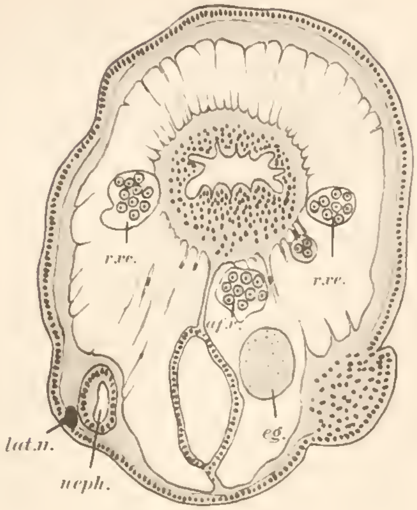

Fig. 75.

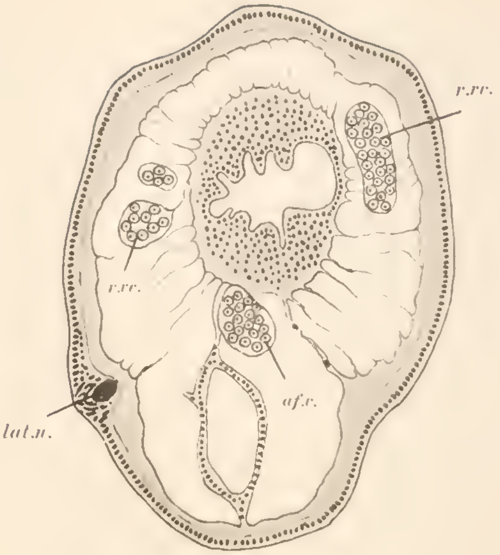

Fig. 76.

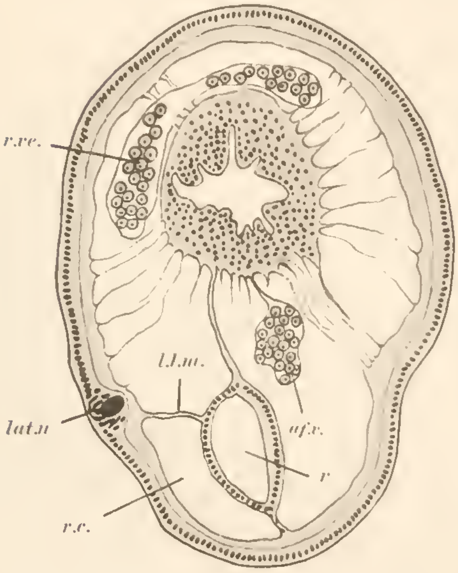

Fig. 77.

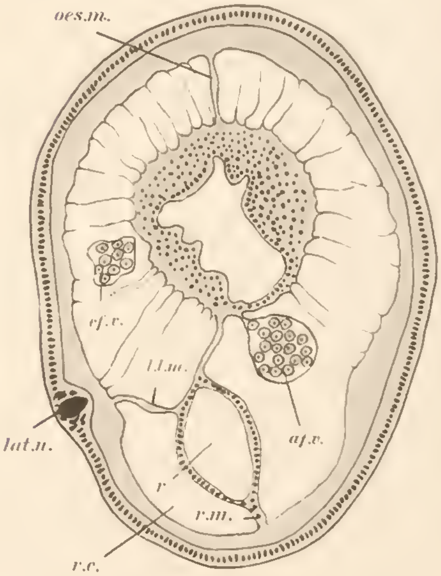

Fig. 78.

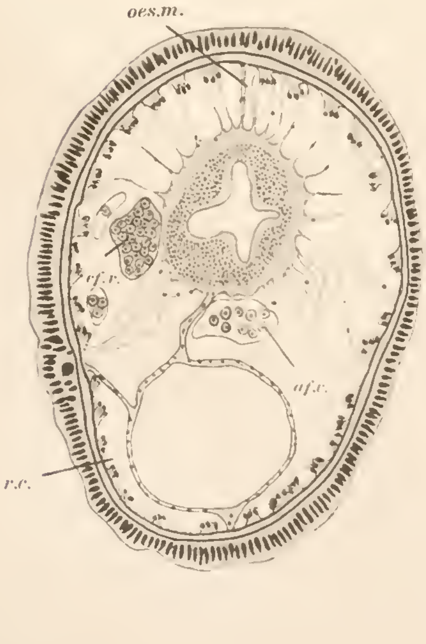

Fig. 79.

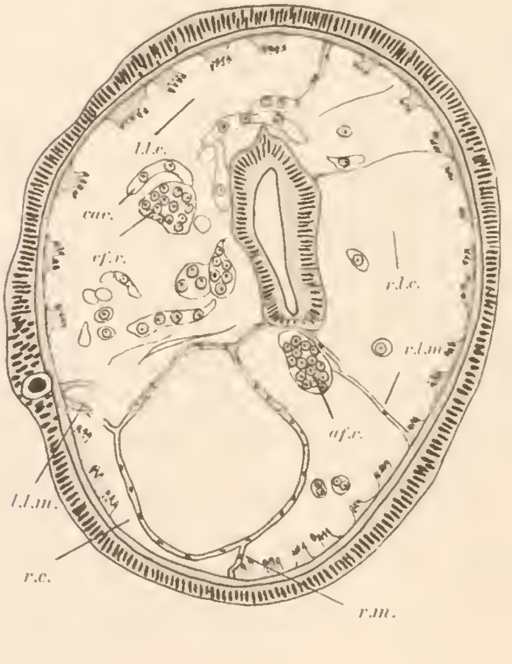

Fig. 80.

PHORONIS ARCHITECTA

PLATE XVI.

PLATE XVI.

Fig. 81.—Continuation of series 63. Taken a little posteriorly to that of fig. 80. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 82.—Continuation of series 63. Typical transverse section through the middle of the trunk. $\frac{2}{3}$ Ob. × 8 Oc. Camera. × 130.

Fig. 83.—Longitudinal section through the recipient and distributing vessels. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 450.

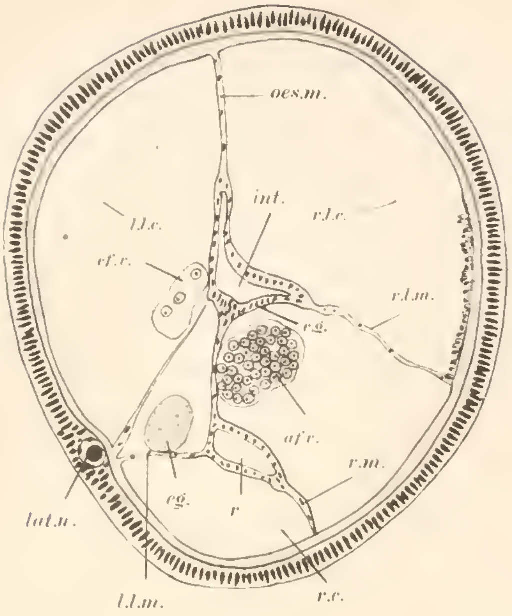

Fig. 81.

Fig. 82.

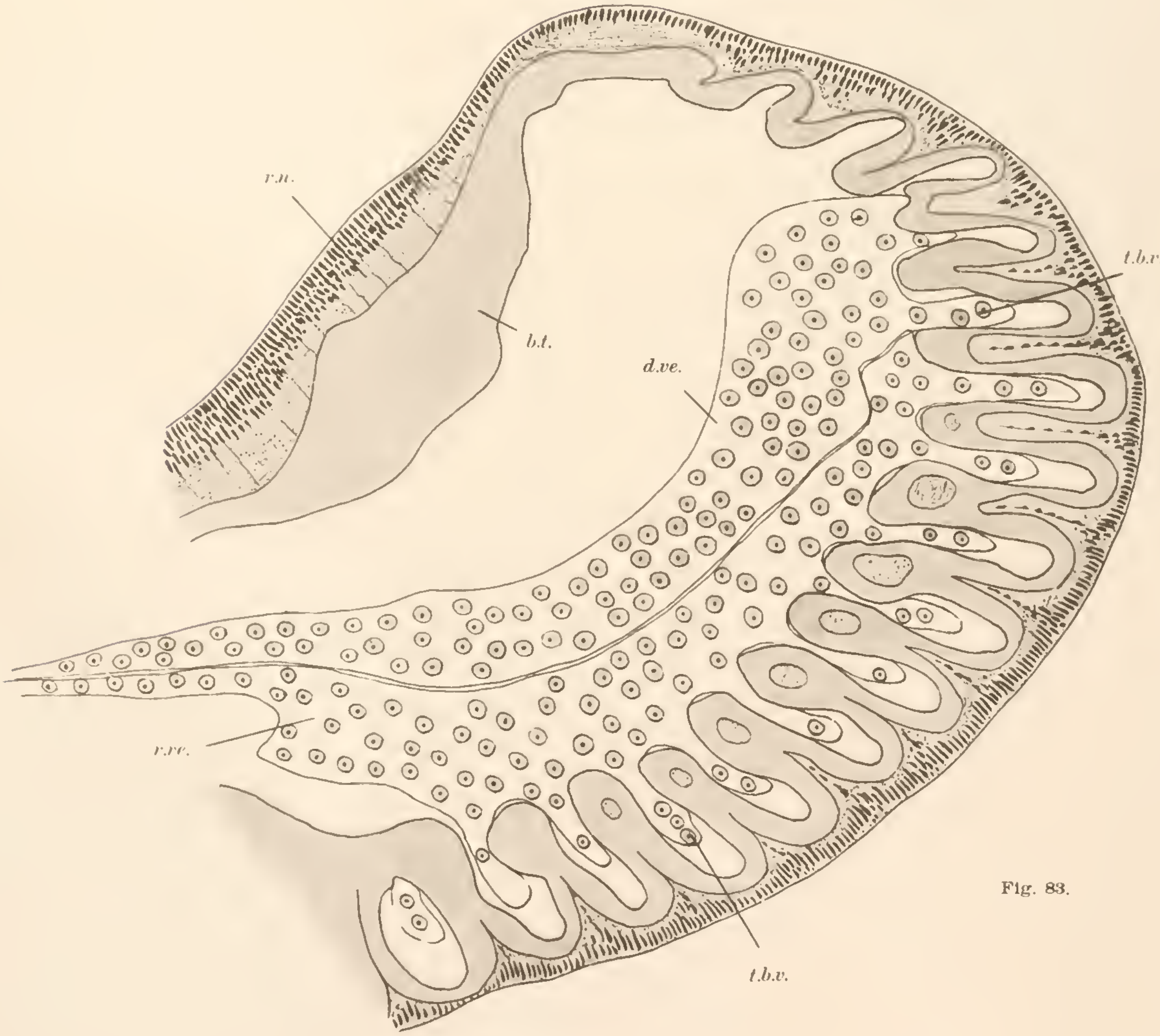

Fig. 83.

PHORONIS ARCHITECTA

Cowles Del.

PLATE XVII.

PLATE XVII.

FIG. 84.—Longitudinal section through the anal region. Showing the ganglion and its relation to the lateral nerve cord. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 450.

FIG. 85.—Transverse section through the region of the anal papilla. Showing the relation of the nerve ring to the lateral nerve. $\frac{1}{6}$ Ob. × 4 Oc. Camera. × 450.

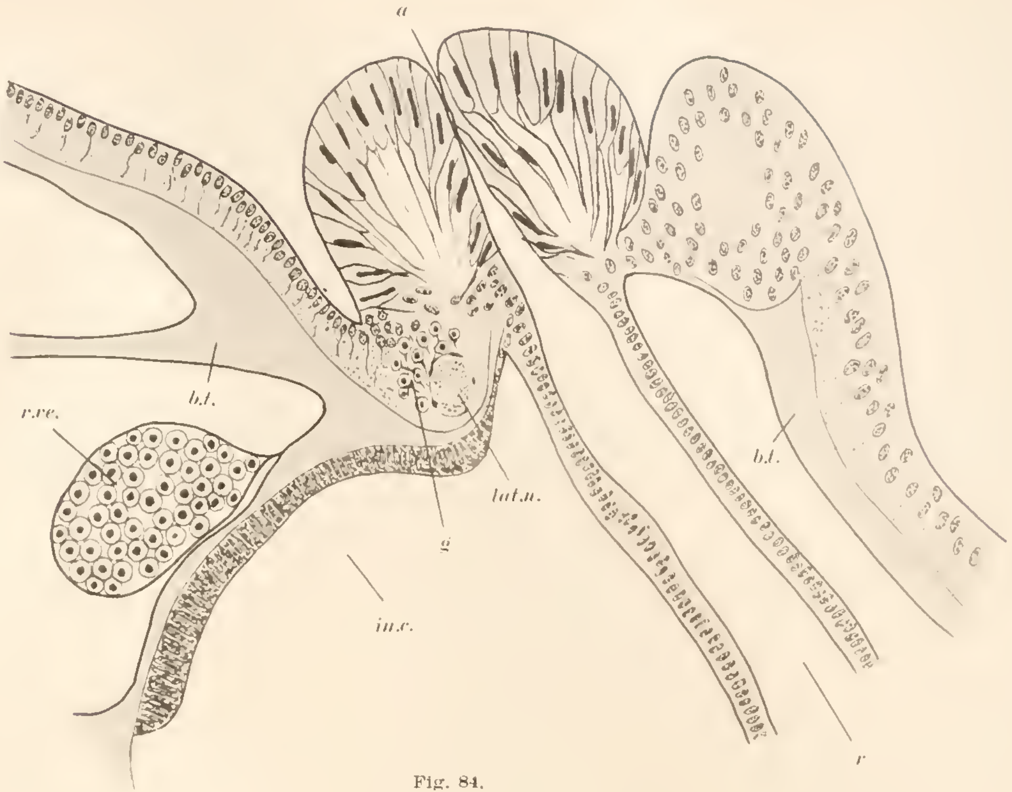

Fig. 84.

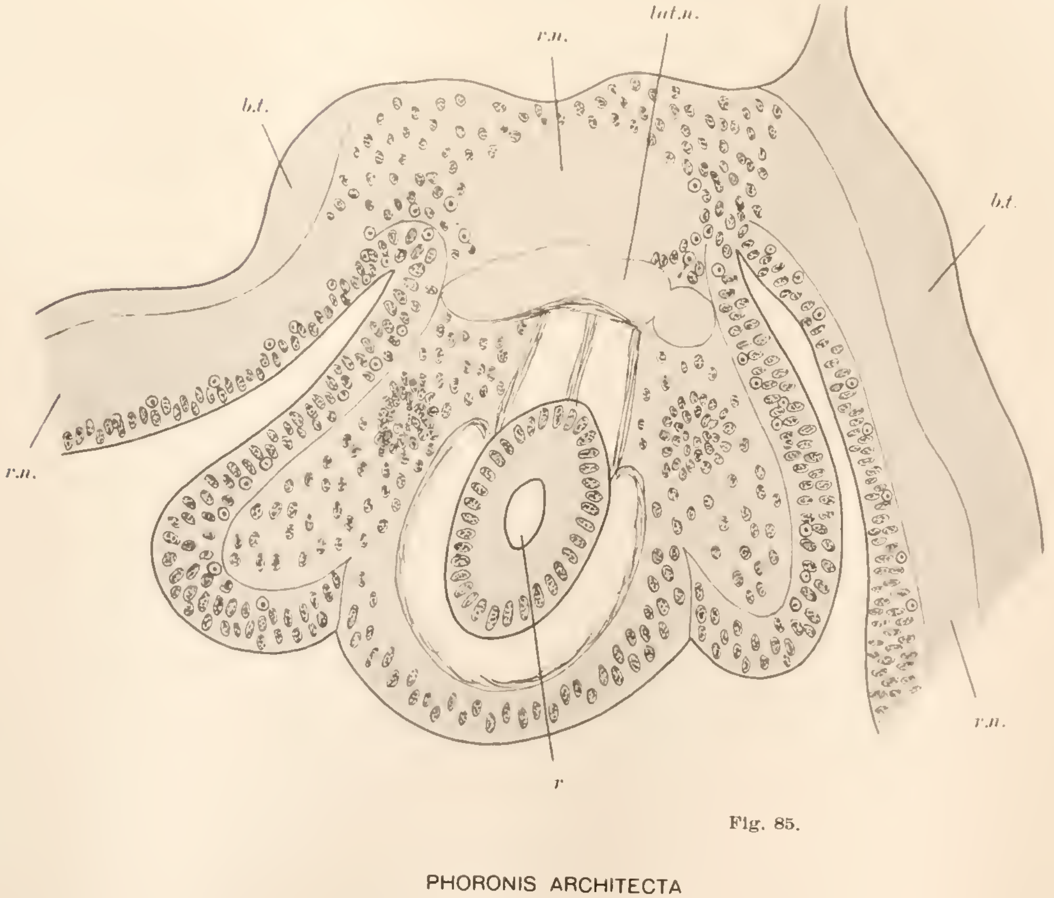

Fig. 85.

PHORONIS ARCHITECTA

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FIFTH MEMOIR.

THE AFFINITIES OF THE PELAGIC TUNICATES.

No. 1. ON A NEW PYROSOMA.

(*Dipleurosoma elliptica.*)

BY

WILLIAM KEITH BROOKS,

HENRY WALTERS PROFESSOR OF ZOOLOGY IN THE JOHNS HOPKINS UNIVERSITY.

THE AFFINITIES OF THE PELAGIC TUNICATES.

(Presented to the National Academy, November, 1904.)

No. 1. ON A NEW PYROSOMA.

(*Dipleurosoma elliptica.*)

By William Keith Brooks, LL. D.,
Henry Walters Professor of Zoology in the Johns Hopkins University.

Part I.—INTRODUCTORY.

I am indebted to Dr. Caswell Grave for the opportunity to study the Pyrosoma that is here described. The specimens were collected in the Gulf Stream off Beaufort, North Carolina, by the United States Commission of Fish and Fisheries, and were brought to the marine laboratory of the Commission at Beaufort. They were intrusted to me for study by Doctor Grave, the director of the laboratory. The illustrations that accompany the memoir were drawn by Mr. Carl Kellner.

While all the species of Pyrosoma that have been described are circular in cross section, the cross section of the one that is to be described is a flattened ellipse, so that the colony has two broad sides (fig. 4) and two narrow edges (fig. 5).

Except for this flattening, it does not differ in any essential way from other Pyrosomas, which are tubular colonial ascidians that float or swim in the water of the ocean, usually at considerable depth below the surface, but often at or very near it. As their name expresses, they are among the most brilliantly luminous of marine animals, glowing with an intense white light that is notable even under the noonday sun of the tropical ocean. The light, which is under the control of the organism, is emitted by a pair of luminous organs (fig. 2 and fig. 8, *h*), on each side of the pharynx, near the mouth, and in the coelomic cavity.

The basis or foundation of the colony, that binds the ascidians together into an organized whole, is a hollow tube of cellulose (figs. 2 and 4) closed at one end, A, and opened at the other, B. The open end carries a muscular diaphragm, by which the aperture may be reduced or enlarged.

The ascidian units, or ascidiozooids, many hundreds or thousands in number, are so placed that their mouths *d*, are on the outer service of the tube, while their cloacal apertures, *c*, open into the cavity of the tube, or common cloaca (fig. 3, CC), which again opens to the external water through the terminal opening which may be reduced in size, or, perhaps, completely closed by the muscular diaphragm.

The members of the community breathe and obtain their food, like other ascidians, by drawing water through the mouth (fig. 8, *d*) into the pharynx or gill-chamber (fig. 8, *e*) by the vibration of the cilia around the gill slits. The waste water is discharged from the body through the cloacal aperture, and, as the cloaca of each ascidiozooid opens into the common cloaca, this becomes filled with water, which, overflowing through the open end, tends to drive the colony through the water in the opposite direction. This current is modified and controlled by the diaphragm, and by the movements of the ascidiozooids, so that the progress through the water is not slow and continuous, but rapid and intermittent. A muscle, shown near the cloacal aperture in figure 8, extends from each ascidiozooid to those adjacent to it and binds all the units of the colony together, so that they are able to make concerted movements, and thus to control the expulsion of the locomotor current.

The structure and the development of Pyrosoma have been well described by many naturalists, and a good account of the more essential features is to be found in the text-books. Those who wish for a more complete account should consult the memoirs of Herdman (Report on the Tunicata collected during the voyage of H. M. S. "Challenger," XXVI–XXVIII), of Salensky (Beiträge zur Embryonalentwicklung der Pyrosomen. Zool. Jahrb. IV and V), and of Seeliger (Zur Entwicklungsgeschichte der Pyrosomen. Jenaische Zeitschr. für Wiss. Naturw. XXIII., and Die Pyrosomen., Leipzig, 1895).

The subject of this memoir is a new form of Pyrosoma, which seems to me to be generically different from all that have been described; but, as its differences from the forms that are known do not involve its fundamental structure, I have little to add to the published accounts, although a brief sketch of the origin of the colony will be the most satisfactory way to explain the meaning of the terms that are to be used in describing the species.

The egg of Pyrosoma gives rise to an embryo which, while it acquires some indications of ascidian structure, remains rudimentary and quickly degenerates. It is commonly called by the name Cyathozooid, given to it by Huxley. It is shown, in an advanced stage of degeneration, at *cy* in figure 1. Before it begins to degenerate, it gives rise to a tubular outgrowth, which becomes divided, by constrictions, into four segments, each of which ultimately becomes an ascidian. The four segments are in a row at first but as they grow and develop into ascidians they twist so as to form a zone or girdle around the rudimentary Cyathozooid, as is shown in figure 1. These four primary ascidiozooids are the foundation of a new colonial Pyrosoma. As figure 1 shows, they are inclosed in a common mantle of cellulose, and are arranged in a circlet around a common cloaca into which the cloaca of each opens, while the mouths are on the outer surface. The surface that is below in figure 1 is the closed end of the colonial tube, while the opening is above in the figure, in the center of the rosette of eight tubular processes that are shown in the figure. In all ordinary Pyrosomas, the circlet that is formed by the four primary ascidiozooids is a circle, but in the species that is the subject of this paper it is an ellipse; the ascidiozooid marked *pa* 1 and its fellow lying in the long axis of the ellipse, and the one marked *pa* 2 and its fellow in the short axis. They are also shown, at a later stage, at *pa* 1 and *pa* 2, in figure 2.

The four primary ascidiozooids soon begin to multiply by budding, and thus to lay the foundation for a new colony, which may ultimately consist of thousands of ascidiozooids, all produced, either immediately or indirectly, as buds, by the four primary ascidiozooids. As each ascidiozooid that arises as a bud soon begins to produce buds in its turn, only a few of those that enter into the structure of an adult colony arise immediately from the primary ascidiozooids.

Few young colonies, large enough to have all the characteristics of the full-grown colony, and yet small enough and transparent enough to be studied with a microscope, have been found, and none have been adequately figured.

Among Doctor Grave's specimens is one, about half an inch long, which he had stained and mounted in balsam. It is shown in figure 2, with one of its flat sides toward the observer. As it is small enough to be studied as a transparent object under the microscope, and is yet, in all essential particulars, a fully developed Pyrosoma, it presents a more complete picture of the organization of the colony than any drawing that has been published. The colony is represented with its closed end below, and the open end with its diaphragm above. It consists of seventy ascidiozooids, arranged in seven rows or verticils, and of numerous buds. There are four ascidiozooids—the primary ascidiozooids—in the first row, eight in the second, ten in the third, twelve in the fourth, twelve in the fifth, fourteen in the sixth, and ten in the seventh. The ascidiozooids in the first row are the largest, and there is a gradual decrease in size to the last row, in which they are no larger than the buds, *j*, that are carried by those in the first and second rows. All are placed with their dorsal surfaces and brains toward the open end of the colony, and their ventral surfaces and endostyles toward the closed end. The new buds arise at the aboral end of the endostyle, on the ventral surface, as shown at *j* in figure 8, and in figure 2.

As the smallest and youngest ascidiozooids are nearest the open end, while they arise on the surface of the zooid that is nearest the closed end, it is clear, from the figure, that a migration must take place from the region where new buds arise to the region where they complete their growth and development, and that this migration must, in some cases, be from one end of the colony to the other. Each young ascidiozooid has two tubular processes, like those that are shown in figure 1, on the region of the body that is nearest the open end of the colony. These processes lengthen until they reach and enter into the diaphragm, where they are shown in figure 2. With a microscope they may be traced inward among the zooids and buds, although the components of the colony are so crowded, and the tubes so delicate, that I have not been able to follow any of them to the end, except the ones that end in the zooids in the row nearest the opening. The number of tubes in the diaphragm, at the stage shown in figure 2, is nearly equal to the number of zooids, but somewhat less, so that some of them must fail to reach the diaphragm, or else degenerate and disappear after they have reached it. The walls of the tubes are muscular, and they are, no doubt, concerned in the opening of the diaphragm, and in the migration of the zooids, although it is not probable that they bring about the migration by direct muscular contraction, since the distance that the zooids move seems to be too great to be brought about in this way. It is more probable that the tubes become shortened by some structural change, which, aided, it may be, by their muscular contractions, draws the new ascidiozooid into the region of the colony where there is most room for it. In young colonies there is most room at the open or growing end, and the colony grows by the addition of new whorls of zooids at this end, and the zooids are arranged in verticils. As the colony grows, new zooids become fitted into the spaces between the old ones, and the verticillated arrangement which is so notable in the young colony is no longer recognizable (fig. 4).

Part II.—DESCRIPTIVE.

DIPLEUROSOMA, genus nov.

DIAGNOSIS OF THE GENUS.

Colony bilaterally symmetrical with reference to one of the planes that pass through the principal axis. In cross section the colony is elliptical, with the common cloaca, or central chamber, reduced to a narrow slit in the long axis of the ellipse.

DIPLEUROSOMA ELLIPTICA, nov. sp.

Figures 4, 5, 6, 7, and 8.

DESCRIPTION OF THE SPECIES.

Distribution.—Found in the Gulf Stream off Beaufort, North Carolina. It is, no doubt, widely distributed in the waters of the Gulf Stream.

Length of colony.—Twenty-two centimeters.

Greatest diameter of colony.—Fifty-seven millimeters.

Least diameter of colony.—Twelve millimeters.

Ratio between the long axis and the short axis of the elliptical cross section.—About one to four.

Distribution of the ascidiozooids.—Regularly verticillated in small colonies, irregular in large ones.

Outer surface of mantle.—Smooth in young colonies, thickly set in large ones, with tubercles that are very variable, usually conical and symmetrical but often with a tongue-like projection on the dorsal side.

Oral tube.—Conical, axial, nearly as wide as long.

Mouth.—In long axis and usually horizontal or at right angles to the long axis. In young colonies, and in many of the zooids of large colonies, it is at the bottom of a shallow conical pit. In most of the ascidiozooids in large colonies it is at the end of a conical process; in a few, on the ventral surface and near the tip of a tongue-shaped process.

Branchial chamber.—Not narrowed at inner end.

Gill slits.—Thirty-seven or more.

Longitudinal folds of branchial chamber.—Eighteen or more.

Endostyle.—Nearly straight.

Testis.—In a pouch that protrudes beyond the general outline, with from seven to nine lobes.

Cloacal muscle.—Long.

Dorsal tentacles of pharynx.—About seven, variable and irregular.

Oral processes.—The writers on Pyrosoma attribute great taxonomic importance to the absence or presence or shape of the oral processes on the outer surface of the colony, since these structures are conspicuous when present and easy to sketch and to describe.

In many species they are, no doubt, characteristic, affording a ready means of identification, but in others they are too irregular and variable to have any systematic value.

In the species that is here described the outer surface of the test is smooth in young colonies, and the mouths are at the bottoms of conical pits, figure 2, as they are in some of the zooids of old colonies. Most of the zooids of older colonies have processes that are conical and symmetrical, and the mouths are terminal, figure 8. There is nothing distinctive in the length of the processes, for some are short and some long. While they are usually conical and symmetrical with reference to the long axis of the ascidiozooid, they are sometimes elongated on the side that is dorsal to the mouth, which is thus oblique and on the ventral side of the process at some distance from its tip.

Dipleural symmetry.—The dipleural symmetry that characterizes this species is recognizable in the embryo, becoming more marked with the growth of the colony.

The embryonic colony of four primary ascidiozooids, figure 1, is nearly circular, although the two ascidiozooids, *pa* 1, that are to occupy the sides of the colony, are easy to distinguish from the two, *pa* 2, that are to lie on the edges.

The young colony, with seventy ascidiozooids shown in side view in figure 2 and in transverse section in figure 3, exhibits marked dipleuralism.

There are seven ascidiozooids on each edge, or fourteen in all, and twenty-seven on each side, or fifty-four in all, and the four primary ascidiozooids, *pa* 1 and *pa* 2, are readily distinguishable. The diagrammatic section, figure 3, is through the verticil that is fourth from the closed end in figure 2. As the diagram shows, there is one zooid on each edge at this level, and there are five on each side, or twelve in all, and the thickness of the colony is about equal to one-half its breadth, so that the ratio of thickness to breadth is one-half.

In the adult colony, shown in side view in figure 4, in end view in figure 6, in edge view in figure 5, and in section in figure 7, there are about sixty zooids in each cross section, and the thickness of the colony is to its breadth about one to four.

Verticillation.—In the full-grown colony there is no visible trace of an arrangement of the zooids in rings, although this arrangement is regular and conspicuous in the young colony shown in figure 2.

In this there are seven rings, with four zooids in the first, eight in the second, ten in the third, twelve in the fourth, twelve in the fifth, fourteen in the sixth, and ten in the seventh, or seventy in all. The regular verticillation is obliterated, in older colonies, by the interpolation of new buds between the rings.

EXPLANATION OF THE PLATES.

REFERENCE LETTERS.

A.	The closed end of the colony.
as.	An ascidiozooid.
B.	The open end of the colony.
c.	The cloaca of the ascidiozooid.
CC.	The common cloaca of the colony.
d.	The mouth.
f.	The mantle of cellulose.
g.	The endostyle.
h.	The luminous organ.
i.	The testis.
j.	A bud.
k.	The stomach.
l.	The intestine.
n.	First oral muscle.
o.	Second oral muscle.
p.	The œsophagus.
PA. 1.	The primary ascidiozooid on the edge of the colony.
PA. 2.	The primary ascidiozooid on the side of the colony.

FIGURES.

Fig. 1.—The cyathozooid and the four primary ascidiozooids of *Dipleurosoma elliptica.*
Fig. 2.—A young colony of *Dipleurosoma elliptica,* with seven verticils of ascidiozooids.
Fig. 3.—Transverse section of the colony shown in figure 2.
Fig. 4.—Side view of a fully grown colony of *Dipleurosoma elliptica.*
Fig. 5.—Edge view of same.
Fig. 6.—The open end of same.
Fig. 7.—Transverse section of same.
Fig. 8.—A single ascidiozooid from a fully grown colony of same.

Fig.6.

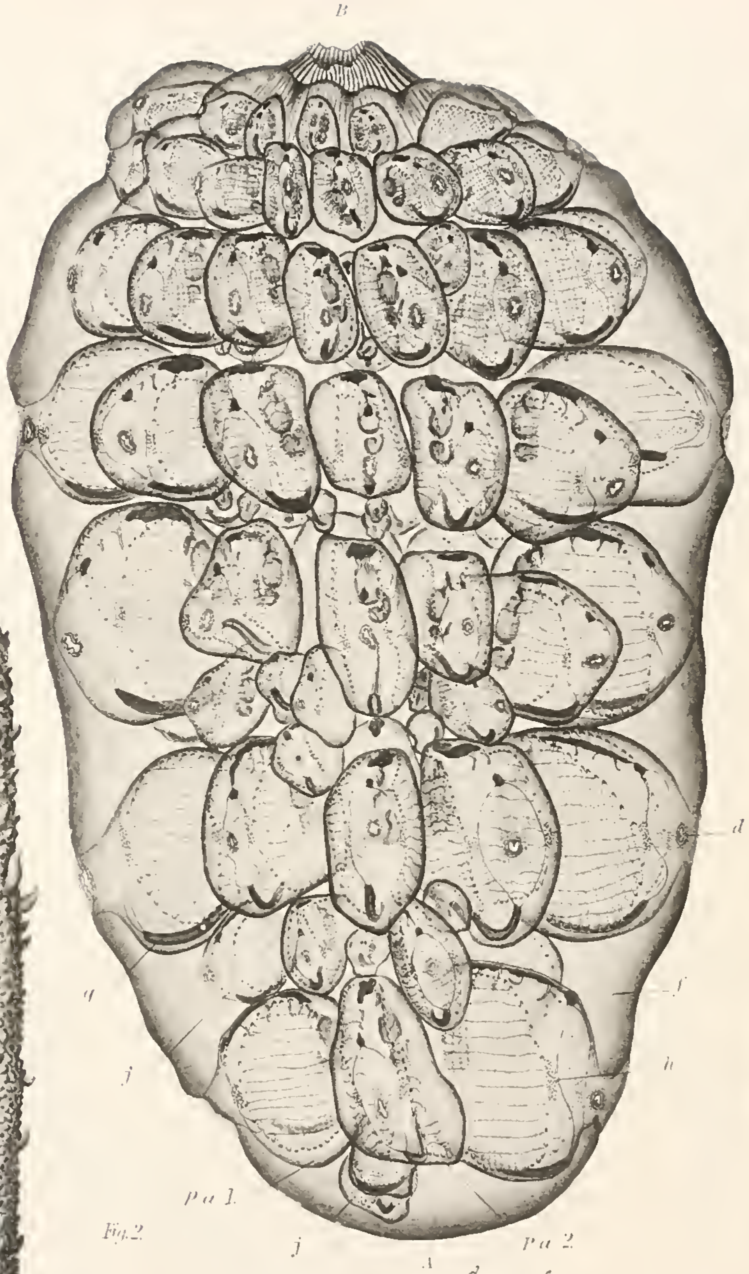

Fig.2.

Fig.4.

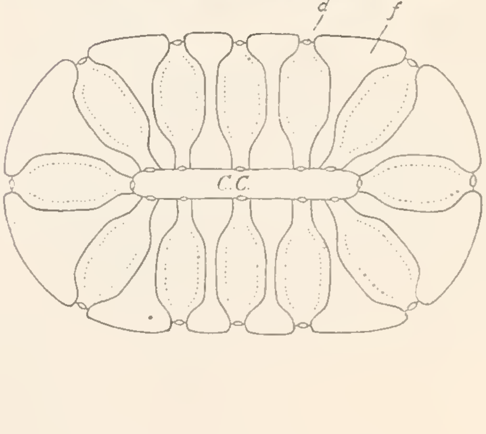

Fig.3.

Fig.5.

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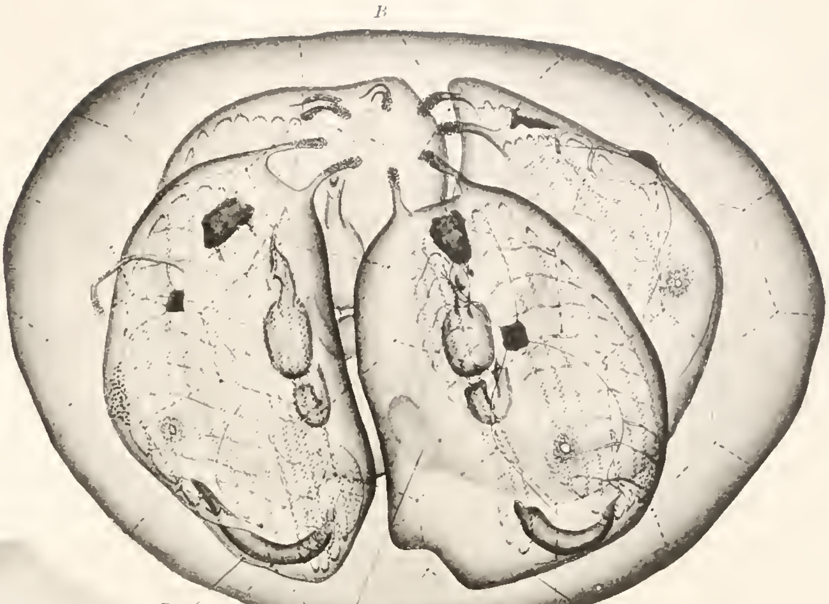

Fig. 1.

Fig. 8.

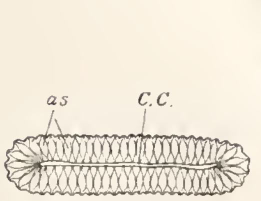

Fig. 7.

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COMMELINACEÆ.

MORPHOLOGICAL AND ANATOMICAL STUDIES OF THE VEGETATIVE ORGANS OF SOME NORTH AND CENTRAL AMERICAN SPECIES.

BY

THEODORE HOLM.

PRESENTED TO THE ACADEMY BY GEORGE L. GOODALE.

COMMELINACEÆ.

MORPHOLOGICAL AND ANATOMICAL STUDIES OF THE VEGETATIVE ORGANS OF SOME NORTH AND CENTRAL AMERICAN SPECIES.

By Theodore Holm.

(With Plates I-VIII.)

Characteristic of the families that constitute the order *Enantioblastæ* is the atropous ovule.[a] The flowers are hypogynous; in some of the families the general monocotyledonous type with five trimerous whorls completely developed may be readily recognized, while in others the flowers are so much reduced that the type is difficult to trace, as, for instance, in *Restionaceæ* and *Centrolepidaceæ*. The habit of these plants is somewhat peculiar, and it seems as if a certain structure in regard to inflorescence, ramification of shoot, shape of leaves, etc., is prevalent in most of these families. The *Mayacaceæ* show a habit unlike that of any other aquatic plants; the *Xyridaceæ* with their cone-shaped inflorescences, the *Eriocaulaceæ* with their capitula, the *Rapateaceæ* and the *Restionaceæ* represent types of very distinct and characteristic aspect. In the *Commelinaceæ*, on the other hand, the structure of the flower exhibits a very pronounced variation from actinomorphic (*Tradescantia*) to zygomorphic (*Commelina*); the foliage is also to some extent different within certain genera (*Tradescantia*), besides that the rhizomes exhibit several types of growth characteristic of certain genera, or of species within the same genus. In other words, the *Commelinaceæ* do not possess a habit of their own or of so special and well-marked peculiarity as the other families of the *Enantioblastæ;* nevertheless the family seems to be a very natural one, and, to use the words of Bentham and Hooker: "Ordo totus optime limitatus, nec cum ullo alio generibus intermediis junctus." Several and very excellent monographs have been published on some of these families. Masters has treated the *Restionaceæ;*[b] Hieronymus the *Centrolepidaceæ;*[c] Seubert the *Xyridaceæ* and *Mayacaceæ;*[d] Bongard,[e] Kœrnicke,[f] and Ruhland[g] the *Eriocaulaceæ;* Hasskarl[h] and Clarke[i] the *Commelinaceæ.* Besides these works a few papers have also been published on the morphology and anatomy of these plants, for instance, by Gilg,[j] Nilsson,[k] Poulsen,[l] Van Tieghem,[m] and the author.[n]

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[a] In a recently published paper, "Beiträge zur Morphologie der Commelineen" (Flora 1904, p. 512), Mr. J. Clark states that the atropous ovule is only characteristic of the genus *Tradescantia* as far as concerns the *Commelinaceæ*, while this type of ovule occurs merely as an exception in "all the other genera of the order." Nevertheless the ovules of *Weldenia* are certainly atropous, and we hope that some future investigator will undertake the study of this particular point in respect to our native representatives.

[b] In De Candolle: Monographiæ Phanerog. Vol. I, p. 218.

[c] Abhdl. Naturf. Gesellsch. Halle. Vol. 12. 1873.

[d] In Martius: Flora Brasil. Vol. III. 1842-1871. Pars. I, pp. 211-227.

[e] Mém. de l'Acad. imp. de St. Petersbourg. 1831 cet.

[f] In Martius: Flora Brasil. Vol. III. 1842-1871. Pars. I, p. 273.

[g] In Engler: Das Pflanzenreich. 1903.

[h] *Commelinaceæ Indicæ.* 1870.

[i] In De Candolle: Monogr. Phanerog. Vol. III. 1881.

[j] Beiträge zur vergleichenden Anatomie der xerophilen Familie der *Restiaceæ.* Inaug. diss. Leipzig. 1891.

[k] Studien ueber die Xyrideen. Kgl. Sv. Vet. Akad. Hdlgr. Vol. 24. 1892.

[l] Anatomiske Studier over Eriocaulaceerne. Thesis. Kjöbenhavn. 1888.

Anatomiske Studier over *Xyris*-Slægtens vegetative organer. Vidensk. Medd. naturh. For. Kjöbenhavn. 1891.

Anatomiske Studier over *Mayaca* Aubl. Overs. Kgl. D. Vid. Forhdlgr. 1886.

[m] Structure de la racine et disposition des radicelles dans les *Centrolepidées, Joncées, Mayacées* et *Xyridées.* Journ. de Botan. 1887.

[n] *Eriocaulon decangulare* L.; an anatomical study. Bot. Gaz. 1901.

In speaking more particularly of the *Commelinaceæ*, this family figures quite often, and sometimes very prominently so, in works on anatomical botany. De Bary[a] mentions several points of great interest, derived from this family: The peculiar arrangement of the vascular system; the structure of epidermis with the stomata; the occurrence of crystals; the root-structure, etc. Falkenberg[b] describes the stem-structure of *Tradescantia argentea* and *crassula*, also of *Commelina Africana*. Schwendener[c] calls attention to the occurrence of collenchyma and discusses the development of the mechanical tissue in some of the species. Van Tieghem[d] refers often to the *Commelinaceæ* as a family of importance in anatomical respect. Furthermore has Eberhard[e] described the structure of leaf and stem of a few species of *Tradescantia*, *Dichorisandra*, *Campelia*, and *Spironema*, besides the distribution of starch, tannin, and chlorophyll in these species. The most comprehensive paper, however, is by Gravis[f], in which *Tradescantia Virginica* is discussed from a morphological, anatomical, and physiological point of view. Among the works dealing more particularly with the morphology of the family may be mentioned those by Eichler[g] and Schumann[h], in which the diagram of the flower and the structure of the inflorescence have been described and explained. Finally, in regard to the germination may be cited Mirbel[i], who described seedlings of *Commelina communis* and *cristata*, and Klebs[j], who has offered a most excellent contribution to the knowledge of the morphology and biology of the germination.

It is thus evident that the *Commelinaceæ* have already been studied from various viewpoints and by authors of prominence. De Bary, Falkenberg, and Schwendener have no doubt demonstrated the most interesting points to be observed in the anatomical structure: The fibrovascular system and the mechanical support. Eichler and Schumann have elucidated the very difficult points in respect to the flowers and inflorescences; in regard to the systematic treatment of the family Hasskarl and Clarke have furnished us with specific diagnoses and sectional divisions of the species, besides notes on the general habit and geographical distribution of these interesting plants.

However, when we examine the literature and consider the species that have been studied more critically, it is readily noticed that relatively only a few species have been treated, and that these are mostly such as are frequently cultivated as ornamental plants. This is not so strange, however, when we remember the exceedingly delicate structure of most of these plants, which makes it necessary that they must either be studied from living specimens or from alcoholic material. When plants of this family are pressed and dried for herbaria they lose their structure to a very great extent, and this is the reason why so very few species have been more closely investigated. The systematic treatment of the family may as far as concerns the external character of flowers, fruits, and leaves be well drawn from herbarium specimens but, as in so many other instances, the parts underground are seldom preserved, and are consequently passed by in diagnoses. The rhizome and the roots have, as a matter of fact, received very little attention; the ramification of the shoot and the anatomical structure of the vegetative organs in general are, on the other hand, well known in some species, but entirely unknown in others.

It would thus appear as if there is still something to be done in regard to investigating the *Commelinaceæ*, and having had the opportunity of observing and collecting several species in the field, and preparing these for further studies, we do not hesitate to present the results of our investigations as a contribution to the knowledge of the family. As will be seen from the following

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[a] Vergleichende Anatomie der Vegetationsorgane der Phanerogamen und Farne. 1877.

[b] Vergleichende Untersuchungen ueber den Bau der Vegetationsorgane der Monocotyledonen. 1876.

[c] Das mechanische Princip. 1874.

[d] Traité de Botanique. 1884.

[e] Beiträge zur Anatomie und Entwickelung der *Commelynaceen*. Inaug. diss. Hannover, 1900.

[f] Recherches anatomiques et physiologiques sur le *Tradescantia Virginica* L. Bruxelles, 1898.

[g] Blüthendiagramme. Leipzig, 1875.

[h] Neue Untersuchungen ueber den Blüthenanschluss. Leipzig, 1890.

[i] Ann. du Mus. d'hist. nat. Vol. 13, p. 54. 1809.

[j] Beiträge zur Morphologie und Biologie der Keimung. Untersuch. Bot. Inst. Tübingen. Vol. 1. 1881–1885.

pages, the writer has endeavored to include as much as possible of the structural peculiarities, but in some cases our material proved to be insufficient, thus we felt obliged to confine ourselves to the external structure alone. The object of our research has been to illustrate some biological features of these plants, as, for instance, their life under ground; the development of a rhizome; the contractile power of the roots, besides their ability to store nutritive matters; furthermore, the mechanical support possessed by stem and leaf, the organization of the leaf, with the differentiation of the chlorenchyma; the stomata and the various types of hairs, etc.

Among the plants which have been studied by the writer are two that actually represent the very rarest members of the family: *Weldenia* and *Tradescantia Warszewicziana*, both from Guatemala. The material of these was carefully collected and preserved by Mr. WM. R. MAXON, who so very kindly gave us the privilege of using it for our present investigation.

The species which we have examined belong to the genera *Commelina*, *Aneilema*, *Tinantia*, *Tradescantia*, and *Weldenia*:

Commelina nudiflora L. District of Columbia: thickets in Brookland.
C. Virginica L. District of Columbia: among rocks on the Potomac shore.
C. erecta L. Florida: near Eustis.
C. hirtella VAHL. District of Columbia: sandy river shore near Marshall Hall.
C. dianthifolia D. C. Texas.
Aneilema nudiflorum R. BR. Georgia: near Thomasville, introduced.
Tinantia anomala (TORR.) CLARKE Texas: at Kerrville, 1,600–2,000 feet altitude, and Alamo Heights, San Antonio.
Tradescantia rosea VENT. Florida: in sandy soil near Lake Dot, Eustis.
T. Virginica L. District Columbia: among rocks on the Potomac shore.
T. scopulorum ROSE. Arizona: Oak Creek.
T. sp. Colorado: in alkaline soil, plains near Denver, 5,000 feet altitude.
T. crassifolia CAV. Mexico: Barranca of Guadelajara, 5,000 feet altitude.
T. pinetorum GREENE. Arizona: Kincon Mountains, 7,500 feet altitude, and Huachuca Mountains.
T. Floridana WATS. Florida: Hammocks, Lee County.
T. micrantha TORR. Texas: Corpus Christi.
T. Warszewicziana K. ET B. Guatemala: Santa Rosa, dry rocks in the open.
Weldenia candida SCHULT. FIL. Guatemala: Volcan de Agua, in fine, hard-packed sand, on rocky slopes within the crater, about 3,600 meters altitude.

Commelina nudiflora L.

THE GERMINATION.

Seedlings of *C. communis* and *cristata* were described by MIRBEL (l. c.), and by KLEBS (l. c.) referred to his second type, where the sheath of the cotyledon becomes very much prolonged and forms a threadlike organ with the apex remaining inclosed in the seed; other representatives of this same type are: *Asphodelus*, *Dianella*, *Aristea*, and *Tradescantia*.

Our figure 1 on Plate I shows the seedling of *Commelina nudiflora*, and we notice at once the long, threadlike portion between the sheath (S) and the apex inclosed in the seed (C); this filiform portion may develop from the side of the sheath, as figured, or near the apex of same. There is a distinct hypocotyl (H), from the middle of which a whorl of three secondary roots have developed, while several others proceed from the base of the hypocotyl. The primary root (R) persists for a few months and ramifies but sparingly (*r*). At this stage of growth we notice, also, the first internode (I^1) with the first leaf (L^1). The internal structure of the various organs of the seedling may be described as follows:

The secondary roots (fig. 14, Pl. III) are very hairy, but possess no exoderm; the cortex (C) consists only of three layers, and the endodermis (End.) is very thinwalled. The pericambium (P) is continuous and surrounds three rays of hadrome (H) alternating with three groups of leptome, of which the proto-leptome cells are plainly visible (PL); the center of the root is occupied by a wide vessel.

A still more delicate structure is observable in the lateral roots (fig. 15, Pl. III), where there are only two layers of cortical parenchyma (C) immediately inside the epidermis; the endodermis (End.) is also here thinwalled with the Casparyan spots plainly visible, but the pericambium (P) is here interrupted by the two proto-hadrome vessels. This root is diarchic and there are thus only two groups of leptome.

The cotyledonary sheath is very thin and perfectly glabrous; the epidermis is thinwalled on both faces and covers a few, two to six, layers of chlorenchyma with chlorophyll. There are only two collateral mestome-bundles containing a broad group of leptome, but only a few vessels. No mechanical tissue was observed. In the cylindrical threadlike portion of the cotyledon the epidermis is also thinwalled, but is here provided with stomata. Two very small collateral mestome-bundles are located in a thinwalled, compact parenchyma of about twenty layers.

The hypocotyl, of which we have figured half of the central cylinder (Pl. IV, fig. 19) has also a thinwalled epidermis covered by a thin, smooth cuticle. The cortex consists of eight layers of roundish cells with narrow intercellular spaces, surrounding a thinwalled endodermis (End., fig. 19.) Four collateral mestome-bundles traverse the central cylinder, of which the innermost portion is occupied by a pith. Secondary roots develop on the hypocotyl, in whorls of three or four, from outside the leptome, but inside the endodermis.

These parts of the seedling, the cotyledon, the hypocotyl, and the first developed system of roots are only of short duration. Thus when the plant commences to bloom they have mostly faded away, while the first internode (I^1 in fig. 1) is generally to be observed as the basal stem-portion in matured specimens.

The Ramification of the Shoot.

The species is an annual and possesses no rhizome, the basal stem-internodes being above ground. The weak ascending main axis is, however, supported by a system of relatively strong roots, which develop in whorls of about five from the basal nodes. (Pl. I, fig. 2.) A profuse development of lateral shoots takes place at an early stage. Thus the plant becomes able to spread over the surface of the ground, the branches being more or less decumbent or ascending. The leaves are alternate and nearly all subtend axillary shoots sometimes accompanied by an accessory bud, which is situated at the side of the shoot. Such collateral buds are also known from various *Liliaceæ* and *Araceæ*, for instance.

Each fully developed and matured shoot becomes, however, terminated by an inflorescence, and the small, leafy shoots which so abundantly occur in this species are only apparently vegetative, the floral apex having become arrested in its further development.

The lateral axes are readily distinguished from the main one by the presence of a fore-leaf, which is membranaceous, colorless, and partly tubular, and which occupies the same position as in most of the other monocotyledonous plants, turning its back toward the mother-axis. By studying the composition of a number of shoots of *C. nudiflora*, we have observed the following arrangement to be the prevalent.

Our figure 3 (Pl. I) represents a stem-portion (A) with a leaf (L^1), in the axil of which a shoot is developed with two leaves (L^2 and L^3), besides two inflorescences (I^1 and I^2), while the fore-leaves are not visible, being hidden within the sheaths of the green leaves. A diagram of this same shoot-complex (fig. 4) may show the exact position of the leaves much better, and we notice here that the axillary branch (B in fig. 3) commences with a fore-leaf (P^1) which alternates with the green leaf L^1, and bears a leaf L^2, turned ninety degrees to the side of L^1 and P^1. Above this leaf (L^2) is an inflorescence (I^1) with its large green spathe, alternating with the leaf (L^2); this inflorescence terminates the shoot (B). Another shoot is visible in the axil of leaf L^2, which, like the former, begins with a fore-leaf (P^2) alternating with the leaf L^2. This little shoot bears, also, a green leaf (L^3), which shows the same turning to the side as the leaf L^2, thus forming an angle of ninety degrees with the fore-leaf (P^2); an inflorescence, I^2, terminates the shoot and the spathe alternates with the green leaf, L^3.

While thus the fore-leaves alternate with the leaf of the mother-shoot, the succeeding green leaf becomes turned ninety degrees to the side, a structure that seems to be typical of *C. nudiflora*. When more than one green leaf is developed on the shoot, a corresponding number of axillary branches is to be observed, in which the same disposition of fore-leaves and spathes becomes repeated, as described above, with the only difference that the upper portion of the shoot may show a turning of somewhat less than ninety degrees from the axis.

It has been mentioned above that accessory buds occur, and these are to be found within the fore-leaves of first or second order, though not in the axils of these; they are usually collateral, when considered in connection with the other shoots, and begin, like these, with a fore-leaf preceding a green leaf and sometimes a rudimentary inflorescence.

The Internal Structure of the Vegetative Organs.

THE ROOTS.

All the roots of *C. nudiflora* are nutritive. As shown in our figure 2, there are several secondary roots developed at the basal nodes of the stem, and these bear lateral ramifications in some distance from the surface of the soil. Of these the secondary are naturally the strongest developed and are quite thick. The epidermis (Ep. in fig. 17. Pl. III) is thinwalled and hairy; it surrounds a thinwalled exodermis (Ex. in fig. 17), the cells of which are much larger than those of epidermis. Between the exodermis and the cortex are usually two layers of stereomatic cells with the cross-walls distinctly oblique. The cortical parenchyma consists of about ten strata of very thinwalled cells which decrease in size toward endodermis; the cortex is quite solid, the intercellular spaces being very narrow. The endodermis (End. in figs. 16 and 18) shows a more or less prominent thickening of the radial and inner cell-walls, but contains no starch. In regard to the pericambium the structure was observed to be somewhat variable in a number of roots. It was either thinwalled throughout or thickwalled outside the hadromatic rays; moreover it was found to be continuous in some roots, but interrupted by the proto-hadrome in others, while in some roots it was continuous near the apex, but interrupted at the base. It would therefore appear as if the pericambium shows no constant structure in our plant, even if we did observe that it was continuous in most of the roots that were examined. Similar irregularities in the structure of the pericambium we have observed in other plants, for instance, *Eriocaulon*,[a] various *Carices*,[b] *Gramineæ*,[c] etc. The leptome, when viewed in transverse sections, forms large and broad groups, with the proto-leptome cells plainly visible. The hadrome consists mostly of five rays, but six or seven were also occasionally observed; the peripheral scalariform vessels are either single or two arranged side by side; the innermost vessels are very wide and reticulated, and one of these may sometimes occupy the center of the root. The conjunctive tissue is thinwalled in some roots, but more or less thickened in others.

If we compare now the structure of these secondary roots with that of their lateral ramifications, we notice only a very few deviations. These consist, in the absence of stereomatic tissue, in the more delicate structure of the endodermis; besides in the smaller number of vessels. But in respect to the pericambium we noticed exactly the same variations as in the secondary roots.

THE STEM.

The basal internode of a flowering specimen (I^1 in fig. 2, Pl. I) shows the following structure:

A thin and smooth cuticle covers the epidermis, of which the outer cell-walls are slightly thickened; then follows a collenchymatic tissue of two or three layers bordering on a thinwalled cortex of about six strata, with small, but distinct, intercellular spaces.

An endodermis (End. in fig. 20 on Pl. IV) with heavily thickened inner and radial walls surrounds the central cylinder, which is furthermore strengthened by a closed ring of stereome bordering directly on endodermis, and which consists of a single layer outside the leptome of the four peripheral mestome-bundles, but of several between these. There are only four mestome-bundles in which the hadrome of wide reticulated and narrower scalariform vessels

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[a] Botanical Gazette, vol. 31, 1901, p. 17.
[b] Am. Journ. Sc., vol. 10, 1900, p. 278.
[c] Bot. Gaz., vol. 39, 1905, p. 131.

surround the leptome in the shape of a V. The innermost part of the central-cylinder is occupied by a thinwalled solid pith with no deposits of starch.

In passing to the second internode (I^2 in fig. 2) we notice the same structure of epidermis, collenchyma, cortex, endodermis and stereome as described above, but the number of mestome-bundles is different, there being three concentric bands of five bundles in each of the two outer ones and of four in the innermost. Of these the peripheral correspond with those observed in the first internode, while those of the two inner bands, which are located in the pith, exhibit a much weaker structure. The stereome is here reduced to a few cells on the hadrome-side or entirely absent as in the innermost; the leptome shows the same development as in the peripheral, while the vessels are much reduced in number; a large lacune, with remnants of some annular vessels, forms a very conspicuous portion of the innermost mestome-bundles. All these mestome-bundles are collateral.

The third internode (I^3 in fig. 2) shows about the same structure, but the number of mestome-bundles has increased now till eight in the outermost band, alternating with six in the following, while there are six others near the center of the pith. Of these the innermost are arranged in two parallel lines close to each other.

These basal internodes thus show a very simple structure of epidermis, but in regard to the other tissues these exhibit relatively the same development as the uppermost portion of the stem. Let us examine the internode B, figured on Plate I, figure 3. The cuticle is smooth and the epidermis is rather small-celled, as in the basal portions. But stomata are present (fig. 21, Pl. IV), and these are surrounded by four cells, two parallel with the stoma and two vertical on this; the stomata are level with epidermis and arranged in longitudinal rows. Hairs are frequent, consisting of two cells with the apex obtuse, but no glandular were observed. Two layers of collenchyma separate the epidermis from a chlorophyll-bearing thinwalled cortex of about five strata. The endodermis is very thinwalled and surrounds directly the peripheral band of sixteen collateral mestome-bundles of the characteristic V-shape, but lacking the support of stereome. The pith contains small deposits of starch, and we find here about five somewhat irregular bands of smaller mestome-bundles, each with one narrow annular and one wide reticulated vessel with some leptome, but destitute of any mechanical support.

THE LEAVES.

The stem leaves, for instance L^1 in our figure 3, Plate I, have large blades and a tubular sheath.

The epidermis of the blade, viewed en face, consists of polygonal cells with straight radial walls, becoming much narrower above and below the mechanical tissue. Stomata occur on both faces of the blade, but are, however, most numerous on the lower; they are projecting and are surrounded by two pairs of subsidiary cells. (Pl. V, fig. 24.) The outer cell-wall of epidermis (Pl. IV, fig. 22) is distinctly thickened on the dorsal face, much less so on the ventral. Epidermal projections of two kinds cover both faces, viz. small wartlike (fig. 30) and long clavate of three cells in one row, which abound on the dorsal face. A large mass of hypodermal water-storage-tissue occurs on the leptome-side of the midrib, but is absent from the hadrome. The chlorenchyma consists of a very open pneumatic tissue on the dorsal face of the leaf-blade (Pl. IV, fig. 23), and of one single stratum of palisade cells on the ventral. Cells containing raphides occur in both of these tissues, and are located directly beneath epidermis; they are very long (Pl. V, fig. 25) when viewed in superficial sections, and are more or less parallel with the veins.

A rather poorly developed collenchymatic tissue of one or two strata is to be observed in the midvein and below the larger parallel secondary veins, but there is none in the leaf-margins.

The mestome bundles occur as about seven almost parallel veins that traverse the entire length of the blade, and as numerous very short anastomoses. Of these the midrib is the strongest developed (Pl. V, fig. 26); there is a thinwalled completely closed parenchyma-sheath, but no mestome-sheath. The leptome represents a roundish group with sieve-tubes and companion cells well differentiated; the hadrome consists of two reticulated and one ring-vessel. Two very small mestome-strands are located in the leaf-margins, and their structure is very simple (Pl. V, fig. 27); the parenchyma-sheath (P), of which two cells are moderately thickened, surround a group of leptome and one or seldom two reticulated vessels.

A somewhat similar structure is to be observed in the green spathe which surrounds the inflorescence. The dorsal face of this leaf is very scabrous from numerous short pointed and somewhat curved hairs, accompanied by the same kind of wartlike and clavate which were noticed on the stem-leaves. The epidermis is otherwise thinwalled and covers a chlorenchyma of two to three strata of open pneumatic tissue, but no palisades; raphide-cells are very numerous, but much shorter than those in the stem-leaves. No collenchyma accompanies the veins, the minor structure of which agrees with that of the veins of the other leaves.

The fore-leaves are tubular and membranaceous, almost colorless. Epidermis is thinwalled on both faces, and lacks the pointed hairs and the papillæ, while a few clavate were observed on the dorsal face. This tissue, the dorsal and ventral epidermis, is the only one of these leaves except around the nerves, where a few parenchymatic cells form an incomplete sheath; the mestome-bundles, eight in all, contain mostly leptome, and are not supported by any cover of collenchymatic tissue.

Although no chlorophyll was observed in the fore-leaf, a few stomata were, nevertheless, noticed, and these showed the same structure as those of the green leaves.

Commelina Virginica L.

THE RHIZOME.

A rhizome is developed in this species, but it is short and condensed (Pl. II, fig. 8); it consists of a few erect internodes, each of which represents the base of an erect aërial shoot with usually two roots. These roots develop from the ventral face of the internodes; they are thick, dark brown, and densely covered with hairs. They branch but sparingly, and the lateral ramifications are more slender and of a lighter color. The rhizome has no horizontal internodes, and its further growth is only secured by the development of a bud in the axil of a scale-like leaf, situated near the base of the short, erect internode. This bud is developed on the side of the shoot, alternately to the right or left; thus the rhizome grows out in a zigzagged direction. This structure of the rhizome may be more easily understood if we examine the smaller specimen drawn on the same plate (fig. 10) with its diagram (fig. 11). The base of the old shoot (A) represents only one internode, and the leaves have faded away completely. A lateral branch has pushed out (A^1) which bears a bicarinate foreleaf (P^1) and two scale-like membranaceous basal leaves (L^1 and L^2). Of these the foreleaf turns its back towards the mother-axis (A), while the two other leaves are turned ninety degrees to the side of this, alternating with each other, as seen in the diagram (fig. 11). Two axillary buds (B^1 and B^2) are visible, and it is the latter of these (B^2) which develops into an aërial shoot during the succeeding year, while the other one (B^1) stays dormant.

If we return now to the larger rhizome (figs. 8 and 9), we notice the same arrangement of leaves and position of buds, besides that the lateral, aërial branch (A^2) from the axil of leaf (L^3) does also begin with an addorsed fore-leaf (P^2).

It seems, thus, characteristic of the rhizome of this species that no horizontal internodes occur, that the growth takes place in a zigzagged direction, and that the bud in the axil of leaf (L^1) remains dormant.

THE AËRIAL SHOOT.

It is not uncommon to find specimens with a simple, erect stem terminated by an inflorescence and with no indication of lateral floral or vegetative shoots. Most frequently, however, the stem is branched and often very profusely so. Lateral shoots may thus develop from the axils of nearly all the stem-leaves, and these lateral shoots are again terminated by an inflorescence, besides that a few, two or three, inflorescences of third order may be observed near the apex of each lateral branch. Purely vegetative shoots are frequent; they are developed on the lateral shoots and contain no rudiments of flowers.

If we examine the ramification we notice an addorsed bicarinate foreleaf at the base of each lateral branch and at the base of each axillary inflorescence. The diagram of the shoot agrees very well with that of *C. nudiflora*, described above, but there is no stem-leaf situated directly on the floral shoot; thus the foreleaf is the only leaf below the spathe. By comparing the exact position of the foreleaf with that of the spathe we noticed that the latter was turned ninety degrees to the side of the former, as in *Commelina nudiflora*.

THE INTERNAL STRUCTURE OF THE VEGETATIVE ORGANS.

THE ROOTS.

As described above, the secondary roots are quite thick and densely covered with root-hairs; they represent a combination of two types, since they are contractile and contain large deposits of starch. Epidermis is thinwalled, and the cells are stretched radially. (Pl. VII, fig. 41, Ep.) There is an exodermis (Ex. in fig. 41) of one layer, with the cells stretched in the same way, and of which the cell-walls show numerous foldings when examined in longitudinal radial sections. About four strata of slightly thickened stereomatic tissue separate the exodermis from the cortex proper. These stereomatic cells are much shorter than typical stereome, and their cross-walls are horizontal instead of oblique.

The cortex represents a broad tissue of about thirty layers, the cells of which are thinwalled and round when viewed in transverse sections, and they are filled with starch. The cortical parenchyma exhibits a very regular radial arrangement with rhombic intercellular spaces. Numerous crystal-ducts occur in the cortex. They are very long, but much narrower than the surrounding cortical cells and contain bundles of raphides.

Endodermis is small-celled and thinwalled, with the Casparyan spots plainly visible, but contains no starch. The pericambium consists of a single layer, and is continuous in some roots, but interrupted by the proto-hadrome in others. The hadrome forms twelve short rays, with the proto-hadrome vessels single or two or three together arranged side by side. The leptome is well developed in broad groups, separated from the center by several layers of thinwalled conjunctive tissue.

The lateral roots are much more slender, and they are not contractile; otherwise the epidermis and exodermis show the same structure as observed in the secondary roots. Cortex consists here of only five layers, with no deposits of starch and with no crystals. Endodermis is thinwalled, or the inner and radial walls may be slightly thickened. The pericambium is continuous and surrounds five to six very short rays of hadrome with the proto-hadrome-vessels mostly single; a very wide reticulated vessel occupies the center of the root. The leptome is well developed, but the proto-leptome cells less distinct than in the thick roots.

THE RHIZOME.

The basal persisting internode shows the following structure: Epidermis is moderately thickened on all the cell-walls, perfectly glabrous and covered by a smooth, thick cuticle. The cortex is moderately thickwalled and consists of numerous layers filled with starch; tubular raphide-cells abound here. Two almost concentric rings of mestome-strands are located in the cortex; they are collateral, and each is surrounded by a sheath of cells which are distinctly smaller than the surrounding cortex and contain no starch. The innermost portion of the internode is occupied by a solid parenchyma of the same structure as the cortex and with similar deposits of starch.

THE STEM ABOVE GROUND.

Epidermis is here thinwalled and quite hairy from small four-celled hairs with the apical cell somewhat curved, thus they represent minute hooks; stomata are present with two pairs of subsidiary cells very plainly differentiated. (Pl. VII, fig. 40.) The cortex is thinwalled except where it is developed as a collenchymatic tissue of four to five hypodermal strata, and the cortex proper contains much chlorophyll, besides raphides in long tubular cells. Inside the cortex is a closed sheath of thickwalled cells which reminds of an endodermis, but they did not resist the effect of concentrated sulphuric acid. This sheath surrounds several strata of typical stereome, which forms a massive closed ring around the mestome-bundles. Some of these, about twenty-five, are arranged in a peripheral band bordering directly on the stereome, while the others, about twenty, are scattered very irregularly in the pith. Of these the peripheral possess a very large group of leptome, two wide pitted ducts, and one annular vessel located between two scalariform. No parenchyma- or mestome-sheath was observed.

The innermost mestome-bundles have only one, but very wide, pitted duct and sometimes an annular and a scalariform vessel, but they lack the support of stereome.

A pith of large roundish cells occupies the center of the stem; it contained very much starch, and tubes with raphides were also observed.

THE STEM-LEAVES.

The blade is held in a horizontal position and is very hairy. Epidermis of the ventral face, when viewed en face, consists of penta- or hexagonal cells (Pl. VI, fig. 37) with many pointed hairs of only two cells, but with very few stomata. The dorsal face, on the contrary, is almost glabrous, but amply provided with stomata of the same structure as those of the stem. (Pl. VII, fig. 40.) A cross-section of the leaf-blade shows a thin and smooth cuticle on both faces. The outer cell-wall of epidermis is moderately thickened, and the lumen of the cells, which is rather narrow above and below the midrib, increases in size from there toward the margins of the blade; the stomata are seen now to be somewhat projecting, and their air-chamber is deep and quite wide. A single stratum of collenchyma is noticeable above and below the midrib, which is prominent only on the lower face of the blade. This collenchyma passes gradually over into a layer of colorless cells on the ventral face of the midvein, while on the dorsal there is a mass of similar colorless tissue, the function of which is evidently to store water. This colorless tissue, together with the collenchyma, is thus confined to the two faces of the midvein alone.

The chlorenchyma consists of a dense palisade tissue of one layer and of a very open pneumatic tissue of very irregular cells in several strata. Cells with raphides are scattered on the ventral face beneath the epidermis.

The stereome is weakly developed and occurs as small strands on the leptome-side of the mestome-bundles except the midvein; no stereome was observed on the hadrome-side or in the margins of the blade.

The mestome-bundles are almost orbicular in cross-section; they are surrounded by a thin-walled, colorless, parenchyma-sheath. No mestome-sheath is developed, but the leptome is, nevertheless, covered and protected by a layer of thickwalled mestome-parenchyma. The leptome is well developed, and the hadrome has, at least in the largest veins, two very wide pitted ducts, one annular and two or three scalariform vessels.

The leaf-sheath is tubular and densely covered by long, hooked hairs. (Pl. VII, fig. 39.) The collenchyma is here only developed on the dorsal face of the midvein, and the chlorenchyma is traversed by broad lacunes beneath the ventral epidermis. No palisades are developed, and the mestome-bundles are somewhat weaker than in the leaf-blade.

Commelina erecta L.

Having been unable to detect any points by which this species may be distinguished from *C. Virginica* L., as far as concerns the ramification of rhizome and aërial shoots, we will confine ourselves to describe the internal structure alone.

THE ROOTS.

The roots are quite long and more slender than in the preceding species; they are very hairy and represent also here a combination of two types, contractile- and storage-roots. The exodermis consists of large, pentagonal cells with the radial walls very prominently folded. The cortex consists of fifteen layers, which are quite compact and contain large deposits of starch; some cells were noticed to contain tannin. The cortical parenchyma is thinwalled throughout, and no stereomatic strata are developed in this species beneath the exodermis. Endodermis is thinwalled, with the Casparyan spots plainly visible; the pericambium is thinwalled and continuous, surrounding five short rays of hadrome with the two to three proto-hadrome vessels situated side by side. The leptome constitutes broad groups, and the conjunctive tissue is thinwalled, but occupies only a very small portion of the central cylinder, since the center contains a very wide vessel.

THE STEM ABOVE GROUND.

In the uppermost internodes below the inflorescence the epidermis is covered by a thick and smooth cuticle, and the cellwalls, especially the outer, are distinctly thickened; pluricellular, strongly curved hairs abound, and the stomata are level with epidermis. Beneath epidermis are several isolated groups of collenchyma, separated from each other by narrow rays of the green cortex, which forms also a closed ring of about three layers around the stereome and the mestome-strands. There is also in this species a sheath like an endodermis which separates the stereome from the cortex proper, but it was very thinwalled in *C. erecta*. The stereome is not very thickwalled, but incloses the peripheral band of mestome-bundles completely. The number of mestome-bundles is rather small, there being about sixteen peripheral and a very few located in the pith, and their structure is exactly the same as noticed in the preceding species. The pith represents a very large thinwalled parenchyma, but contained no starch.

THE STEM-LEAVES.

The leaf-blade is very hairy on both faces, especially on the ventral; these hairs are short and clavate or somewhat longer and with the apical cell strongly curved. The cuticle is smooth or wrinkled outside the subepidermal collenchyma. Epidermis has the outer cell-wall slightly thickened on the dorsal face, much less so on the ventral; the lumen of the cells is large on both faces except above the midrib. Stomata abound on the dorsal face; they are level with epidermis and are surrounded by four cells.

There are hypodermal layers of collenchyma above and below the midrib, which on the dorsal face passes over into a water-storage tissue of thinwalled colorless cells. Similar groups of collenchyma were also noticed at the other large veins. Besides this support of collenchyma the mestome-bundles possess also a little stereome on the leptome-side, separated from the collenchyma by a single stratum of chlorenchyma; a few cells of stereome were, furthermore, observed in the margins of the blade. The chlorenchyma is differentiated into one layer of palisades on the ventral face, very compact and full of chlorophyll, and into a more open pneumatic tissue on the dorsal. Cells with raphides were observed in both of these tissues.

The mestome-bundles are surrounded by a thin-walled parenchyma sheath and show the same structure as described above for *C. Virginica*.

Commelina hirtella VAHL.

THE RHIZOME.

A rhizome of a flowering specimen is figured on our Plate 1, figure 5. It is perennial, horizontally creeping, with distinct, more or less stretched internodes, the leaves of which are membranaceous and tubular, when young. The roots are hairy, somewhat fleshy, but never tuberous; they are sparingly branched and develop in a number of three or five at the nodes, above the insertion of the leaves. The ramification of the rhizome is sympodial, and the lateral branches begin with an addorsed foreleaf. Dormant buds occur in the leafaxils. The length of the complete rhizome is very variable, and we have noticed as many as nine internodes between two flower-bearing shoots, representing the growth of one season.

THE RAMIFICATION OF THE AËRIAL SHOOT.

The species is more robust and taller than the others, but the stem is less branched. Vegetative shoots may develop near the base, but seldom at the upper part, and a few inflorescences are to be observed at the apex. The stem-leaves are ample and provided with large sheaths; they are on the lateral shoots preceded by a small tubular foreleaf, which is bicarinate and slit on the frontal face. (Pl. I, figs. 6 and 7.)

By examining the position of the leaves, foreleaves, and spathes in a lateral shoot we notice that the green leaves are turned 90 degrees to the side of the foreleaf, as in the species described above. As many as three green leaves may be observed on a single, flowering, lateral shoot, alternating with each other and supporting lateral inflorescences, each of which begins with an addorsed foreleaf and where the spathe is turned 90 degrees to the side of this.

THE INTERNAL STRUCTURE OF THE VEGETATIVE ORGANS.

THE ROOTS.

As mentioned in the preceding the roots of this species are somewhat fleshy, but not tuberous; they may be designated as "nutritive" and at the same time "contractile," but not as storage roots.

The thinwalled epidermis shows a profuse development of hairs. An exodermis of a single layer of, in transverse sections, polygonal thinwalled cells separate epidermis from the cortex; viewed in longitudinal sections the cell-walls of the exodermis show numerous foldings. (Pl. V, fig. 29.) The cortical parenchyma constitutes a homogeneous thinwalled tissue, which frequently collapses tangentially; or the peripheral strata of the cortex may consist of thickwalled cells, stereomatic, with the lumen quite narrow; these cells are, however, relatively short and the cross-walls horizontal instead of oblique as in typical stereome.

Endodermis is mostly thinwalled, but we observed, also, cases where the inner and radial cell-walls were moderately thickened. The pericambium consists of a single layer and we noticed no instances in the secondary roots where it was interrupted by the proto-hadrome vessels. (Pl. VI, fig. 34.) The leptome occurs as broad groups as in the other species examined, and the hadrome constitutes a very variable number of rays from four to eight, but five being the most frequent; the rays are very short, and the innermost vessels, which are reticulated, are the widest. One of these may occupy the center of the root, but very seldom. The proto-hadrome vessels (PH in fig. 34) are very narrow and either single or two together. The conjunctive tissue is often more or less thickwalled, and extends to the center of the root.

If we now examine the much thinner lateral roots, we notice only a few layers of thinwalled cortical parenchyma which do not collapse. The number of hadromatic rays may be reduced to only two, of which the proto-hadrome vessels border directly on endodermis; when four or five rays were developed, these vessels were located inside the pericambium as in the mother root. But otherwise the structure of the lateral roots appeared to be very uniform with epidermis, exodermis, endodermis, and the conjunctive tissue thinwalled throughout.

It would thus appear as if the pericambium is continuous in the secondary roots, judging from the large number of roots that have been studied and at different places, but sometimes interrupted in the lateral. Finally may be mentioned that "thyllen" were observed in the reticulated vessels of some of these roots.

THE RHIZOME.

The horizontal internodes show the following structure: A thin, smooth cuticle covers epidermis, from which numerous clavate hairs are developed. The cortex is differentiated into a hypodermal collenchyma of about three strata, and a cortex proper of about twenty layers;

the latter contains raphides and tannin, and the intercellular spaces are often very wide, especially near the endodermis. A thinwalled endodermis with the Casparyan spots plainly visible surrounds the central cylinder and borders directly on a continuous ring of stereome. This stereome is rather thinwalled and incloses the peripheral mestome-strands completely; it occurs also around the inner mestome-bundles, but is weakly developed. The collateral mestome-bundles are arranged in four bands, which are barely concentric; the peripheral are the highest developed, consisting of a large group of leptome and several vessels, two wide reticulated, one annular, and a few scalariform. The inner mestome-bundles, which are located in the pith, possess also a large leptome, but only one very wide reticulated vessel. A thinwalled pith with large deposits of starch occupies the greater portion of the central cylinder.

THE STEM ABOVE GROUND.

The basal internodes show the same structure as the rhizome, but with the collenchyma much more typically developed and with the stereome more thickwalled.

By examining the upper internodes, which are completely covered with the leaf-sheaths, we notice the same structure; epidermis, however, is more hairy, and besides the clavate hairs there are also some that are sharply pointed. (Pl. VI, fig. 35.) Stomata are frequent and show variation in regard to the position of the surrounding cells. (Pl. V, fig. 28, and Pl. VI, fig. 33.) Viewed en face the cells of epidermis are short and broad in the stomatiferous strata, but narrower between these; the cell-walls are thin throughout.

Beneath the epidermis are several isolated groups of collenchyma of very thickwalled cells in five or six strata. The cortex contains chlorophyll and is developed as dense palisades between the collenchymatic groups, but inside it represents a very open tissue of in transverse section roundish cells. Raphides in long tubular cells are frequent in the cortex, besides large globose crystals of Calcium oxalate. (Pl. VI, fig. 36.)

A thinwalled endodermis surrounds the central cylinder in which we notice the same structure as in the rhizome—a continuous ring of thinwalled stereome, four bands of mestome strands, and a pith. The last of these, the pith, contains no starch, but numerous crystals and raphides. (Pl. VII, fig. 38.) It is a rather open tissue with the intercellular spaces very wide.

If we now examine the nodus, we find the same structure as described above in regard to epidermis, collenchyma, cortex, endodermis, and stereome, but the mestome-bundles show naturally a somewhat modified structure. The peripheral mestome-strands are almost orbicular, when viewed in cross-sections, and the leptome is on both sides covered by several reticulated vessels. The mestome-strands of the inner bands are larger than the peripheral, since some of these have fused together, forming bicollateral and perihadromatic strands; the pith was observed to be more solid than in the internode.

The aërial shoot is actually terminated by a single flower borne upon a slender, glabrous peduncle; a lateral and much thicker peduncle proceeds from the base of the terminal, and bears usually two or three flowers. The internal structure of these two peduncles is almost identical, with the exception of the arrangement and number of the mestome-strands. There are only four or five peripheral strands in the terminal, while the lateral contains three almost concentric bands of collateral mestome-bundles, about fifteen in all. The epidermis is thinwalled and bears many pointed hairs; the cortical parenchyma, which occupies most of the cross-section, is very open from the presence of wide lacunes. An endodermis surrounds the central cylinder with a closed ring of stereome, the mestome-bundles, and the solid, but thinwalled pith.

THE STEM-LEAVES.

The green leaves are provided with a long, tubular sheath and a flat blade, held in a horizontal position.

The sheath is very veiny and covered with hairs on the outer face. These hairs represent three kinds: Very long and sharply pointed, consisting of four cells, which are located along the ventral suture and around the orifice of the sheath; some that are very short, but pointed like the others, and which occur in rows near the stomatiferous strata: finally clavate hairs are very abundant and show the same distribution as the short ones. The epidermis is thinwalled on both faces, and is covered by a smooth cuticle. A collenchymatic tissue is developed as a few layers on the dorsal face of the largest veins. There is a homogeneous chlorenchyma of, in transverse sections, roundish cells with wide intercellular spaces near the ventral face (the inner) of the sheath. Druids, but no raphides, were observed in the chlorenchyma. The stereome is poorly represented, and occurs as a few cells on both faces of the veins, and is more thickwalled on the leptome-side than on the hadrome; in no instances was the stereome observed to be subepidermal. In regard to the mestome-bundles, these are collateral and of the usual structure, as described above.

The leaf blade is scabrous on the ventral face and along the margins; the midvein is thick and very prominent on the dorsal face. Clavate and two-celled, pointed hairs abound on the ventral face, but only the clavate are frequent on the dorsal. Stomata were observed on both faces, but they are most numerous on the dorsal; they are generally surrounded by four cells (Pl. VI, fig. 32) or, though seldom, by five (fig. 31); the guard-cells are conspicuously larger on the leaf-blade than on the stem and the sheath. Viewed en face the cells of epidermis are mostly pentagonal or hexagonal, with the radial walls straight, a structure that was observed on both faces of the blade. Examined in transverse sections epidermis consists of a double layer above the middle portion of the blade, covering the midrib, and also above some of the larger veins. But otherwise there is only one stratum of epidermis, and the cell-walls are thin. The epidermis of the lower face consists of a single layer throughout: the cells are thinwalled and very small underneath the veins, but larger between these.

A collenchymatic tissue of one layer covers the leptome-side of the midvein and of some of the larger, but there is none on the hadrome-side. The chlorenchyma is differentiated into one stratum of long palisades on the ventral face of the blade, and a pneumatic tissue on the dorsal. The palisade-tissue is quite compact; it contains tannin, but no cells with crystals were observed. The pneumatic tissue, on the other hand, is very open on account of the very irregular shape of the cells, and raphides and crystals were observed here.

The mestome-bundles are collateral; they possess a colorless parenchyma-sheath, which is generally thinwalled; a few layers of thickwalled mestome-parenchyma occurs, sometimes, on the leptome-side, or on both the leptome- and the hadrome-side. The primary veins have a large group of leptome, and several wide vessels.

THE SPATHE.

The structure of the spathe is more simple than that of the stem-leaves. While the ventral face is destitute of stomata and hairs, the dorsal has numerous stomata and short, pointed hairs in abundance; epidermis is thinwalled on both faces and represents the only tissue in the leaf-margins which are grown together, thus the spathe is partly closed. The chlorenchyma is only developed as a pneumatic tissue, which is very open. No collenchyma was observed, but the mestome-bundles are supported by a few strata of thickwalled mestome parenchyma. Druids and single crystals occur in long, narrow cells beneath the epidermis.

Commelina dianthifolia D. C.

THE RAMIFICATION OF THE SHOOT.

The parts underground consist of a few vertical internodes covered by leaf-sheaths and bearing many fleshy, brown roots with slender lateral ramifications. Our dried material showed no stems from the previous year, but it appears, nevertheless, as if the species is perennial. The aërial stem is quite tall, erect, and profusely branched, each branch being terminated by an inflorescence. These axillary shoots bear membranaceous, tubular fore-leaves and show the same disposition of the leaves as described above. The number of green leaves on the lateral shoots is somewhat variable, from two to four on the basal, and only one on the uppermost of these. The flowers are surrounded by a large, green spathe, which is relatively long and acuminate in this species.

THE INTERNAL STRUCTURE OF THE VEGETATIVE ORGANS.

THE ROOTS.

The fleshy, secondary roots are very hairy. An exodermis of one layer of thinwalled cells with prominent foldings surrounds a cortical parenchyma of large size. This parenchyma consists of about twenty strata thinwalled cells with narrow intercellular spaces and filled with starch. The endodermis and the pericambium are thinwalled and surround six broad groups of leptome alternating with six short rays of hadrome; the exact position of the proto hadrome vessels could not be ascertained, since the roots had been pressed and dried. A thinwalled conjunctive tissue occupied the center of the root.

THE STEM ABOVE GROUND.

The internodes are smooth and minutely hairy from small, clavate hairs. The cuticle is thick and smooth, and covers a thickwalled epidermis; stomata are frequent and are arranged in longitudinal rows, where the cortical parenchyma extends to epidermis. Inside the epidermis are three layers of very thickwalled collenchyma, which is frequently interrupted by the cortex, as mentioned above. The cortex constitutes a rather narrow zone of thinwalled cells containing chlorophyll. A thinwalled endodermis surrounds the central cylinder and borders directly on a closed sheath of stereome of three layers. The mestome-bundles are collateral and are arranged in three concentric bands. Of these the peripheral are very numerous and they are completely surrounded by stereome. The inner band consists of ten mestome-bundles with a smaller number of vessels and the innermost of only three. While the stereome is usually confined to the peripheral mestome-bundles in the species of *Commelina*, described above, we noticed in the present species, *C. dianthifolia*, that a small group of this tissue was also developed on the leptome-side of all the inner mestome-strands. The pith is thinwalled and filled with starch.

THE STEM-LEAVES.

The leaf-blade is scabrous on both faces and along the margins from two-celled, short, but sharply pointed hairs and one-celled, roundish, very thickwalled warts. Besides these some clavate hairs were also observed, but only on the ventral face of the blade, and not in any large number. The cuticle is thick and smooth. Viewed en face the cells of epidermis are mostly octagonal; in transverse sections the cells show a wide lumen and the outer walls are moderately thickened. Stomata are distributed over both faces of the blade; they are level with epidermis and have two pairs of subsidiary cells parallel with the stoma. Thickwalled collenchyma was observed on the leptome-side of the larger veins, and in the margins. The stereome is weakly developed as a few strata on the leptome- and hadrome-side of the larger mestome-bundles, separated from the collenchyma by a few layers of chlorenchyma. The chlorenchyma consists of one single layer of palisades, vertical on the ventral face, and of a more open pneumatic tissue near the dorsal portion of the blade. Many cells were observed to contain tannin. The structure of the leptome and hadrome showed nothing of particular interest.

THE SPATHE.

The structure of the spathe is almost identical with that of the leaf-blade in regard to epidermis with the stomata and hairs; the wartlike papillæ were, however, not observed. The mechanical tissue is somewhat poorer developed, there being only a small group of collenchyma on the leptome-side of the midvein, and stereome is totally absent. But in regard to the chlorenchyma and the minor structure of the mestome-strands we did not notice any important difference between the spathe and the stem-leaf.

Aneilema nudiflorum R. Br.

The Ramification of the Shoot.

The species is an annual with decumbent stems rooting at the lower nodes. The narrow leaves are alternate with distinct sheaths which inclose the axillary buds; the fore-leaf is membranaceous, tubular with the apex extended into two small, green teeth. Nearly all the shoots are terminated by an inflorescence borne on a long, slender scape. In regard to the arrangement of the leaves, the diagram is the same as that figured on our Plate II of *Tradescantia rosea*, i. e., a regular alternation of the green stem-leaves and the fore-leaf.

The Internal Structure of the Vegetative Organs.

THE ROOTS.

Two to three slender and sparingly branched roots are developed on the lower face of the nodes. Their structure is as follows: Epidermis is hairy, and covers an exodermis of one layer of thinwalled, pentagonal cells, which are larger than those of epidermis and the adjoining cortex; no foldings of the cell-walls were observed. The cortical parenchyma consists of ten strata, of which the four peripheral are persisting, while the others were collapsed tangentially; no starch was observed. The endodermis and the continuous pericambium are thinwalled. There are five short hadromatic rays with one very wide, reticulated vessel in the center, and two to three narrower, spiral in each ray. The leptome is well developed, and the conjunctive tissue, which occupies only a small portion of the central cylinder, is thinwalled.

THE STEM.

The structure of the stem could not be studied satisfactorily, since the material had been pressed and dried. We noticed, however, that a continuous sheath of hypodermal collenchyma surrounded a narrow zone of green cortical parenchyma, and that the peripheral mestome-bundles, located inside the cortex, had a support of stereomatic tissue on the leptome side.

THE STEM-LEAVES.

Viewed en face epidermis of the dorsal face consists of rectangular cells with some few rows of clavate hairs between the stomatiferous strata. The stomata have one pair of subsidiary cells and are slightly raised above the adjoining epidermis. The outer cell-wall of epidermis exhibits a number of longitudinal ridges, which are covered by the thin but distinct cuticle.

The ventral epidermis shows the same structure, but has no stomata. Along the margins of the blade are minute, one-celled warts, but no hairs or prickle-like projections. Viewed in transverse sections the leaf shows a large-celled epidermis on both faces, and the stomata have deep and wide air-chambers. Underneath the ventral epidermis is a water-storage tissue of two layers of very large thinwalled cells, which covers the chlorenchyma. This tissue represents a homogeneous, open pneumatic tissue, since no distinct palisades were noticed. The mestome-bundles are very thin, and only the mediane has a support of hypodermal collenchyma on the leptome-side; some of the other veins, had a small group of stereome on the leptome- but none on the hadrome-side, and some few layers of this tissue were, furthermore, observed in the leaf-margins.

Tinantia anomala (Torr.) Clarke.

This plant was originally described by Torrey[a] as a *Tradescantia* "*anomala*," and his material came from the shady woods on the Blanco, Comale, and other rivers in Texas. As stated by Torrey, "the species is intermediate between *Tradescantia* and *Commelina*, resembling

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[a] U. S. and Mex. Bound. Survey under Lieut. Emory. Washington, 1858, p. 225.

the latter in the unequal petals and difformed stamens as well as in the terminal leaf or bract (which is like a spatha laid open), and the former in the six fertile stamens with bearded filaments." Several years later the species became transferred to the genus *Tinantia* by C. B. CLARKE (l. c.).

THE RAMIFICATION OF THE SHOOT.

The species is an annual with an ascending stem; the roots are very slender, much branched, and develop from the very base of the stem. The lowest leaves, one to three, are lanceolate, the others ovate to cordate and acuminate. Axillary shoots develop from the basal leaves and also from some of the higher situated. It seems characteristic of this plant that the axillary buds break through the sheath of the supporting leaf. However, as will be shown later, we noticed the same peculiarity in *Tradescantia Floridana*, and CLARKE (l. c.) describes the same as characteristic of *Polyspatha paniculata* BENTH. and *Buforrestia Mannii* CLARKE.[a]

The accompanying diagram of the shoot of *Tinantia* (Pl. VIII, fig. 46) shows the arrangement of the leaves. L^1–L^3 are alternating stem-leaves; a lateral shoot is developed in the axil of L^2, and the fore-leaf (P^1) alternates with this, while the succeeding green leaves (L^4 and L^5) are turned 90° to the side, as in *Commelina*. In the axil of L^3 are two shoots developed; the main one of these commences with the fore-leaf P^2, upon which two green leaves (L^6–L^7) follow; the secondary, which belongs to the axil of the fore-leaf (P^2) begins, also, with a fore-leaf (P^3) succeeded by a green leaf (L^8). We notice thus in these three shoots exactly the same position of the leaves as in *Commelina*, described above; furthermore, the fore-leaves in *Tinantia* support lateral ramifications.

Although axillary buds are present on the secondary branches, it seems as if these stay dormant, unless the terminal inflorescences should become injured. In the specimens which we have examined the main stem was invariably terminated by an inflorescence. There were, furthermore, two or three long, lateral branches, all of which bore several green leaves and were terminated by a few-flowered inflorescence. In no instance did we observe that the small buds (in the axils of L^4–L^8) attained any further development. Thus we presume they are merely auxiliary.

THE INTERNAL STRUCTURE OF THE VEGETATIVE ORGANS.

THE ROOTS.

A hairy epidermis covers a thinwalled exodermis of a single layer and of which the cell-walls show no foldings. The cortical parenchyma consists of eight compact strata, showing a very regular radial arrangement of the cells; the parenchyma is thinwalled throughout, and no deposits of starch were observed. The endodermis and the continuous pericambium are thinwalled. Seven short rays of hadrome alternate with seven roundish groups of leptome. A wide, reticulated vessel occupies the center of the root, and the proto-hadrome-vessels are mostly only one in each ray. The conjunctive tissue is thinwalled and sparingly represented.

THE STEM.

The glabrous internodes are covered by a thick, smooth cuticle. Epidermis is thinwalled, and the stomata are arranged in longitudinal, very narrow rows outside the narrow hypodermal rays of cortical parenchyma. The stomata have one pair of subsidiary cells, parallel with the stoma, and they are sunk below the surrounding epidermis; the air-chamber is wide, but rather shallow. A collenchymatic tissue is well developed, and represented by many hypodermal groups of one or two layers; the cells are very thickwalled and of a regular stellate shape. The cortex consists only of a few layers of thinwalled cells filled with chlorophyll, and, as stated above, this tissue extends to epidermis between the groups of collenchyma. No raphides were observed. Inside the cortex is a single layer of very large, thinwalled cells, which doubtless represents an

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[a] It, moreover, occurs in *Tradescantia geniculata* JACQ. and in *Campelia Zanonia* H. B. K., besides that Schönland mentions it as common to several species of *Dichorisandra*. (Natürl. Pflanzenfam., II, 4, p. 68.)

endodermis. It borders on a closed ring of thinwalled stereome, which surrounds the peripheral mestome-bundles completely and separates the cortex from the pith. The peripheral mestome-strands are thus supported by stereome on all sides; they are collateral and have many very wide vessels, which cover the sides of the leptome in the shape of the letter V. The thinwalled pith contains no starch or raphides, but is traversed by a few mestome-bundles, with a little stereome on the leptome-side.

THE LEAVES.

The stomata show the same structure as those of the stem, and they occur only on the dorsal face of the blade. No hairs were observed, but along the margins the epidermis is extended into roundish warts, which are quite thickwalled. The chlorenchyma contained many cells with raphides, but we were unable to ascertain whether a palisade-tissue was developed, since our material had been dried and pressed. The midrib is slightly thicker than the other veins on account of the presence of a group of collenchyma and water-storage tissue on the leptome-side.

Tradescantia rosea Vent.

The Rhizome.

This species possesses a horizontally creeping rhizome with stretched internodes partly covered with membranaceous, scale-like leaves and provided with fleshy roots. The ramification is, as may be seen from our figure (Pl. 11, fig. 12), monopodial, until the partly subterranean stem becomes terminated by an inflorescence (I^6). The internodes I^1 to I^5 are all horizontal, while the long internode I^6 is vertical and constitutes the base of an aërial, flowerbearing shoot. Four axillary, flower-bearing shoots (S^1–S^4) are developed in this specimen, and the basal internodes of these have partly fused together with the respective main axes the internodes I^3 to I^6; these axillary shoots are, of course, aërial and ascending, but in order to facilitate the view of the complete rhizome we have drawn all the axes, the main and the lateral, in one plane. Thick and fleshy roots develop at the nodes of the main rhizome, while some more slender ones are to be observed at the nodes of the axillary shoots.

The Ramification of the Shoot.

If we examine one of the axillary shoots, for instance, S^3, we notice the following structure (fig. 13): *l* signifies the scale-like leaf, from the axil of which the shoot has developed; I^5 is the internode above this leaf. As normally in monocotyledonous plants the first leaf of the lateral shoot is an addorsed fore-leaf (P^1), succeeded by a green leaf (L^1), while an inflorescence (S^3) terminates the shoot. In the axil of L', however, another shoot is visible, which also commences with an addorsed fore-leaf (P^2), succeeded by two alternating green leaves L^2 and L^3, which surround a minute inflorescence of third order; this inflorescence stays dormant until the following season. If we compare now the diagram of *Tradescantia* (fig. 13) with those of *Commelina* (figs. 9 and 11), we notice at once that all the leaves, the fore-leaves and the green ones, alternate with each other in *Tradescantia*, while in *Commelina* the green leaves are turned 90° to the side of the fore-leaf.

The Internal Structure of the Vegetative Organs.

THE ROOTS.

A thick, secondary root, examined near the apex, shows the following structure: The thinwalled epidermis is exceedingly hairy, and covers an exodermis, which consists of a single layer and of which the cellwalls are folded and very slightly thickened. The cortex is represented by about eight strata with narrow intercellular spaces and with large deposits of starch. The endodermis is moderately thickened and surrounds a thinwalled pericambium, which is continuous in some of these secondary roots, but interrupted in others. When such interruptions were noticed, it was generally only a few of the proto-hadrome vessels that had broken through the pericambium—for instance, two rays in pentarchic roots. The hadromatic rays are short, consisting only of one wide, central, reticulated, and a few much narrower scalariform vessels. The leptome is well developed and the proto-leptome cell plainly visible. By examining this same root near the base we noticed that the cortex and endodermis had become considerably thickwalled and porous. (Pl. VII, fig. 42.) The somewhat thinner lateral roots show the same structure as the secondary, described above, with the only exception that the cortical parenchyma is less developed, and consists of only two or three strata; moreover, the pericambium is mostly interrupted by all the proto-hadrome-vessels. These interruptions of the pericambium appear, however, as being very irregular, and we noticed, for instance, that in one root this tissue was continuous in some places, but interrupted in others, besides that it was either interrupted by all the proto-hadrome vessels or only by two or three of these in tetrarchic roots.

The roots, especially the secondary, of *Tradescantia rosea* are thus contractile, and at the same time storage-roots.

THE RHIZOME.

The structure of the horizontal internodes is identical and may be described as follows: The internodes are cylindric and smooth, covered by a thick, wrinkled cuticle. The outer cell-walls of epidermis are moderately thickened, and stomata with the guard-cells raised (Pl. VII, fig. 45) occur on the upper face of the rhizome, where also chlorophyll was observed. There is no collenchyma, and the cortex borders thus directly on epidermis. The cortical tissue is slightly thickwalled and quite compact; it contains starch and raphides. The mestome-strands are arranged in two concentric bands, sixteen peripheral and five near the center. Of these the peripheral are supported by one or sometimes two layers of thickwalled cells, which resemble stereome; the leptome is mostly covered by the hadrome on the sides. In regard to the inner band of mestome-bundles these show the same structure, but their mechanical support is much weaker and each contains a wide lacune with an annular vessel. The pith is thinwalled and contains no starch.

The sixth internode (1^6 in fig. 12) is almost above ground and differs from the others, the horizontal, by being hemicylindric and densely hairy. The cuticle is thick and prominently wrinkled. Epidermis is quite thickwalled and the outer cell-walls show several and very distinct longitudinal ridges; stomata and clavate hairs were observed. Two to three layers of collenchyma in isolated groups are located beneath the epidermis. The cortical parenchyma is thinwalled and very open from wide intercellular spaces; it contains a little chlorophyll and passes gradually over into the central pith, the cells of which are much larger. Two concentric bands of mestome-bundles traverse this internode, there being eighteen peripheral and about five near the center. The peripheral are located in the cortex in the same radius as the groups of collenchyma, though separated from these by the cortex, and several of these are almost leptocentric, since the leptome is more or less surrounded by the vessels; no stereome was observed. The innermost mestome-strands are all collateral and somewhat larger than the peripheral; they are located in the pith, which is thinwalled and which contains no deposits of starch.

THE STEM ABOVE GROUND.

The basal internodes show exactly the same structure as the sixth internode of the rhizome, described above. If we, on the other hand, examine the upper portion of the stem near the inflorescence we notice some slight modification in structure, which principally depends upon the number of the mestome-bundles. These are present in a smaller number, only nine peripheral and seven near the center; they constitute two bands, which are not quite concentric, but the mestome shows the same position as described above, the leptome being almost surrounded by the hadrome in the peripheral as well as in the central strands. The upper internodes are cylindric, glabrous, and smooth, but exhibit otherwise the same structure as the basal in regard to cuticle, epidermis, collenchyma, cortex, and pith. No stereome was observed, and the cortical parenchyma did not show the innermost stratum differentiated as an endodermis.

THE LEAVES.

The green leaves are very narrow, with a broad but shallow groove on the upper face. The cuticle is thin and wrinkled. Epidermis, viewed en face, consists of rectangular cells and has no hairs or stomata on the upper face of the blade. On the lower face of the leaf-blade epidermis shows the same structure outside the collenchyma, but not where it covers the chlorenchyma. Because we notice here that the cells are more quadratic; besides that stomata and hairs occur in abundance. The stomata have two subsidiary cells parallel with the stoma and are level with epidermis; the air-chamber is shallow, but wide. Hairs of two kinds were observed—short, clavate and long, straight, sharply pointed, four-celled; these hairs, especially the clavate, cover the lower surface of the blade, especially underneath the chlorenchyma.

A transverse section of the blade shows that the cells of epidermis are much smaller on the dorsal face than on the ventral, besides that the outer cell-walls are moderately thickened. Beneath the entire ventral epidermis is a large water-storage tissue, which only consists of two layers, but of which the cells are very large and thinwalled. The ventral face of the blade is thus occupied by a large-celled epidermis and a hypodermal water-storage tissue, which reminds very much of some bulliform cells of certain *Gramineæ*, *Cyperaceæ*, etc.

The chlorenchyma represents an almost homogeneous tissue of somewhat oblong or roundish cells (in transverse sections) and with wide intercellular spaces. It is developed as a very open pneumatic tissue underneath the water-storage tissue on the ventral face, but near the margins where this tissue ceases a few palisade cells were observed. On the dorsal face of the blade the chlorenchyma is more compact, and some of the cells show actually the shape of true palisades, vertical on the leaf-surface. Near the mestome-bundles the chlorenchyma shows also here and there some palisades, but we can not say that a typical palisade-tissue was developed in any parts of the leaf-blade.

The mestome-bundles are arranged in one plane and are supported by a few cells of hypodermal collenchyma on the leptome-side. The mestome-strands are thus embedded in the chlorenchyma, and are surrounded by a colorless, thinwalled parenchyma-sheath. The midvein is larger than the others and is not projecting. There are fourteen mestome-bundles in the blade, seven large and seven much smaller, arranged very regularly in alternation with each other; the leptome is rather small in comparison with the hadrome, which contains about five scalariform vessels and a large lacune with an annular.

Toward the apex of the blade the margins become involute, forming an almost closed channel on the ventral face.

THE FORE-LEAVES.

A fore-leaf of a young, vegetative shoot from near the base of a flower-bearing stem is tubular, membranaceous, and hyaline. The cuticle is thin, but wrinkled (Pl. VII, fig. 44); epidermis is thinwalled and glabrous; it constitutes the only tissue between the two ribs and has but a few stomata. The chlorenchyma is very poorly developed as an open tissue, almost destitute of chlorophyll, and is only to be observed around the mestome-strands, which form two prominent keels, one on each side of the tube. The leptome and hadrome are quite well differentiated and surrounded by a colorless parenchyma-sheath, but without any support of mechanical tissue such as collenchyma or stereome. The fore-leaf has thus two projecting ribs, of which the one is somewhat more conspicuous than the other, since it contains a small mestome-strand besides the larger one; the leaf is, therefore, actually three-nerved instead of two-nerved, the latter being, however, the most common case among the Monocotyledones.

Tradescantia Virginica L.

THE RHIZOME.

The minor structure of the rhizome has been very carefully described and figured by Gravis (l. c.), who studied the development of the stem from seedling to matured plant. When cultivated in gardens our species grows in dense tufts and the rhizome is thus very densely matted.

But in its natural surroundings, in woods or among rocks on the river-shores, the plant does not show such profuse development of shoots, and the rhizome is consequently much less branched. However, the principal features of the structure are identical, and the following characteristics may be mentioned: The rhizome is at first creeping, and during the life of the plant some of the shoots develop in this manner with horizontal internodes, while the majority of the buds underground develop immediately into ascending shoots. The internodes of the rhizome are usually short and densely covered with membranaceous. sheathing leaves like the base of the aërial stem. All these leaves subtend axillary buds, and the biseriate arrangement of the leaves is readily recognized by the very regular position of the buds upon the rhizome in two rows. The root-system is represented by numerous fleshy though rather slender roots, which develop from all sides of the nodes.

THE INTERNAL STRUCTURE OF THE VEGETATIVE ORGANS.

THE ROOTS.

The secondary roots are quite long, rather slender and sparingly branched; their color is dark brown, and their surface shows a very pronounced wrinkling. They represent a combination of contractile- and storage-roots. Lateral roots occur, but these are mostly filiform and of short duration.

In the secondary roots the epidermis is thinwalled and hairy; it becomes suberized at an early stage and covers the old roots as a stratum of partly collapsed cells. Inside the epidermis is an exodermis of a single layer, the cells of which are thinwalled and in which the radial walls are very prominently folded (Pl. VII, fig. 43). The cortical parenchyma consists of many strata of thinwalled cells with distinct intercellular spaces and sometimes with lacunes near the periphery; deposits of starch and cells with raphides were observed in the cortex. A thinwalled endodermis with the Casparyan spots plainly visible surrounds the central cylinder. The pericambium, which is thinwalled, was found to be continuous in all the secondary roots examined. The hadrome forms about ten rays, of which the innermost vessels are reticulated and very wide, surrounding a central group of thinwalled conjunctive tissue. The leptome is well developed and shows the proto-leptome cell very plainly.

A similar structure was noticed in the lateral roots, but only in some of these was the exodermis observed. We might also mention that the center of these roots was constantly occupied by a wide reticulated vessel and that the pericambium was interrupted by some of the proto-hadrome vessels. These interruptions appeared, however, as being very irregular; in lateral roots of first order one proto-hadrome vessel out of six rays had broken through, while in lateral roots of second order two vessels out of four rays were bordering on endodermis.

THE STEM ABOVE GROUND.

The basal internode is smooth and glabrous. A thin, smooth cuticle covers the epidermis, of which the outer and partly also the radial cellwalls are somewhat thickened. About four strata of thickwalled collenchyma separate epidermis from the cortex, which constitutes about six quite compact layers, filled with chlorophyll and some raphides. Inside the cortex is a closed sheath of stereome in one to two layers, which surround the mestome-bundles. These are arranged in three almost concentric bands; those of the peripheral band border directly with their leptome on the stereome. They are often approximately perihadromatic, due to anastomoses, and the hadrome contains several wide reticulated, some narrower scalariform, besides an annular vessel in a lacune. The mestome-bundles of the innermost two bands are not so numerous as the peripheral; they are mostly collateral and are very conspicuous by containing large lacunes with remnants of annular vessels. "Thyllen" were frequently observed in these vessels.

The mestome-strands are thus located in the pith, and none of these were surrounded by parenchyma- or by mestome-sheaths. The pith is thinwalled, and shows very distinct intercellular spaces; cells containing raphides were observed in the pith, but no starch.

The third internode above the basal bears a green leaf with an axillary, small inflorescence. The structure of the cuticle, epidermis, and collenchyma is as described above, but the cortex is more open. The stereome surrounds here four concentric bands of mestome-bundles, which are mostly regularly collateral.

The upper internodes are hairy from two-celled hairs, of which the apical cell is very long and pointed, straight or slightly curved, but not hooked as we noticed in *Commelina*. Stomata abound, and are located in longitudinal rows. They have one pair of subsidiary cells parallel with the stoma. Otherwise the epidermis shows the same structure as in the lower internodes. The cortex is very open and borders outward on a collenchymatic tissue, inward on a sheath of stereome. The mestome-bundles are also here arranged in four almost concentric bands, but are mostly perihadromatic. The pith is thinwalled and not broken.

THE FLOWERING PEDUNCLE.

The stem-structure is readily recognized in the peduncle, since the tissues are arranged in the same manner, but developed somewhat differently. Epidermis is much more hairy from very long, pointed hairs, mixed with some glandular. The collenchyma and stereome are both quite thinwalled, and the mestome-bundles occur here in only two concentric bands, of which the peripheral are more or less fused together, two and two.

THE STEM-LEAVES.

The green leaves are smooth and glabrous on the ventral, but hairy on the dorsal face. Viewed en face the radial cell-walls of epidermis are straight, not undulate; the hairs are short and pointed. Stomata occur on both faces of the blade, but are most numerous on the dorsal. They are surrounded by four cells, of which the one pair is parallel with the stoma. The guard-cells are mostly raised a little above the surrounding epidermis. Viewed in cross-sections the cells of epidermis are quite large on both faces, especially on the ventral, where it covers three to four strata of colorless thinwalled cells above the midrib. Similar but smaller groups of colorless cells were, furthermore, noticed between the other veins, but only on the ventral face. A collenchymatic tissue of two or three strata is developed below the midrib and the stronger veins, but is entirely absent from the ventral portion of the leaf-blade.

The mesophyll represents an almost homogeneous tissue of irregular cells with wide intercellular spaces. Some few palisade cells were observed, however, on the ventral face, but only in the lateral parts of the blade, and without forming a distinct tissue. Cells with raphides abound in the mesophyll, especially near epidermis.

The mestome-strands possess a thinwalled parenchyma-sheath, which does not contain chlorophyll, and is therefore readily distinguished from the surrounding cells of the mesophyll. The midvein is barely larger than the others, but is prominent by its larger support of collenchyma. The leptome and hadrome are well developed, and show the usual structure, the mestome-bundles being all collateral.

Tradescantia scopulorum Rose.

The Ramification of the Shoot.

The rhizome is very short and bears many slender, but somewhat fleshy roots, which are almost unbranched; it resembles that of *T. Virginica*. The aërial stems are erect and branched from near the base. These lateral branches begin, as usually, with an addorsed fore-leaf, the shape of which is quite characteristic: it is membranaceous and consists of a tubular sheath and a very distinct blade, reaching until 15 milimeters in length. This fore-leaf is thus only partly covered by the sheath of the stem-leaf, which supports the lateral branch. The other leaves of the branches are green and alternate with the fore-leaf, showing the same position as described above under *Tradescantia rosea*. It appears as if the branches become terminated by inflorescences, but these are usually not so rich-flowered as the one that terminates the main shoot.

The Internal Structure of the Vegetative Organs.

THE ROOTS.

The secondary roots show the structure as follows: The epidermis is hairy and covers an exodermis of large cells with the walls thin and distinctly folded. The cortex is differentiated into three zones, a peripheral which consists of about four strata of relatively small cells, an inner of about ten layers of large cells filled with starch, and finally an endodermis. The endodermis is thinwalled, showing the Casparyan spots very plainly; it did not contain starch. The pericambium is thinwalled and continuous. The hadrome forms eight short rays, in which the protohadrome vessels were observed to be mostly single or sometimes two arranged side by side. Broad groups of leptome alternate with the hadromatic rays, and a few strata of thinwalled conjunctive tissue surround the two central, reticulated and very wide vessels.

THE STEM ABOVE GROUND.

The internodes from the middle of the stem are cylindric, furrowed, and hairy. The hairs are of the same kind as observed in *T. Virginica*, long and pointed or short and clavate. Epidermis is moderately thickened and covered by a thin, smooth cuticle. A thickwalled collenchyma of about six layers, but in isolated groups, separate the epidermis from the cortical parenchyma. The cortex is very thinwalled and consists of only four or five layers; it contained chlorophyll. Inside the cortex is a closed sheath of stereome in one or two layers, but the cells are rather thinwalled. Three almost concentric bands of mestome-bundles traverse the inner part of the stem; the peripheral border directly on the stereome with their leptome, while the two inner bands are located in the pith.

THE STEM-LEAVES.

The blade is glabrous and smooth, with a thin, but distinct cuticle. Epidermis consists of large cells on both faces of the blade, and the outer cell-walls are slightly thickened on the dorsal; stomata occur on both faces and the subsidiary cells are raised above the surrounding epidermis. Prominent groups of thickwalled collenchyma cover the leptome-side of the larger mestome-bundles; besides that an isolated group of this tissue occupies the outermost portion of the leaf-margin. The chlorenchyma is poorly developed, and consists only of a few layers of roundish cells. The mestome-strands possess a thinwalled parenchyma-sheath, and show the same structure as observed in *T. Virginica.*

Tradescantia sp.—While the specimens of *T. scopulorum*, described above, were collected in the mountains of Arizona, there is still another western member of the genus which inhabits the alkaline plains of Colorado. This *Tradescantia* is by Mr. Rose included in his *scopulorum*, but it appears to be distinct from this. It is a much coarser plant, with larger flowers and broader leaves; the fore-leaves are destitute of blades, and the broad calyx-leaves and peduncles are very hairy. The anatomical structure is somewhat different and may be described as follows:

THE ROOTS.

The secondary roots are fleshy, but slender and ramify but sparingly. Epidermis is thinwalled and very hairy; it covers an exodermis of large, pentagonal cells, the walls of which are thin and prominently folded. The cortex consists of twelve compact layers of thinwalled parenchyma, filled with starch. Endodermis and the pericambium are thinwalled, continuous. There are six short, hadromatic rays alternating with six broad groups of leptome; the protohadrome-vessels are very narrow, and are present in the number of two or three situated side by side. The conjunctive tissue is thinwalled, and does not extend to the center of the root, which is occupied by three wide, reticulated vessels.

THE STEM ABOVE GROUND.

The stem is cylindric, deeply furrowed. The smooth cuticle covers a very thickwalled epidermis with stomata, but without hairs. A very thickwalled collenchyma occurs as isolated groups beneath the epidermis and borders on a narrow zone of thinwalled cortical parenchyma. A closed ring of rather thinwalled stereome surrounds the central cylinder in which the mestome-bundles are arranged in a few bands of the same structure as described above. The pith is thinwalled and does not contain starch.

THE STEM-LEAVES.

The ventral face of the blade is smooth and glabrous, while the dorsal is distinctly furrowed. Stomata with one pair of subsidiary cells occur on both faces; they are level with epidermis, but the subsidiary cells were observed to be somewhat raised on the ventral face. The cuticle is smooth and very distinct. Epidermis consists of large cells on both faces, and the outer walls are quite thick on the dorsal, but thin on the ventral face. Two or three strata of colorless cells (water-storage tissue) are located beneath the entire ventral epidermis. A few, one or two, layers of thickwalled collenchyma were observed on the leptome-side of the larger veins, but separated from these by small groups of water-storage tissue; no collenchyma or stereome was observed on the ventral face of the blade, but a few layers of the former occupy the margins. The chlorenchyma contains much chlorophyll and represents a homogeneous tissue of oblong cells, but of no palisades. A thinwalled colorless parenchyma-sheath surrounds the mestome-bundles in which the leptome and hadrome are well developed in the larger of these. No lacunes were observed in the leaf: thus the structure is quite compact throughout.

Tradescantia crassifolia CAVAN.

The species is perennial with erect or ascending villous stems, simple or branched. The leaves are oblong, acute, densely villous, and thick. There are about five sessile inflorescences, one terminal and four axillary, remote. The roots are fusiform, very thick, and develop from the basal nodes. Our specimens were dried, thus we were unable to examine the internal structure of the parts above ground, but we succeeded in preparing some of the roots so as to study their structure.

The roots are tuberous at the middle, but rather slender toward the base and apex. Epidermis is very hairy and covers an exodermis of a single layer of thinwalled cells; no foldings were observed. Inside the exodermis are five to six strata of stereïds, which are not very thickwalled and of which the cross-walls are barely oblique. These tissues show the same structure in the slender and tuberous portions of the root, but the cortex and the pith are somewhat different. The cortical parenchyma consists of ten layers in the tuberous portion; the cells are thinwalled with narrow intercellular spaces. The innermost four layers were filled with starch, bordering on a thinwalled endodermis. A thinwalled pericambium surrounds numerous very short rays of hadrome, alternating with broad groups of leptome; the position of the proto-hadrome vessels could not be ascertained. The pith occupies the larger part of the central cylinder, and consists of numerous compact strata of which the peripheral, two or three, are densely filled with starch.

If we now examine the slender portions of these roots, we notice the complete absence of starch in the cortex and in the pith; moreover the pith occupies here only a small portion of the central-cylinder, while the number of layers in the cortical parenchyma is the same, but the lumen of the cells much smaller. The roots of this species represent, thus, a combination of two types nutritive and storage roots.

Tradescantia pinetorum GREENE.

(*T. tuberosa* GREENE—NON ROXB.)

This species possesses a long, creeping rhizome with cylindrical, stretched internodes from 3 to 5 centimeters in length. There are roots, from one to three at each node, which are very thick and hairy; they vary from oblong to fusiform at the base and are terminated by a long, very slender apex with several lateral ramifications; the length of the tuberous portion is about 2 centimeters, the thickness about 1 centimeter. Besides these there are, furthermore, some that are filiform in their whole length. The leaves of the rhizome are membranaceous and buds were observed in the axils of these. The stem above ground is the direct continuation of the rhizome and all the internodes, even the basal, are stretched; it is erect and bears several leaves with narrowly linear, conduplicate blades. Vegetative shoots are sometimes developed in the axils of the lowest stem-leaves and there is usually only one terminal infloreseence unless the lateral shoots develop further and become flower-bearing. The arrangement of the leaves is the same as that described above as characteristic of the genus.

Tradescantia Floridana WATS.

THE RAMIFICATION OF THE SHOOT.

The species shows the habit of *Commelina nudiflora*: there is no rhizome, and the long, slender stem is creeping with the lateral branches erect or ascending; the stem-leaves are sessile with short sheaths and ovate blades. The lateral branches bear a short, membranaceous and tubular fore-leaf at the base and it seems characteristic of this species that the lateral shoots, although strictly axillary, break through the base of the sheath of the supporting leaf, thus the shoot with its fore-leaf becomes perfectly free. The other leaves of the shoots show the same shape as the supporting leaf, but it was frequently observed, however, that the first leaf above the prophyllon was merely developed as a sheath with a minute, rudimentary blade. In regard to the diagram of the axillary shoot, we noticed exactly the same position of the leaves as described under *Commelina*. The small inflorescence is terminal, sometimes accompanied by a few lateral, developed in the axils of the uppermost leaves. The stems are rooting, one to two secondary roots being developed at each node.

THE INTERNAL STRUCTURE OF THE VEGETATIVE ORGANS.

THE ROOTS.

The secondary roots are very thin and ramify freely; they are very hairy and the thinwalled epidermis covers a large-celled exodermis, of which the outer cellwalls are slightly thickened; no foldings were observed, thus the root is not contractile. The cortex consists of three compact strata of thinwalled cells, and the endodermis is moderately thickened on the inner and radial walls. The pericambium is thinwalled and continuous. Six very short rays of hadrome alternate with six broad groups of leptome, while the center is occupied by two very wide, reticulated vessels. The conjunctive tissue is poorly represented and very thinwalled.

THE STEM.

Clavate hairs abound, and the outer cellwall of epidermis shows numerous longitudinal ridges, covered by the thin and smooth cuticle. A collenchymatic tissue was observed beneath the epidermis, but very poorly developed. The cortex constitutes a narrow zone of parenchyma, containing chlorophyll. No stereome was observed, thus the thinwalled endodermis surrounds the central-cylinder directly. Two bands of mestome-bundles traverse the stem, the peripheral bordering on endodermis, while the innermost are located in the thinwalled but solid pith.

THE STEM-LEAVES.

Viewed en face epidermis of both faces of the blade shows the same structure, viz: Polyëdric cells with the walls straight and very thin. Clavate hairs abound on the dorsal face together with the stomata, which possess two pairs of subsidiary cells parallel with the stoma; two-celled, sharply pointed hairs cover the margins, rendering these very scabrous. Viewed in transverse sections epidermis shows large cells on both faces, and the outer wall is extended into a number of minute, wartlike papillæ, covered by a thin and smooth cuticle; these papillæ occur, however, only on the ventral face of the blade. No collenchyma and no stereome was observed, and the chlorenchyma represents a homogeneous tissue of mostly roundish cells, filled with chlorophyll and raphides. The veins are very fine and possess no mechanical support.

Tradescantia micrantha TORR.

The stems are weak, decumbent, and often rooting at the nodes. The small, ovate leaves are alternate, and the species reminds very much of the former, *T. Floridana*, in respect to its habit. The roots, about five at each node, are very thin and show several minute ramifications; they are not confined to the one face of the nodes, but develop all around these. The stems are profusely branched, and the axillary branches begin with a fore-leaf, which is membranaceous, very short, tubular, and truncate. In regard to the axillary buds, these do not break through the sheath of the supporting leaf, and the diagram of the shoot with its leaves and inflorescence corresponds with that of *Tradescantia rosea*, as described in the preceding.

In some of the specimens which we have examined the lateral branches bore a number of leaves, developed as mere sheaths with minute blades, as if they were subterranean.

Tradescantia Warszewicziana KUNTH ET BOUCHÉ.

This remarkable *Tradescantia* is figured in Curtis's Botanical Magazine,[a] and one of the figures shows an entire plant with "the stem stout, forked, terete, having a subarborescent character, and marked with the scars of fallen leaves. The branches are leafy, chiefly toward the apex." The peduncle is figured and described as "axillary, 1 to 1½ feet long, terete, purplish above, forming a not very copiously branched panicle of purple-lilac densely crowded but small flowers." The habit of the plant, considering the stem and the foliage, is thus much more like that of an *Aloe* or a *Dracæna* than of a *Tradescantia*. The internodes of the stem are exceedingly short, and the leaves are crowded. The relatively short and compact inflorescence is borne upon a long, naked scape, which is axillary. The bracts that subtend the inflorescential branches are very short and broad. In regard to the flowers, the sepals and petals are uniform and purplish, the latter the largest; the stamens are all uniform and beardless. In spite of these very pronounced habital characters the species is by Clarke placed in his section: *Eutradescantia;* we do not consider this classification a natural one, for even if the floral characters may be identical, to some extent, the habit of the plant in connection with certain points in its anatomical structure make us believe that the species really represents a section of its own.

With Planchon our species was a *Dichorisandra;* with Hasskarl a *Spironema* (fide Clarke l. c.).

THE INTERNAL STRUCTURE OF THE VEGETATIVE ORGANS.

THE ROOTS.

Numerous long, whitish and somewhat fleshy secondary roots are developed from the nodes, and they are amply ramified. Their structure is as follows:

The epidermis is very hairy, and there is an exodermis of one layer of pentagonal cells with the outer walls moderately thickened, and with the radial walls very distinctly folded. Cortex consists of about ten layers of thinwalled cells arranged radially toward endodermis. No starch or raphides were observed. The endodermis is thickwalled in the manner of an U-endodermis and is very porous. A thinwalled, continuous pericambium surrounds sixteen short rays of hadrome with some narrow (spiral) and a few wider (reticulated) vessels; the proto-hadrome-vessels were noticed to be single in each ray. The leptome is well developed and represents round groups in transverse sections, with the proto-leptome cell plainly visible. The center of the root is occupied by a narrow group of thickwalled conjunctive tissue.

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[a] Vol. 16, Tab. 5188.

THE STEM.

The stout stem, which bears the rosette of leaves, is cylindrical. In the older internodes several strata of cork have replaced the epidermis, while in the younger portions the epidermis is still preserved and consists of thinwalled cells. From epidermis to the center of the internode a large parenchyma is developed of very uniform structure, and not interrupted by any sheaths of collenchyma, endodermis or stereome. In other words the peripheral cortex passes insensibly over into the central pith. Both tissues are thinwalled and contain raphides and deposits of starch, but in some of the outermost strata of the cortex (in younger internodes) chlorophyll was, also, observed. The outer mestome-bundles are arranged in several peripheral and concentric bands, while the inner ones, the most numerous, are scattered among each other in no order. A thinwalled parenchyma-sheath is developed around each mestome-bundle, but otherwise their structure is somewhat different. The peripheral bands are of more or less typical, collateral structure, while the inner ones are very variable, representing several transitions from almost collateral to strictly lepto-centric, with a number of wide, reticulated vessels inclosing the leptome completely. The structure of the older internodes, which we have thus examined reminds more of that of a rhizome than of a stem above-ground; we mention this, because Mr. Maxon, who collected the specimens and who found the plant in great abundance, did not notice any such large stem-portion above ground as figured in Curtis's Botanical Magazine (l. c.). The stems were in accordance with his observations mostly subterranean, and the leaves of the rosette were not recurved, but ascending to almost erect.

THE SCAPE.

The long internode that bears the inflorescence is cylindric and almost glabrous. A thin but distinct cuticle covers the epidermis, consisting of long rectangular cells when viewed en face. Stomata with one pair of subsidiary cells parallel with the stoma are arranged in longitudinal rows alternating with strata in which clavate hairs and short, roundish papillæ occur. In cross-sections the cells of epidermis show a prominent thickening of the outer walls. Underneath epidermis are many broad groups of thickwalled collenchyma. The cortex contains much chlorophyll, but occupies only a small portion of the scape; it extends to the epidermis between the collenchymatic strands. A sheath of very thinwalled stereome surrounds the central cylinder and borders directly on the innermost strata of the cortical parenchyma; it consists of about four layers and separates the cortex from the pith. The mestome-bundles constitute one peripheral band of about thirty-five, and several inside these, but apparently scattered. The peripheral are approximately V-shaped and contain several wide reticulated vessels and a lacune with the remnants of a ring-vessel; besides being surrounded by the stereomatic sheath, as mentioned above, they have, furthermore, a few layers of more thickwalled stereome on the leptome-side. The central mestome-bundles did not show any mechanical support; they traverse the pith, which is compact but very thinwalled.

THE LEAVES.

The green leaves have a broad lanceolate and acuminate blade and a short sheath; their length averages about 15 centimeters, their width about 4 centimeters. Epidermis of the dorsal face shows a very characteristic structure. Viewed en face the outer wall of many of the cells shows a number of minute roundish warts (Pl. VIII, fig. 48) covered by a thin, perfectly smooth cuticle; the shape of the cells is hexagonal with straight radial walls. Stomata abound on this face of the blade (the dorsal); they have one pair of subsidiary cells parallel with the stoma, and one pair vertical on this, thus the stoma is surrounded by four cells, all containing chlorophyll. Hairs are frequent; they are composed of three cells, of which the apical is quite long and obtuse. Besides these obtuse hairs, some others with the apical cell sharply pointed and curved occur along the leaf-margins, rendering these very scabrous. The ventral epidermis shows the same structure of the cells, but no stomata or hairs were observed here.

A transverse section of the blade shows the following structure: Epidermis consists of rather low cells on both faces (fig. 47), and the thickening of the outer walls is very distinct in some of the cells; the stomata are level with epidermis, and the air-chamber is wide, but shallow. Underneath the ventral epidermis is a large water-storage-tissue, which occupies the entire upper face of the blade without being interrupted by the chlorenchyma or by any strands of mechanical tissue. It reaches its highest development above the middle portion of the blade and decreases in thickness toward the margins. This water-storage-tissue consists of three layers of cells that are much larger than those of epidermis; the innermost layer is the thickest on account of the greater height of the cells. When exposed to a dry atmosphere the cells of this tissue shrink rapidly by foldings of the radial cell-walls. A like tissue, but of smaller dimensions, occurs also beneath the dorsal epidermis. The chlorenchyma is differentiated into one to two layers of short palisades on the ventral face and a larger pneumatic tissue on the dorsal. The palisades are best developed near the margins of the blade where the water-storage-tissue is not so thick. The cells of the pneumatic tissue are somewhat irregular, more or less star-shaped, and they contain much chlorophyll. Cells with raphides were observed inside the ventral water-storage-tissue and above the palisades. While the chlorenchyma on the ventral face of the blade is completely separated from epidermis by the continuous strata of water-storage-tissue, it does reach the dorsal epidermis by narrow rays, which thus interrupt the colorless-tissue, but only here and there between the veins. The mechanical tissue is weakly developed as an isolated strand of stereome in each margin and as a few layers on the leptome-side of the veins. No collenchyma was observed. The mestome-bundles are collateral and very small; they possess a thinwalled parenchyma-sheath, a small group of leptome, and a few vessels.

Weldenia candida Schult. fil.

The first description and illustration of this remarkable plant was published in Flora (January, 1829), by J. H. Schultes, jr., who received a specimen from Mexico collected by v. Karbinsky. The genus is dedicated to Baron v. Welden, an Austrian botanist. Ten years later the plant was described by Bentham[a] as a new genus *Lampra volcanica*, and his material came from Volcan de Agua, at an elevation of about 14.000 feet, in Guatemala. Since then the plant has been collected in a few other places, in Sierra de las Cruces and Ojo Caliente, Zacatecas, both in Mexico. It is fairly well illustrated by Sir Joseph Hooker,[b] but the drawing, which was based upon dried material, does not show the petals correctly. The petals are not spreading, but almost erect in accordance with a photograph taken by Macgraw Coxe, United States minister to Guatemala and Honduras (1897).

The Ramification of the Shoot.

The plant is a perennial herb provided with a dense cluster of fusiform roots developed from the basal nodes of the shoot. The shoot is single, judging from the material that has been examined, and consists of a few short or sometimes more or less stretched internodes which bear membranaceous sheathing leaves without blades. Two buds, one larger and one smaller, and both evidently dormant, are generally found at the base of the flowering shoot; these buds are situated somewhat lower than the flowering shoot, and they belong to basal leaves of the shoot of the previous year. If we now examine the structure of the flowering shoot of this season we notice (Pl. VIII, fig. 49) five membranaceous leaves alternating with each other (l^1–l^5); the internodes, especially the basal, are very short, while the upper ones (between l^3 and l^5) are longer, from two to five cm. in length. Three axillary buds are developed, and these belong to l^1, l^2, and l^3; it appears as if the bud in the axil of l^3 is the one that will develop into a floral shoot during the succeeding year, and that the two others correspond with the two dormant ones at the base of the shoot of last year's growth. The other leaves of the flowering shoot form a rosette

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[a] Plantæ Hartwegianæ. London. 1839.

[b] Icones plantarum. Ser. 3, vol. 3, 1877–1879, p. 28, tab. 1236.

and are provided with green blades, but only the first one of these, L[1], alternates with the membranaceous: the four succeeding are turned 90° to the side (L[2]–L[5]), and we noticed, furthermore, that the two outermost (L[2] and L[3]) were united at the base, forming a closed sheath around the inner ones. While thus the leaves described above are arranged alternately, but in two planes, the succeeding (6–13) represent a spiral and surround the terminal inflorescence. The numerous flowers are almost sessile and are destitute of bracts and fore-leaves; the central is the first one to bloom, and judging from the rudimentary stage of the peripheral flower-buds the time of flowering must extend to several months with only a few (two ?) flowers developed at the same time.

While thus the subterranean stem-portion of *Weldenia* often possesses a few stretched internodes, the aërial shoot is merely represented by a dense rosette of green leaves surrounding the sessile many-flowered inflorescence, which is of the centrifugal type.

THE INTERNAL STRUCTURE OF THE VEGETATIVE ORGANS.

THE ROOTS.

Most of the roots are thick and fusiform, but some few thin and cylindric ones were also observed. These slender roots were developed at the base of the dormant buds, and they show the structure as follows: The thinwalled and hairy epidermis covers an exodermis of two layers, of which the cellwalls are not contractile. The cortex consists of ten layers; the cells are very thinwalled and are arranged radially toward the endodermis. Deposits of starch were observed in the innermost strata of the cortical parenchyma. Endodermis is thinwalled and shows the Casparyan spots very plainly. The pericambium is thinwalled and continuous; it surrounds nine broad groups of leptome alternating with nine very short rays of hadrome, which consist of one or, seldom, two spiral proto-hadrome vessels and a single, wide, scalariform inside. A thinwalled pith without starch occupies the greater part of the central cylinder. No raphides or crystals were observed.

The fusiform roots consist of a short, slender base, a long tuberous portion, that averages from 4 to 7 centimeters in length and 6 to 10 millimeters in thickness, and finally of a long, slender apex.

The slender, basal portion of these fusiform roots is hairy and the exodermis is contractile. The cortical parenchyma is composed of numerous layers, but only the three innermost are preserved and contain starch; the others are collapsed. Endodermis is thinwalled and shows prominent tangential foldings; the pericambium is also thinwalled and continuous. In regard to the leptome and hadrome we noticed the same structure as described above, but the number of rays is larger, there being 21, alternating with a corresponding number of leptomatic strands. The thinwalled pith represents a broad parenchyma containing starch.

In passing to describe the swollen portion of these same roots, we might state at once that the structure in general is identical with that of the slender base; the larger dimensions depend merely upon a larger size of the cells in the cortical parenchyma and in the pith, while the number of strata is the same. The cortex is, moreover, solid in this portion of the root, and not collapsed. In the slender apical portion of these same roots the structure is almost the same. However the exodermis showed no foldings of the cell-walls; the cortex consisted of only 12 layers filled with starch; the number of hadromatic rays was only 12, and the pith represented a smaller parenchyma.

In regard to the proto-leptome cells the accompanying drawings (Pl. VIII, figs. 50 and 51) illustrate two cases from the swollen portion of these roots. The leptomatic groups are sometimes very broad, and in such cases it appears as if two proto-leptome cells were developed instead of but one, when the groups are narrower.

THE RHIZOME.

One of the basal stretched internodes shows the following structure. It is cylindric, with a shallow and narrow groove on the one side. The cuticle is thin and smooth, and covers a thinwalled epidermis of small cells; viewed en face the cells are narrow and rectangular. A few stomata, but no hairs, were observed. Cortex consists of ten strata of thinwalled cells, with narrow intercellular spaces; no starch, but raphides and very little chlorophyll, was observed. The cortex is not separated from the broad central mass of parenchyma by any sheath of stereome or by any stratum that might be distinguished as an endodermis. Nevertheless we did notice one or sometimes two layers of cells that were more closely connected with each other than those of the cortex, and these bordered on the leptome-side of the peripheral mestome-bundles. Examined in longitudinal sections these cells did not differ from those of the adjoining parenchyma, nor did they resist concentrated sulphuric acid any better.

The peripheral mestome-bundles (twenty-five) are arranged in a circle. They are relatively small and almost orbicular in transverse sections; they are collateral and contain only a few vessels and a small group of leptome. Besides these regularly arranged peripheral mestome-strands we find in the central portion of the pith about forty others, which are apparently scattered and not arranged in any order. These mestome-bundles are larger, since they possess more leptome and much wider vessels, but they are all collateral like the others. The pith is thinwalled, quite solid, and contains many raphides, but no deposits of starch.

Characteristic of the stem of *Weldenia* is the absence of collenchyma and stereome. We must remember, however, that the stem is subterranean and of relatively short duration.

THE GREEN LEAVES.

The lanceolate blades are quite thick and smooth. Viewed en face the ventral epidermis consists of very regular hexagonal cells, some of which are developed into four-celled hairs with the apical cell very long and obtuse. (Pl. VIII, fig. 52.) On the dorsal face the cells show the same shape, but are much shorter in the stomatiferous strata than between these. The stomata (Pl. VIII, fig. 53) are arranged in longitudinal rows parallel with the longitudinal axis of the blade; they have one pair of subsidiary cells and are slightly raised above the surrounding epidermal cells; the air-chamber is broad and deep. Between the stomatiferous strata are longitudinal rows of hairs of the same type as described above, but these are very numerous on this face of the blade, the dorsal, and they are often developed in small tufts of four or five together. These hairs occur, furthermore, along the margins of the blade. Viewed in transverse sections the epidermis-cells are thinwalled and rather small on both faces; the cuticle is thin and smooth. Underneath the ventral epidermis is a large tissue of colorless, thinwalled cells in about five strata above the middle portion of the blade, but of only one near the margins. This tissue, composed of large cells, represents a water-storage-tissue and is distributed over the entire ventral face of the blade, but decreases in thickness toward the apex and the margins. A much narrower portion of the leaf-blade is occupied by the chlorenchyma. This consists of two layers of short palisades which border on the water-storage tissue and of a pneumatic tissue of star-shaped cells with broad intercellular spaces. The latter tissue is thus located near the dorsal epidermis, from which it is separated by groups of collenchyma which support the larger veins, while it borders directly on the epidermis between these. The collenchyma is very thickwalled and is confined to the leptome side of the mestome bundles. No stereome was observed. Cells with raphides abound in the chlorenchyma.

There are ten almost parallel veins which traverse the chlorenchyma from the base of the blade to the apex; they are connected with each other by numerous fine anastomoses. The larger veins are collateral, with the leptome and hadrome well developed and surrounded by a thinwalled, colorless parenchyma-sheath, but they have no mestome-sheath and no thickwalled mestome-parenchyma. The anastomoses are much smaller and orbicular in transverse sections.

If we examine the small leaves that surround the inflorescence, we find the same structure as described in the preceding, but the blade is thinner on account of the lesser development of the water-storage tissue.

THE MEMBRANACEOUS LEAVES.

These leaves have a tubular sheath and a minute free blade, and they cover the subterranean internodes of the stem. They are perfectly glabrous and smooth, and contain no chlorophyll. The epidermis is very thinwalled and consists of large cells on both faces, somewhat higher on the dorsal than on the ventral face. A few layers of a homogeneous chlorenchyma surround the veins, but between these the leaf consists only of the two epidermes. No collenchyma or stereome was observed, and the mestome-strands are very thin, but surrounded by a parenchyma sheath. In regard to the structure of the mestome-bundles we noticed that the hadrome was better represented than the leptome.

SUMMARY.

These species of *Commelinaceæ*, which we have described in the foregoing pages, thus represent different types of biological interest: *Commelina nudiflora*, *Tinantia*, and *Aneilema* are annual: all the others are perennial. Among the latter are some of which the habit resembles that of the annual species, but which, nevertheless, are able to persist throughout the winter-months, at least in the southern parts of this continent: *Tradescantia Floridana* and *micrantha;* these may be designated as photophilous, their vegetative propagation being secured by axillary buds developed wholly above ground. The other perennials (except *Trad. Warszewicziana*) are scotophilous,[a] in which the herbaceous stems die to the surface of the soil each year, and in which the vegetative propagation takes place by means of buds developed upon rhizomes. In regard to *Tradescantia Warszewicziana*, we feel uncertain about its manner of growth, even if we did observe that the stem bears some buds underground.

If we now examine and compare the external structure of the rhizomes and the roots with that of the foliage, we do not notice any definite correlation between these. In our species of *Commelina* the foliage is the same whether the species are annual or perennial, and whether the rhizomes are horizontally creeping with slender roots (*C. hirtella*) or very short and provided with fleshy, thick roots (*C. Virginica*, etc.). In the genus *Tradescantia* we meet with species of which the leaves are long and narrow and of which the rhizomes are either creeping and bearing tuberous roots (*T. pinetorum*) or very compact, with tuberous (*T. crassifolia*) or more slender roots (*T. Virginica*, *scopulorum*). In *Weldenia* and *T. Warszewicziana* the leaves are fleshy and arranged in a rosette; in the former the roots are thick and fusiform, in the latter they are slender and much branched. In some of the other *Tradescantiæ* the habit becomes more like that of *Commelina*, especially in *T. Floridana* and *micrantha*, with their short and broad leaves and decumbent stems, or with the stems more ascending or erect as in *T. commelinoides* R. ET S., *pulchella* H. B. K., and *disgrega* KUNTH. The position of the leaves, as shown in the diagrams, and the axillary shoots perforating the leaf-sheaths are also characteristic of certain members of the family.

While thus several variations exist in regard to the development of the foliage, stems, and roots, we shall now extend the comparison to the structural peculiarities possessed by the same organs as represented by these species.

THE ROOTS.

Simply nutritive roots were observed in *Commelina nudiflora*, *Tinantia*, *Aneilema*, and *Tradescantia Floridana;* the slender roots of *Weldenia* belong to this same category. Nutritive and at the same time contractile are characteristic of *T. Warszewicziana* and *C. hirtella*. Nutritive and at the same time storage-roots were found in *Tradescantia crassifolia*. In the remaining species the roots showed a combination of contractile- and storage-roots. An exodermis was observed in all the species, and it consists of two layers in *Weldenia*. Stereïds occur in *Commelina nudiflora*, *Virginica*, *Tradescantia Floridana* and *crassifolia;* they attain the highest development in the last species. The cortical parenchyma is partly collapsed in

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[a] Goebel, K., Organographie der Pflanzen, Jena, 1900, p. 645.

Aneilema, but not so in the others. Endodermis was observed to be more or less thickwalled in *Commelina nudiflora*, *Tradescantia Floridana*, *rosea*, and *Warszewicziana*, but thinwalled in the others. The pericambium is represented by a single layer and is thinwalled in all the species; it was found to be interrupted by the proto-hadrome in *Commelina nudiflora*, *Virginica*, and *Tradescantia rosea*. The number of hadromatic rays is, of course, very variable, and the largest number (twenty-one) was observed in *Weldenia*. In this same genus the pith is very well developed and occupies the greater portion of the central-cylinder. In the other species the pith is generally very little developed.

THE RHIZOMES.

In *Tradescantia rosea* the cuticle is quite thick and wrinkled, but rather thin and smooth in the others. Hypodermal strands of collenchyma were observed in *Commelina hirtella*, but not in any of the others. The cortical parenchyma is moderately thickwalled in *Commelina Virginica* and *Tradescantia rosea;* an endodermis was only noticed in *Commelina hirtella*. A continuous sheath of stereome surrounds the peripheral mestome-bundles in *C. hirtella*, while in *T. rosea* this tissue occurs only as a few layers on the leptome-side. The mestome-bundles of the peripheral bands are collateral in contrast to some of those of the inner bands, which are very irregular and more or less leptocentric in *T. Warszewicziana*. The pith contains deposits of starch in *Commelina Virginica*, *hirtella* and in *T. Warszewicziana*, but not in the others; starch was, furthermore, observed in the cortex of the last species, in *C. Virginica* and *T. rosea*.

THE STEM ABOVE GROUND.

Several hypodermal strata of more or less thickwalled collenchyma was observed in all the species examined. The innermost layer of cortex is differentiated as an endodermis in the species of *Commelina* and *Tinantia*, also in *Tradescantia Floridana*, but not in the others. A closed sheath of stereome surrounds the mestome-bundles in the species of *Commelina*, *Tinantia*, and *Tradescantia*, with the exception of *T. Floridana* and *rosea*. In *Aneilema* the stereome occurs only as a few isolated strata on the leptome-side. The mestome-bundles are collateral and mostly arranged in several concentric bands. Deposits of starch were found in the pith of *C. Virginica* and *dianthifolia*.

THE GREEN LEAVES.

The leaves are dorsiventral in the species of *Commelina*, and in *Tradescantia Warszewicziana*, besides in *Weldenia;* they are almost dorsiventral in *T. Virginica*, but isolateral in *T. scopulorum*, *Floridana*, and in *Aneilema*. These dorsiventral leaves are held in a horizontal position.

In *T. Virginica* the chlorenchyma is imperfectly developed as palisades, and in the isolateral leaves the palisades are totally absent. The leaves of these *Tradescantiæ* are also held in an almost vertical position, except in *T. Floridana;* in this species we were unable to discover any trace of palisades, but our material, having been dried and pressed, was not quite suitable for this purpose, and it would seem somewhat strange if the leaves of this species, which are held in horizontal position, should really be isolateral instead of dorsiventral.

In regard to the palisade-tissue, we might state that the palisades observed in *T. rosea* were not typically developed. The pneumatic tissue attains its highest development in *Weldenia* and *T. Warszewicziana*, where it is composed of star-shaped cells, while in the others the shape is more irregular, but always with wide intercellular spaces.

The mechanical tissue is, to some extent, well represented in the leaves. Collenchymatic strands were thus observed above and below the midvein in *Commelina nudiflora*, *Virginica*, and *erecta*, or below this in *Aneilema;* or only on the leptome-side of the larger veins in *C. hirtella*, *dianthifolia*, *T. rosea*, *Virginica*, *scopulorum*, *Weldenia*, and *Tinantia;* or in the leaf margins, as in *C. dianthifolia*. Stereome was observed in *T. Warszewicziana* on the leptome-side and in the margins; on the leptome-side alone in *Aneilema* and *C. Virginica;* or on both faces of the veins in *C. dianthifolia*.

The water-storage-tissue reaches a high development in several of these plants. It is always hypodermal and covers the entire ventral face of the leaf in *Tradescantia Warszewicziana*, besides that it is very amply represented on the dorsal face, but interrupted here and there by narrow strata of chlorenchyma, inside the stomatiferous strata of the epidermis. In *T. rosea*, *Aneilema*, and *Weldenia* it is distributed over the entire ventral face of the blade. It occurs as a large group below the midvein in *C. nudiflora*; above the larger veins in *C. hirtella*; above and below the midvein in *C. erecta* and *Virginica*, or only above this; as in *T. Virginica*.

Finally, the epidermis, with its various kinds of projections, as warts, obtuse, pointed, or curved hairs, and the stomata do also show several modifications within the family. The number of subsidiary cells appears to be constant, at least in the leaves, and it deserves notice that *Tradescantia Floridana* is the only species of the genus in which two pairs of subsidiary cells were observed; all the *Commelinæ* have two pairs, while the *Tradescantiæ* and *Weldenia* only one.

We might ask now whether it is possible to classify these plants as *Xerophytes*, *Mesophytes*, or *Hydrophytes*. Judging from the nature of the habitat where these plants occur, it appears as if we might consider, for instance, *T. Warszewicziana*, *T. sp.* (from Colorado) and *Weldenia* as xerophilous, but from higher elevations. *T. rosea* from low sandy woods in subtropical Florida is not exactly a xerophyte in the stricter sense of the word. *T. Virginica* appears intermediate between a mesophyte and xerophyte. *Aneilema* on the other hand may be well classified among the hydrophytes. In regard to *Commelina hirtella* from sandy river-shores, it seems difficult to express any opinion whether this is to be considered a hydrophyte or a mesophyte.

Corresponding difficulties are met with when we examine and compare the dominating features of the leaf-structure of these same species, if these are to be brought in connection with the nature of the habitat. They may be enumerated as follows:

Aneilema: Leaf isolateral; water-storage-tissue over entire ventral face; collenchyma and stereome on leptome-side of midrib.

Commelina hirtella: Leaf dorsiventral; water-storage-tissue above the larger veins; collenchyma on leptome-side.

Tradescantia Virginica: Leaf partly dorsiventral; water-storage-tissue above midvein; collenchyma on leptome-side.

T. sp. (Colorado): Leaf isolateral; water-storage-tissue over entire ventral face and on leptome-side; collenchyma on leptome-side.

T. rosea: Leaf almost isolateral; water-storage-tissue over entire ventral face; collenchyma on leptome-side.

Weldenia: Leaf dorsiventral; water-storage-tissue over entire ventral face; collenchyma on leptome side.

Tradescantia Warszewicziana: Leaf dorsiventral; water-storage-tissue over both faces of the blade; stereome on leptome-side and in margins.

Of these tissues the water-storage-tissue is somewhat unequally developed so far as concerns *T. Virginica*, since it is so very prominent in the other species. It is very scantily represented in *Commelina hirtella*, but, as we remember from the foregoing, none of the other species possessed any large quantity of this tissue. The presence of a large water-storage-tissue in the isolateral leaf of *Aneilema* is a frequent occurrence among hydrophilous plants. In regard to the other species, the great development of this tissue may be well brought in connection with the nature of the habitat.

The collenchyma is absent from the leaf of *T. Warszewicziana*, but is replaced by stereome; it is present in all the others, accompanied by stereome in *Aneilema*. It seems strange that this tissue is not developed in the leaf of *T. Warszewicziana*, since it is so well represented in the scape. It seems also strange that stereome occurs in *Aneilema*, but not in the species of *Tradescantia* from Colorado, Florida, or District of Columbia.

The collenchymatic tissue is evidently a character of the family; the water-storage-tissue an epharmonic.

But from the present knowledge of these plants we dare not enter any further into a discussion of their classification as members of certain associations, mesophilous, hydrophilous, or xerophilous. To fully appreciate the importance of the morphological and anatomical structures which we have described above it seems necessary to study many of the other representatives of the family. We hope that the present investigation may prove useful to future studies as a contribution to the knowledge of these interesting plants.

BROOKLAND, D. C., *March, 1906.*

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. *Commelina nudiflora* L. A seedling, natural size. C=the seed with the apex of the cotyledon inclosed; H=the hypocotyl; S=the sheath of the cotyledon; R=the primary root; r=two lateral roots; I^1=the first stem-internode; L^1 and L^2=the first green leaves.

Fig. 2. Same species. Basal portion of a flowering specimen, natural size. I^1–I^3=the first three stem-internodes.

Fig. 3. Same species. A flower-bearing shoot, natural size. A=internode of main stem; B=internode of axillary shoot; L^1=leaf borne on main stem; I^1–I^2=inflorescences.

Fig. 4. Same species. Diagram of the shoot B. For explanation see the text.

Fig. 5. Rhizome of *Commelina hirtella* Vahl, natural size.

Fig. 6. Same species; a fore-leaf, seen from the front, natnral size.

Fig. 7. Same species; a fore-leaf, removed from the branch and seen from the back, natural size.

PLATE II.

Fig. 8. *Commelina Virginica* L. The rhizome with the base of an aërial shoot, natural size. P^1–P^2=fore-leaves; A^1=continuation of main stem; A^2=an axillary stem; L^1–L^2=scale-like leaves; L^3=scar of stem-leaf.

Fig. 9. Same species. Diagram of the aërial shoot, figured in Fig. 8. For explanation see the text.

Fig. 10. Same species. A rhizome, natural size. A=basal stem-internode from the previous year; A^1=basal portion of aërial stem of this year; P=the fore-leaf; L^1–L^2=scale-like leaves.

Fig. 11. Same species. Diagram of the shoot, figured in Fig. 10. For explanation see the text.

Fig. 12. *Tradescantia rosea* Vent., a rhizome, natural size. I^1–I^5=the internodes of the rhizome; I^6=the basal internode (above ground) of the main stem; S^1–S^4=axillary floral shoots; P=fore-leaves; L^1–L^2=green leaves.

Fig. 13. Same species. Diagram of the axillary floral shoot S^3 figured in Fig. 12. For explanation see the text.

PLATE III.

Fig. 14. *Commelina nudiflora* L. A secondary root of the seedling, transverse section. End.=endodermis; P=Pericambium; H=hadrome; PH=proto-hadrome; PL=proto-leptome. × 744.

Fig. 15. Same species. A lateral root of the seedling; letters as above. × 744.

Fig. 16. Same species. A secondary root of fullgrown specimen, transverse section; letters as above. × 744.

Fig. 17. Same species. A secondary root of fullgrown specimen, transverse section. Ep.=epidermis; Ex.=exodermis. × 480.

Fig. 18. Same species. A secondary root, transverse section; letters as above. All the proto-hadrome-vessels are located inside the pericambium. × 744.

PLATE IV.

Fig. 19. *Commelina nudiflora* L. The hypocotyl of the seedling, transverse section. End.=endodermis. × 480.

Fig. 20. Same species. The basal internode I^1, transverse section. End.=endodermis. × 480.

Fig. 21. Same species; stomata from the stem. × 360.

Fig. 22. Same species; transverse section of part of stem-leaf. Ep.=epidermis. × 744.

Fig. 23. Same species; transverse section showing the pneumatic tissue. × 480.

PLATE V.

Fig. 24. Same species; stomata of the leaf. × 360.

Fig. 25. Same species; raphide-cells from the leaf. × 480.

Fig. 26. Same species; the midrib of the leaf, transverse section; P=parenchyma sheath. × 744.

Fig. 27. Same species; transverse section of a marginal vein from the leaf, letter as above. × 744.

Fig. 28. *Commelina hirtella* Vahl. A stoma from the stem. × 480.

Fig. 29. Same species. Tangential section of root, showing a cell of exodermis with foldings. × 480.

PLATE VI.

FIG. 30. *Commelina nudiflora* L. Epidermis with warts, from dorsal face of leaf. × 480.
FIG. 31. *Commelina hirtella* VAHL. Stoma from the leaf. × 360.
FIG. 32. Same species. Stoma from the leaf. × 360.
FIG. 33. Same species. Stoma from the stem. × 360.
FIG. 34. Same species. A secondary root, transverse section; C = the cortex; End. = endodermis; P = pericambium; PL = proto-leptome; PH = proto-hadrome. × 480.
FIG. 35. Same species. Epidermis from the stem, showing stomata and two kinds of hairs. × 360.
FIG. 36. Same species. Cells with crystals from the stem (cortex). × 480.
FIG. 37. *Commelina Virginica* L. Epidermis of ventral face of leaf-blade. × 360.

PLATE VII.

FIG. 38. *Commelina hirtella* VAHL. Transverse section of inner portion of stem, showing the pith, with crystals and very wide intercellular spaces. × 360.
FIG. 39. *Commelina Virginica* L. Hair from the leaf-sheath. × 360.
FIG. 40. Same species. Stomata from the leaf. × 360.
FIG. 41. Same species. Transverse section of the root, showing epidermis (Ep.), exodermis (Ex.), and stereïds. × 360.
FIG. 42. *Tradescantia rosea* VENT. Transverse section of the root. End. = endodermis; P = pericambium; PH = proto-hadrome; PL = proto-leptome. × 480.
FIG. 43. *Tradescantia Virginica* L. A cell of exodermis of root, showing the foldings of the wall. × 744.
FIG. 44. *Tradescantia rosea* VENT. Transverse section of fore-leaf, showing epidermis and cuticle. × 840.
FIG. 45. Same species. A stoma from the rhizome. × 360.

PLATE VIII.

FIG. 46. *Tinantia anomala* (TORR.) CLARKE. Diagram of the shoot. L^1–L^8 = green leaves; P^1–P^3 = fore-leaves; there is one shoot in the axil of L^2, beginning with the fore-leaf P^1, and another shoot in the axil of L^3, beginning with the fore-leaf P^2. In the axil of P^2 is a third shoot, which begins with the fore-leaf P^3.
FIG. 47. *Tradescantia Warszewicziana* K. ET B. Epidermis of leaf, transverse section. × 480.
FIG. 48. Same species. Epidermis of leaf, viewed en face. × 480.
FIG. 49. *Weldenia candida* SCHULT. FIL. Diagram of the shoot; l^1–l^5 = scale-like leaves of stem underground; L^1–L^5 = green leaves; 6–13 = the innermost leaves, which surround the inflorescence.
FIG. 50. Same species. Transverse section of central-cylinder of root. Letters as above. × 480.
FIG. 51. Same species. Transverse section of central-cylinder of root. Letters as above. There are two proto-leptome cells (PL). × 480.
FIG. 52. Same species. Hair from the leaf. × 360.
FIG. 53. Same species. Stoma from the leaf. × 360.

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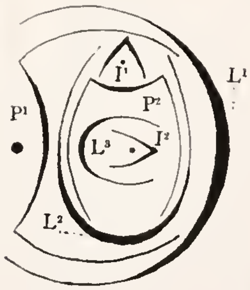

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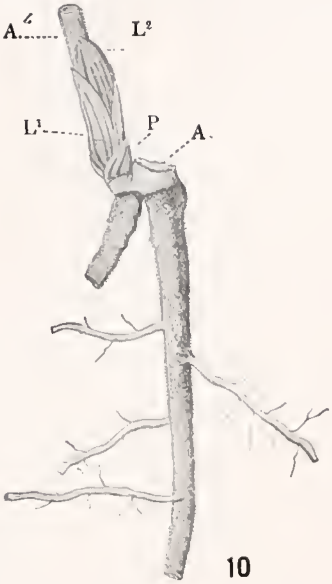
Auctor ad nat. delin.

COMMELINACEÆ.



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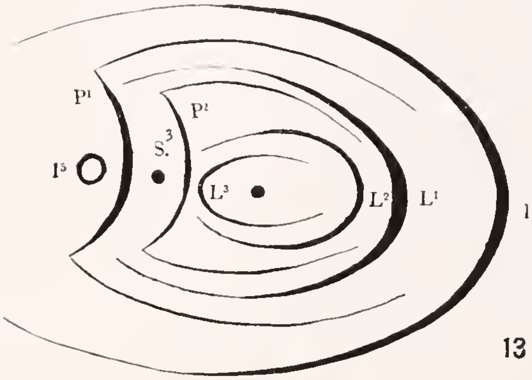

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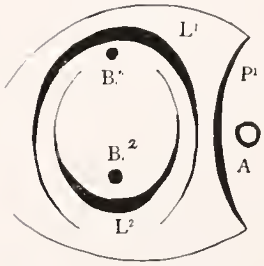

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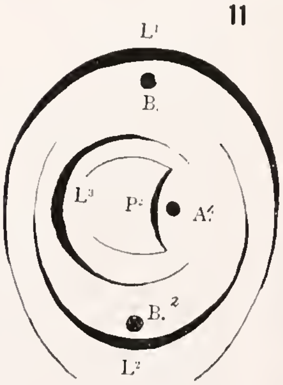

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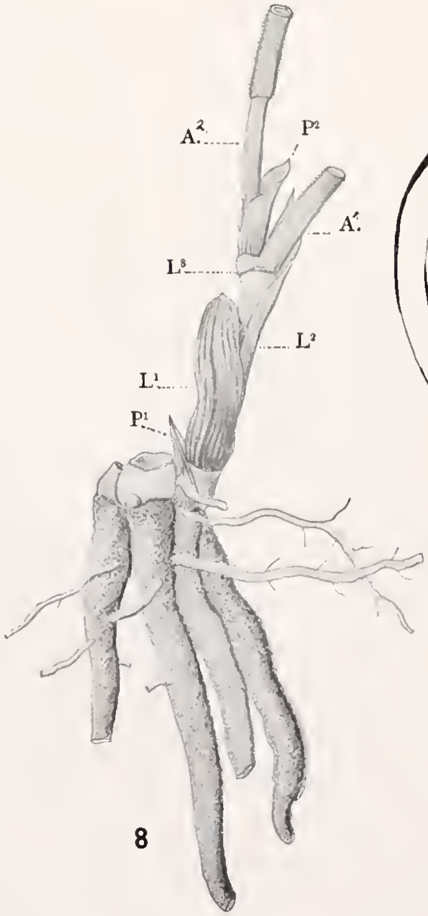

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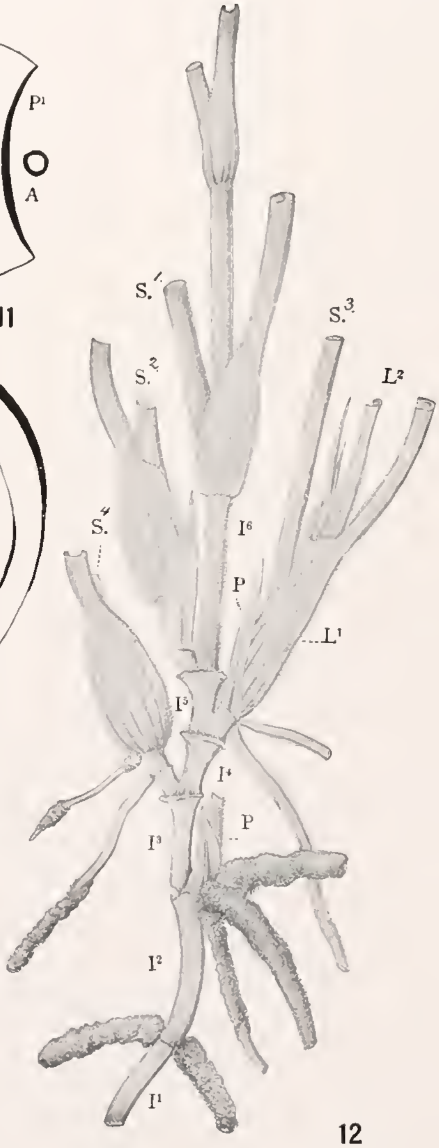

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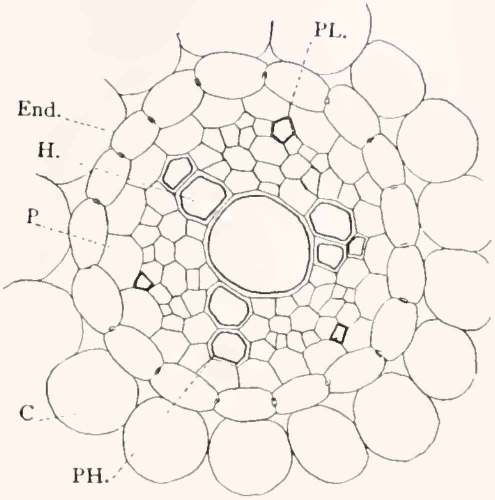
COMMELINACEÆ.



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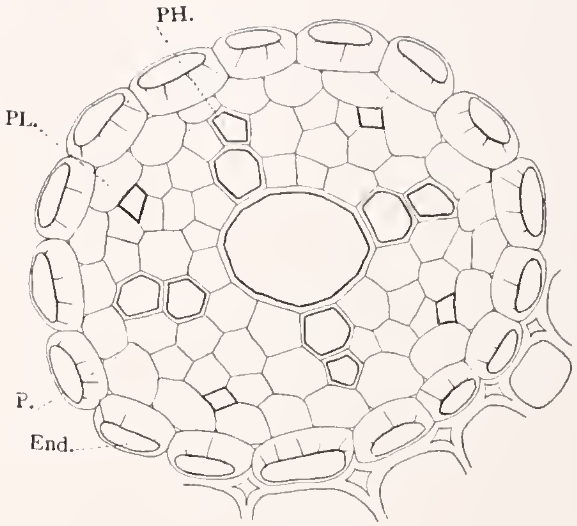

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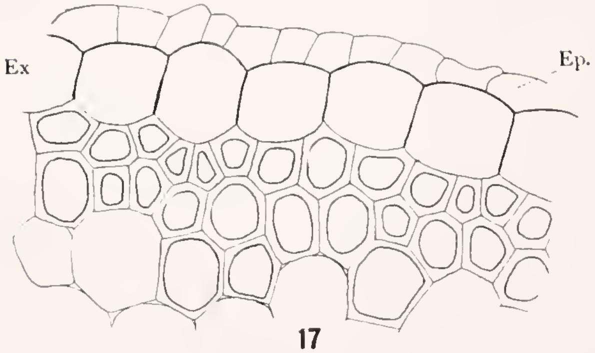

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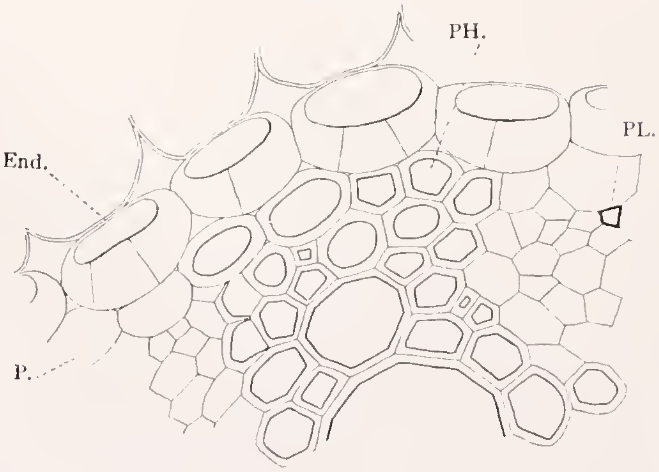

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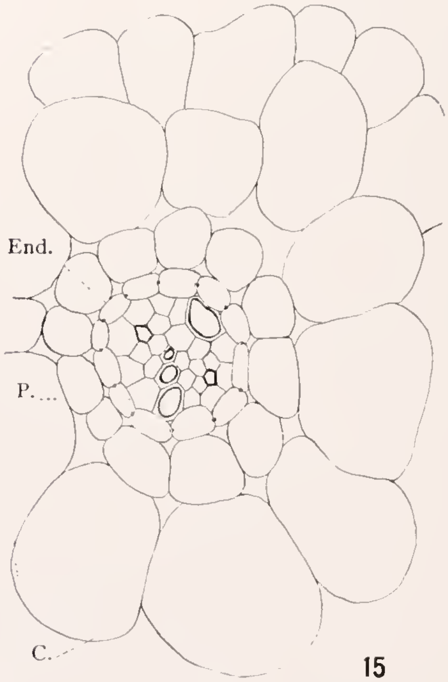

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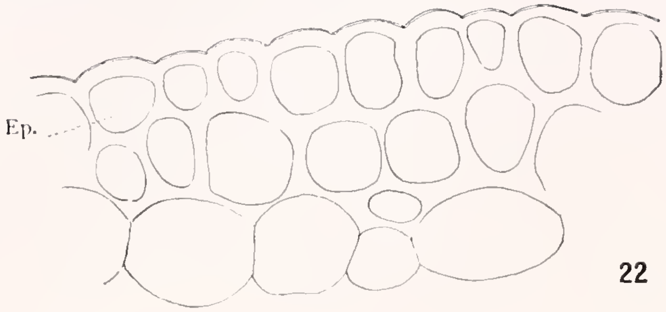
Auctor ad nat. delin

COMMELINACEÆ.



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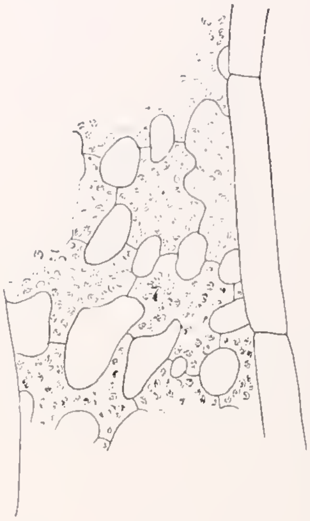

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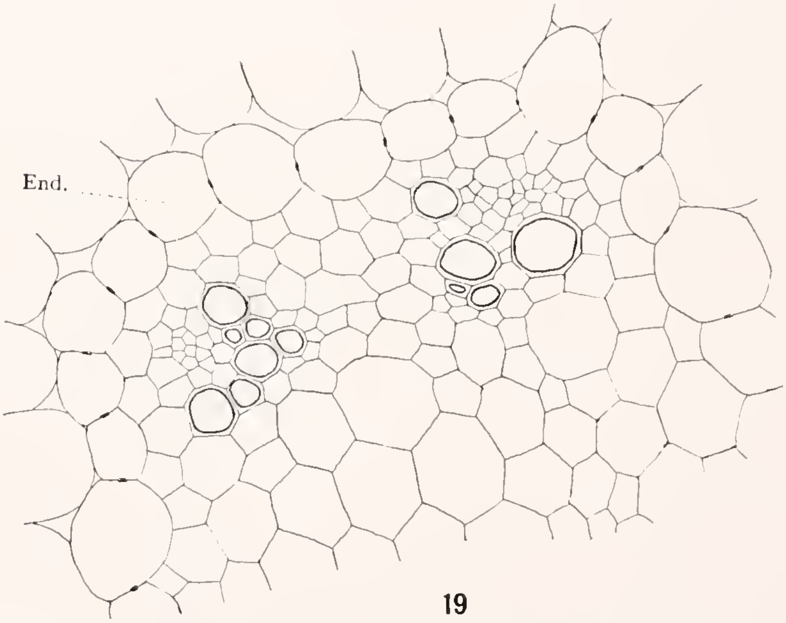

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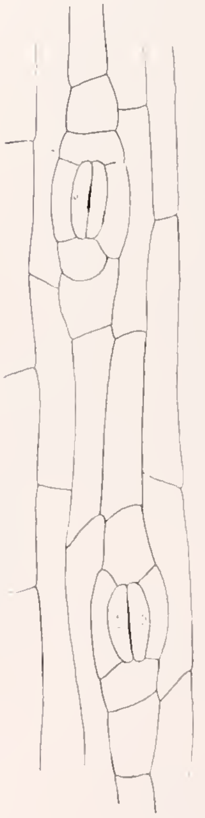

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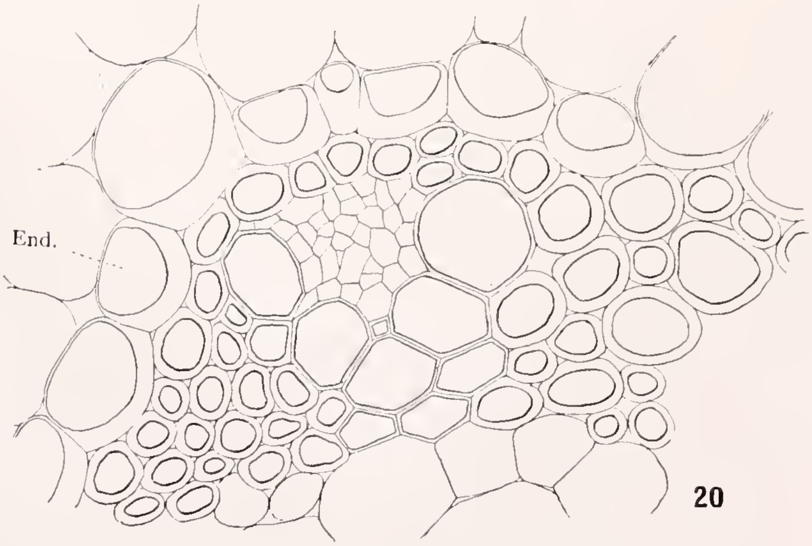

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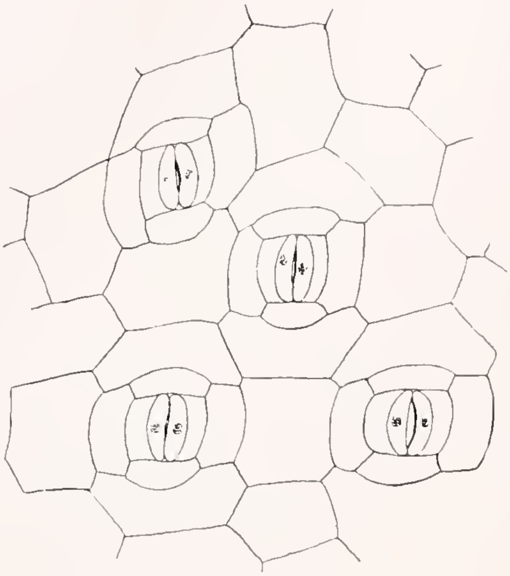
Auctor ad nat. delin.

COMMELINACEÆ.

PLATE V.



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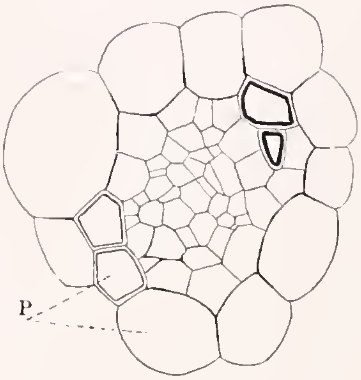

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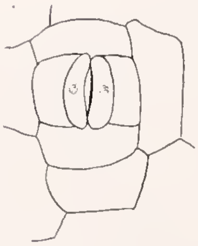

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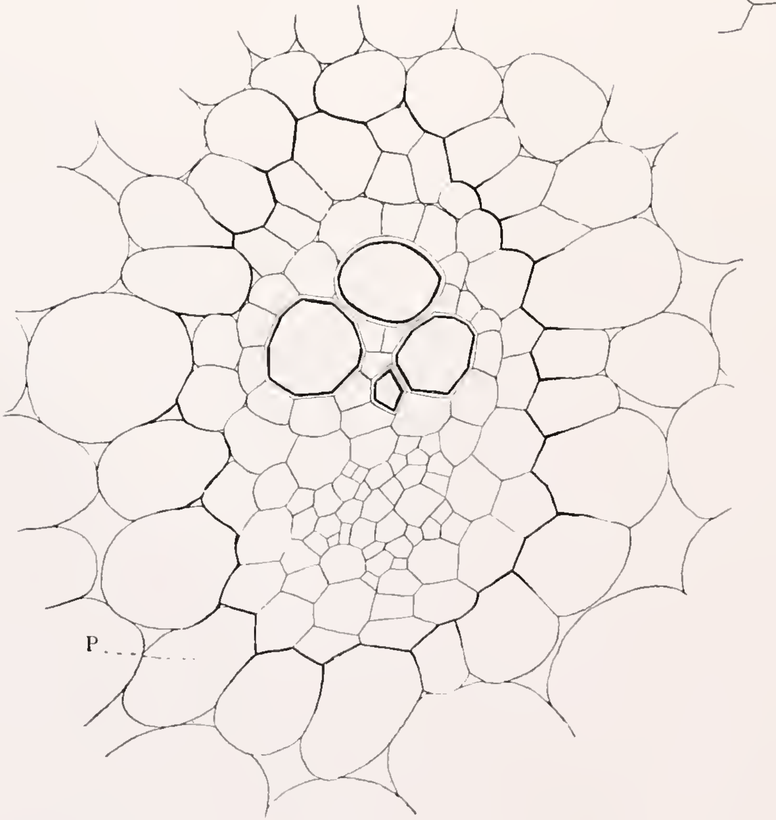

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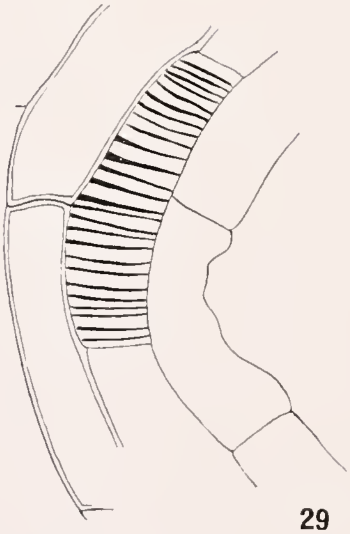

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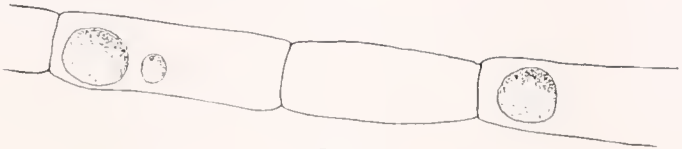

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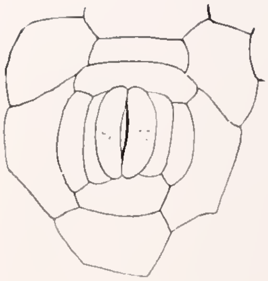

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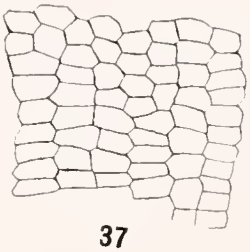

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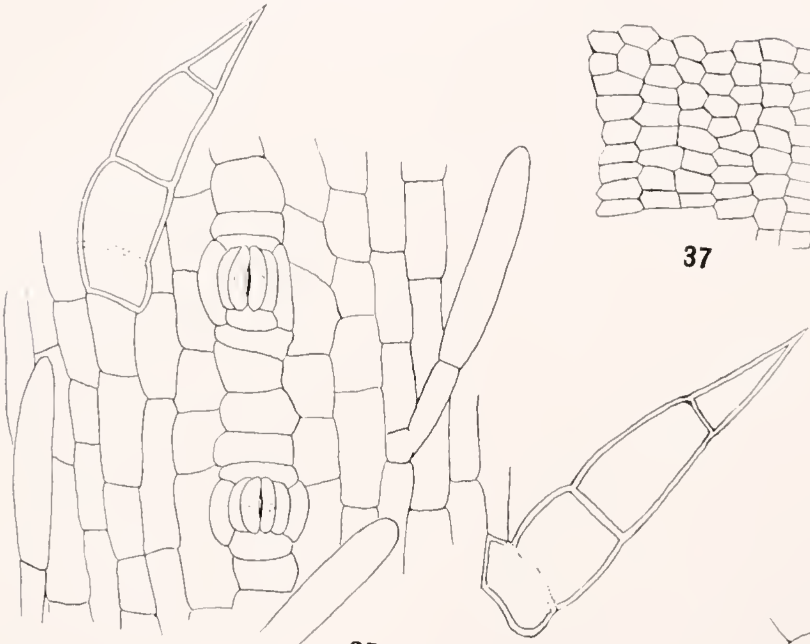

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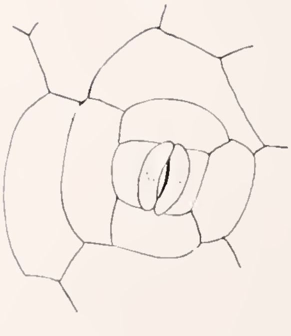

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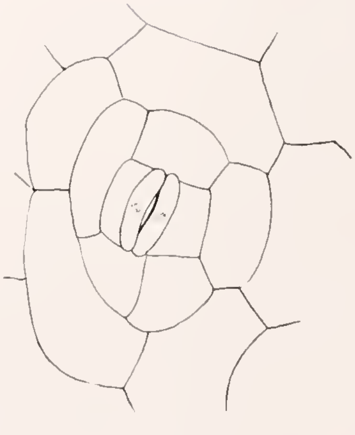

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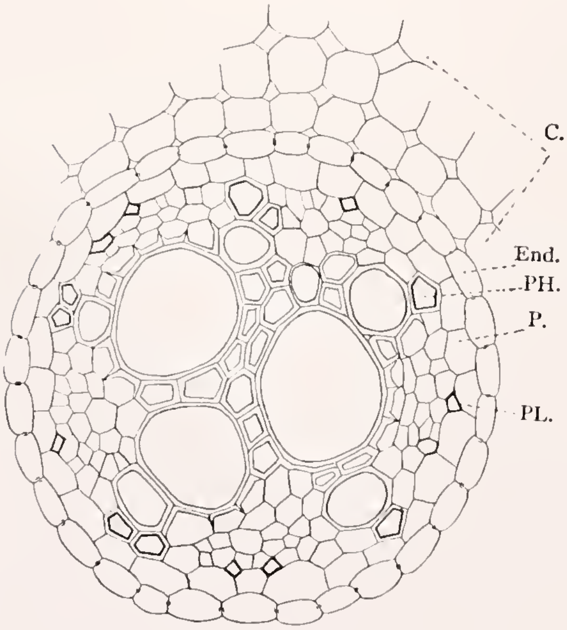

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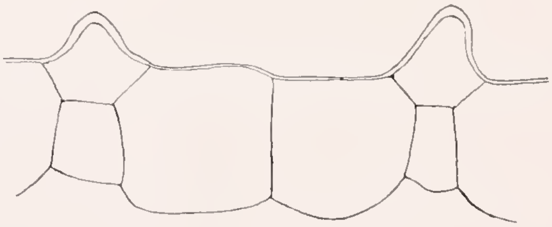

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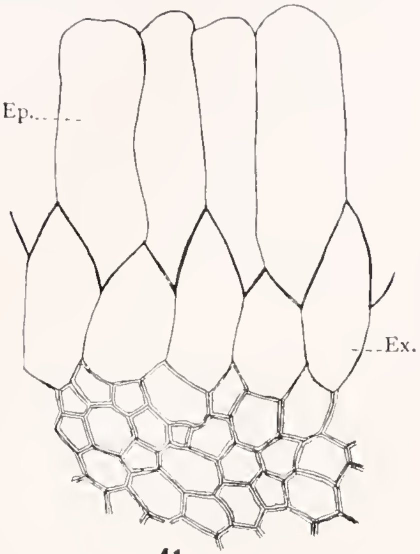

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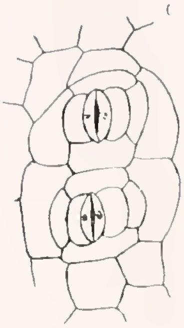

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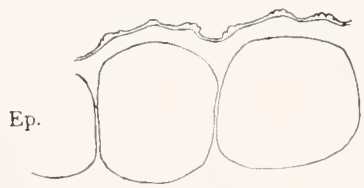

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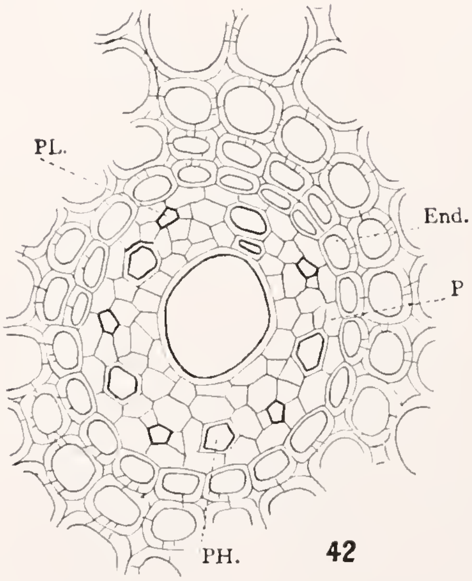

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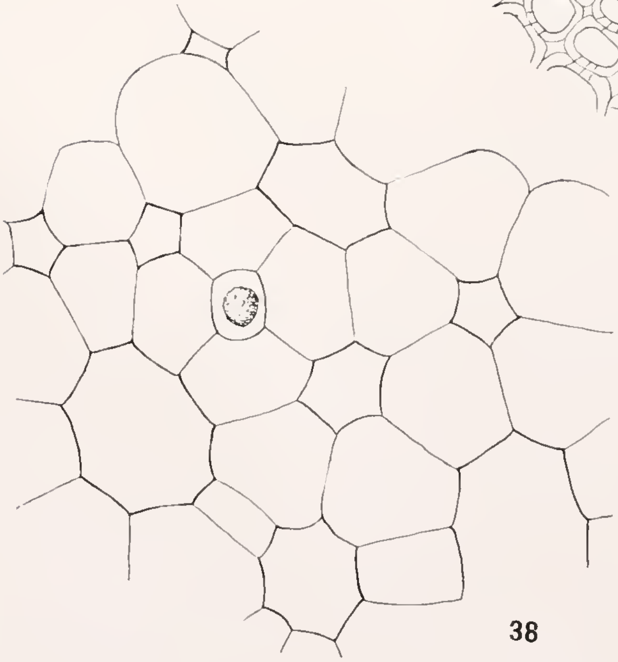

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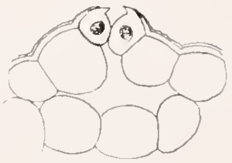

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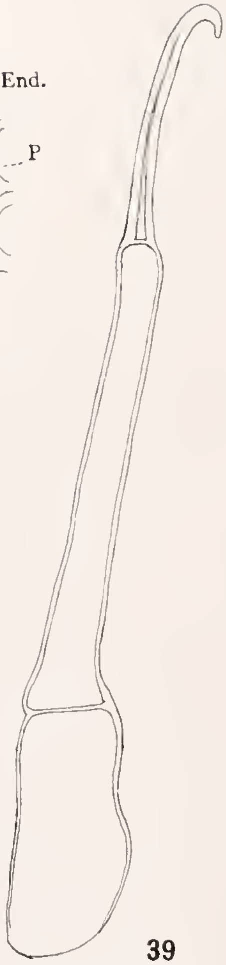

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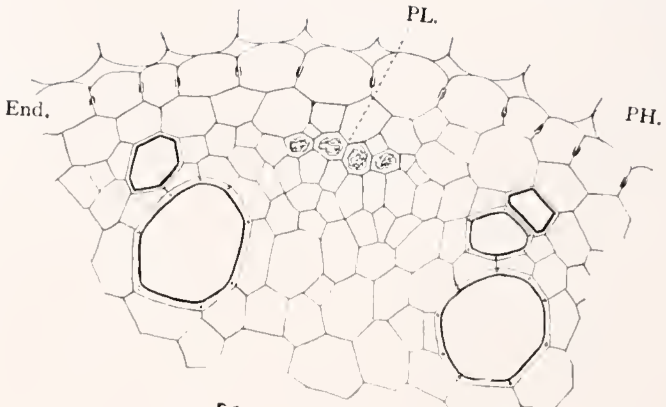

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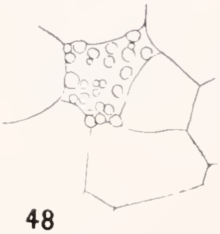

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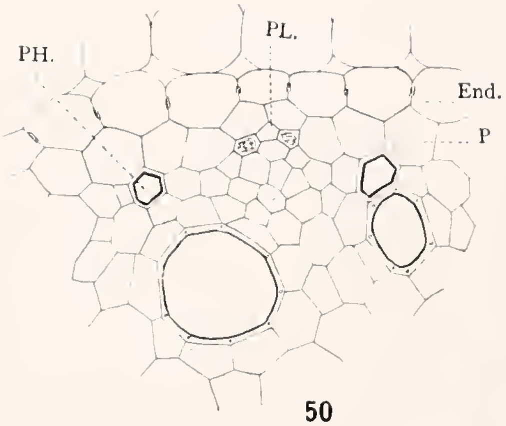

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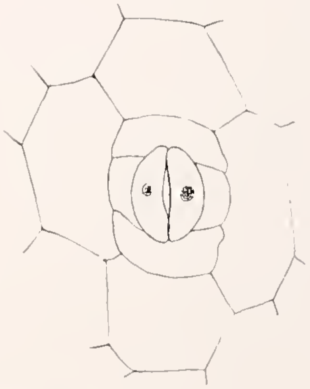

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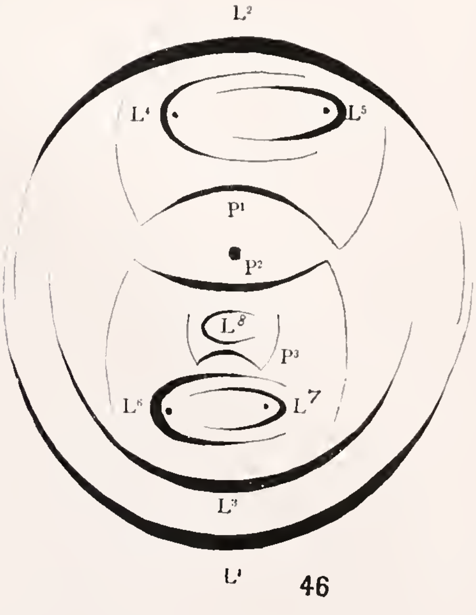

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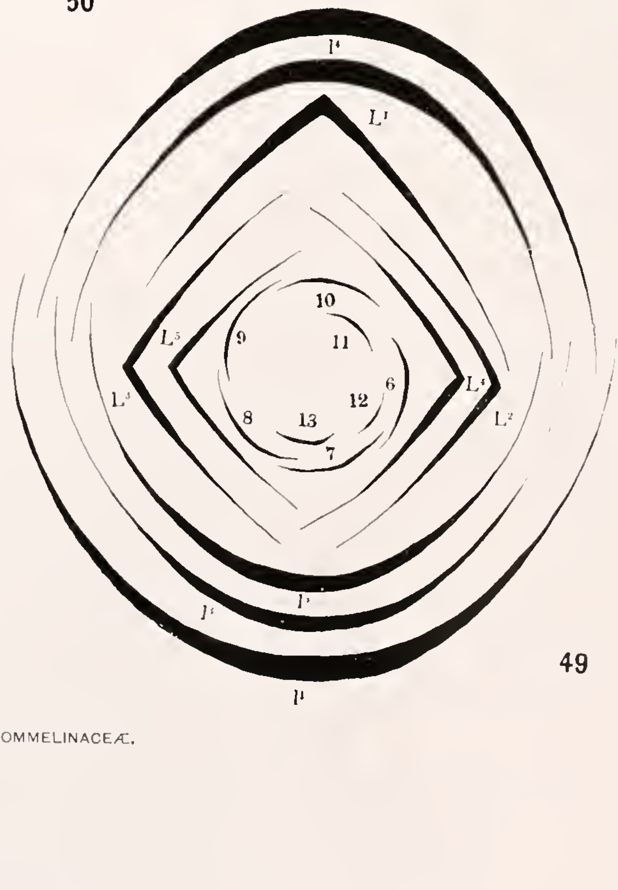

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Auctor ad nat. delin.

COMMELINACEÆ.

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OF THE

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Volume X.

SEVENTH MEMOIR.

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NATIONAL ACADEMY OF SCIENCES.

Volume X.

SEVENTH MEMOIR.

TABLES OF MINOR PLANETS DISCOVERED BY JAMES C. WATSON.

PART I.

TABLES OF

(93) MINERVA.
(101) HELENA.
(103) HERA.
(105) ARTEMIS.
(115) THYRA.
(119) ALTHAEA.
(128) NEMESIS.
(133) CYRENE.
(139) JUEWA.
(161) ATHOR.
(174) PHAEDRA.
(179) KLYTAEMNESTRA.

BY

ARMIN O. LEUSCHNER,

WITH THE ASSISTANCE OF

R. T. CRAWFORD, FRANK ROSS, BURT L. NEWKIRK,
ADELAIDE M. HOBE, ESTELLE GLANCY, AND OTHERS,

BEING IN PART A CONTINUATION OF PREVIOUS INVESTIGATIONS BY
E. BECKER, W. S. EICHELBERGER, WILLIAM McKNIGHT RITTER, and G. K. LAWTON.

NATIONAL ACADEMY OF SCIENCES.

MEMOIRS.

VOLUME X.

SEVENTH MEMOIR.

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CONTENTS.

ERRATA.

Page 200, line 21: For "Ritter", read "Eichelberger".

Page 211, line 28: In argument of *cos* for "$g' - g$", read "$g' - \mu g$".

Page 216, line 7 from bottom: For "9.60706", read "9.60706 n".

Page 234, Foot-note: After the words "osculating for the epoch" insert "(excepting (93) *Minerva*, for which the date of osculation is 1872, Nov. 2.0, Gr. M. T.)"

Page 359, line 3: For "$[a_i + (\varDelta b_i)_t]$", read "$[a_i + (\varDelta a_i)_t]$".

Page 361, line 3: For "Epoch and Osculation", read "Epoch".

Page 361, under line 3: Insert "Date of Osculation = 1872, Nov. 2.0, Gr. M. T."

Page 362, first column: For "Arg. $i\,g - i'\,g'$", read "Arg. $(i - i'\,\mu)\,\varepsilon - i'\,(g' - \mu\,g)$".

Page 363, first column: For "Arg. $i\,g - i\,g'$", read "Arg. $(i - i'\,\mu)\,\varepsilon - i'\,(g' - \mu\,g)$".

Page 364, last line: For "$[a_i + (\varDelta b_i)\ ]$", read "$[a_i + (\varDelta a_i)_t]$".

Page 364, last line: For "$[bi + (\varDelta b_i)_t]$", read "$[b_i + (\varDelta b_i)_t]$".

Pages 365–372, inclusive, last line of each: For "$[a_i + (\varDelta b_i)_t]$", read "$[a_i + (\varDelta a_i)_t]$".

TABLES OF MINOR PLANETS DISCOVERED BY JAMES C. WATSON.

By Armin O. Leuschner.

PREFACE.

By the will of James C. Watson, who died in 1880, a fund was bequeathed in trust to the National Academy of Sciences for the purpose of promoting astronomical research. Objects specifically designated were the awarding of a medal not oftener than once in two years for important astronomical works and the construction of tables of the minor planets discovered by the testator. The expenditures were to be made under direction of a board of three trustees. The first board was named in the will, the members being J. E. Hilgard, John H. C. Coffin, and Simon Newcomb. At the present time, March, 1908, the members of the board are: Simon Newcomb, chairman; William L. Elkin, and Lewis Boss.

The construction of the tables was long delayed by the difficulty of finding computers competent to carry the work through in a satisfactory way. To lessen this difficulty an arrangement was made with Prof. E. Becker, director of the Strassburg observatory, for supplying a complete form for computing the perturbations according to Hansen's method, in which the eccentric anomaly was taken as the independent variable. An example was also supplied by Professor Becker in the form of a computation of the perturbations of *Eurynome* by *Jupiter*. Tables of *Minerva* were completed and published on this plan by Dr. W. S. Eichelberger.

The conclusion subsequently reached was that the system of employing the eccentric anomaly was not a desirable one, and that it was better to adhere to the use of the time as the fundamental variable. Several experts were engaged in computing the perturbations of different asteroids by *Jupiter* under the general direction of the writer, but in no case except that of *Minerva* were the processes of tabulating the perturbations and correcting the elements brought to a satisfactory conclusion.

The slow progress of the work made it evident that it must be prosecuted in a more systematic way under the personal direction of a leader who would bring it to a conclusion. After a careful survey of the field, Prof. Armin O. Leuschner, of the University of California, was selected as the leader, and all the papers were placed in his hands. He undertook to construct the tables with the aid of the students and assistants in the Berkeley Astronomical Department of the University of California. The system agreed upon was that the tables should be carried only to the degree of precision necessary for finding ephemerides. The only perturbations then required would be those of the first order by *Jupiter*, though approximate quantities of higher order would in some cases be advisable. The construction of even these approximate tables proved vastly more laborious than had been expected, owing to circumstances set forth by Professor Leuschner in the introduction. As the general outcome of the work up to the present time, tables of twelve of the asteroids in question are herewith presented, with the hope that they will be sufficiently accurate for as long a period as if entire theoretical precision had been aimed at in their construction. The remaining tables are in an advanced state, and it is expected that they will be completed and published at no distant day with the single exception of *Aethra* which must await rediscovery.

Simon Newcomb.

Washington, *1908, March.*

INTRODUCTION.

The results recorded in these pages are the outcome of an effort to supplement the author's lectures on celestial mechanics in the University of California by extensive numerical application in the field of perturbations.

During the summer of 1901 the Watson trustees of the National Academy of Sciences agreed to engage students and graduates of the University of California in the work of computing the perturbations of the minor planets discovered by Watson on condition that the author would assume the immediate direction of the work and sole responsibility to the trustees for its success. The original scope of the undertaking as fixed by Prof. Simon Newcomb, chairman of the Watson trustees, was to embrace the numerical development of the perturbations, including terms only of the first order with respect to the mass of *Jupiter*, by Hansen's method; a correction of the elements by means of the differences between the computed and observed positions for all available oppositions; and the construction of tables to facilitate the computation of positions to the nearest minute of arc, from the date of discovery to 1930.

As the undertaking is now nearing completion, it is deemed advisable to make the tables available to astronomers in advance of the details of the investigations. The present series, containing the tables of twelve planets, is to be followed by several others, which will contain the tables of the remaining planets, and possibly also the detailed investigations.

Many difficulties of a theoretical as well as a practical nature were encountered during the progress of the work, necessitating departures from the general program for individual planets, particularly for planets of the *Hecuba* type.

It is unnecessary to enter here upon a discussion of the progress and organization of the investigation. It is sufficient to say that all computations were done independently by two computers, frequently by different methods, and that the system of checks used makes it highly probable that the results are free from numerical error. Particular attention was paid to the investigation of the differences between the theoretical and observed positions. The origin of all unusually large residuals has been traced. When they occur they are, in general, accounted for by higher order perturbations of *Jupiter*, or by perturbations of other major planets, or by the fact that sufficiently accurate initial elements of the disturbed planet were not available for the rigid computation of the coefficients of the perturbations. Corrections to the perturbations, due to the differences between the initial and final elements of a planet may be included, if it be deemed necessary, in subsequent series. Much useless labor has been caused by erroneous identifications of the Watson planets on the part of the observers. A comparison of the tables with future observations will be necessary to decide whether all erroneous observations have been eliminated.

Actual work was commenced in August, 1901, with Dr. Russell Tracy Crawford and Dr. Frank Elmore Ross as computers. They continued in the work for one year, and in that time computed, under the author's direction, the perturbations of ten planets in duplicate, by Hansen's method. Tables of seven of these are included in the present series: (105) *Artemis*, (128) *Nemesis*, (133) *Cyrene*, (139) *Juewa*, (161) *Athor*, (174) *Phaedra*, and (179) *Klytaemnestra*. Since then the computations have been carried on almost entirely by university students, except that Dr. Burt L. Newkirk was appointed in September, 1903, a special assistant and was assigned with Miss Adelaide M. Hobe chiefly to take charge of some twelve piece computers in revising perturbations, correcting elements, and constructing tables. Doctor Newkirk and Miss Hobe have also developed the perturbations of (115) *Thyra* and (93) *Minerva*. The tables of *Minerva*, however, contained in this series, are based on a previous investigation by Dr. W. S. Eichelberger.

Several interruptions, of which one lasted for nearly a year, were caused by the resignation of assistants who were called to permanent positions elsewhere. Thus Doctor Crawford, Doctor Ross, Doctor Newkirk, and Miss Hobe were lost in turn to the work. Other interruptions arose from the necessity of temporarily employing the Watson computers as assistants in the regular departmental work of instruction. So far three distinct sets of computers have been trained in succession for the work. At present, the investigations are progressing with Miss Estelle Glancy, a graduate student in the university, as chief computer.

The original program, which included only those planets for which the investigation of the general perturbations had not been undertaken by other astronomers, has since been extended by the trustees, at their own initiative, to embrace the publication of tables of all of the twenty-two Watson planets excepting (132) *Aethra*, which is lost. Investigations, however, by Mr. A. J. Champreux, which are under way, point to the possibility of deciding the fate of this planet.

To enable the author to prepare all the available material for publication, the Watson trustees placed in his hands such original computations and manuscripts as were in their possession. These included, in the main, perturbations and tables of (103) *Hera* and (119) *Althaea* by William McKnight Ritter; perturbations and tables of (93) *Minerva* by Dr. W. S. Eichelberger; perturbations of (101) *Helena* by Ritter, tables by Eichelberger, and fragments of a comparison between theory and observation by G. K. Lawton; development of the perturbations and partial comparison between theory and observation for (79) *Eurynome* by Prof. E. Becker, continued by Ritter.

In regard to these planets, the trustees desired that certain discrepancies between theory and observation should be investigated, that such revision of the results be made as might seem necessary, and that the tables which in general gave the theoretical positions to a tenth of a second of arc, should be abridged to correspond to the limits of accuracy fixed by the method of investigation used in each case.

This task proved far more laborious than was anticipated. In the case of (93) *Minerva* the perturbations were checked by a complete independent development. Yet, it has ultimately been possible to preserve, in the main, the original results of the author's predecessors in the work, and thus to secure for them the credit which is their due. No change whatever has been made in Eichelberger's results on (93) *Minerva*.

The aim of the trustees was not that a theoretical study should be undertaken of the relative merits of the various methods of developing the perturbations of the minor planets, but that tables of the Watson planets be produced in the most expeditious manner. It was therefore not within the scope of this work to arrange for practical application to the minor planets such analytical methods as have been made available by Poincaré, E. W. Brown, and others, in a manner similar to that employed by Brendel in his "Theorie der Kleinen Planeten," which is based on Gyldèn's researches.

Furthermore, Hansen's and Bohlin's methods have so far been found eminently suitable for the objects aimed at. Nevertheless, the details of the investigation to be published later will furnish abundant material for studies of a purely analytical nature.

The length of time required to develop perturbations by Hansen's method is not such an important factor after all in these considerations, for after gaining the necessary experience Crawford and Ross were able to completely develop the perturbations of the first order in normal cases in from forty to sixty hours.

For three planets of the *Hecuba* type the development of the perturbations remains to be made. Preparatory to this, special tables for the group $\frac{1}{2}$ have been computed on the basis of the method employed by Bohlin for the group $\frac{1}{3}$ in his "Formeln und Tafeln zur gruppenweisse Berechnung der allgemeinen Störungen benachbarter Planeten" and "Sur le développement des Perturbations Planétaires."

The tables for the group $\frac{1}{2}$ were barely completed when similar tables by H. von Zeipel appeared in the Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg, VIII série, Classe Physicomathématique, Volume XII, No. 11, under the title "Angenäherte Jupiterstörungen für die Hecuba-Gruppe."

A thorough comparison of v. Zeipel's and the author's tables for the group ½ remains to be undertaken before either are applied to the development of the perturbations of the three planets belonging to the *Hecuba* type.

Acknowledgment is due to Prof. Simon Newcomb, chairman of the Watson trustees of the National Academy of Sciences, for his constant efforts in promoting this investigation.

Acknowledgment is also due to Professor Bohlin for facilitating the construction of the special tables for the group ½ by placing his revised computations for tables of group ⅓ in the author's hands; to Director Campbell, of the Lick Observatory of the University of California, and to Superintendents Asa Walker and W. J. Barnette, of the United States Naval Observatory, for furnishing especially needed observations, and finally to the author's coworkers, particularly to Messrs. Crawford, Ross, and Newkirk, and Misses Hobe and Glancy, for their untiring devotion to the numerical work connected with this undertaking.

EXPLANATION OF THE TABLES.

GENERAL PLAN OF THE TABLES.

The tables consist of *general tables* and *special tables*. The *general tables* are those tables which are required for all planets in the computation of a geocentric position. The tabular values were computed to one more figure than given in the tables, to insure correctness of the last tabulated figure. Decimals of a degree are used throughout and computations may be readily conducted on the basis of these tables with the aid of Bremiker's five-place logarithmic tables.

The perturbations, excepting those of (93) *Minerva*, are developed with the argument $(ig-i'g')$, and a uniform plan is adopted for the *special tables* of the various planets, except for those planets for which the development of the perturbations and the construction of tables was originally undertaken elsewhere. In these latter cases the original plan of tabulation has been adhered to to avoid laborious and unnecessary transformations.

GENERAL TABLES.

In the *general tables* are included tables of *Jupiter's* mean anomaly from 1863, the year of discovery of the first Watson planet, to 1930; Traverse Tables giving the products $a \sin A$ and $a \cos A$; and a table of Elements. All other general tables necessary for the computation of a geocentric position may be found in Bauschinger's "Tafeln zur Theoretischen Astronomie" and in Tietgen's "Tafel zur Berechnung der Wahren Anomalie," which may be used in connection with the tables here given. The particular tables to be employed at various stages of the computation of a geocentric position are referred to in the example given on page 215.

TABLES OF JUPITER'S MEAN ANOMALY, g' (TABLE A).

The values of g' are tabulated from 1863 to 1930. They are taken from Hill's Tables of *Jupiter* and *Saturn*,[a] Tables VIII to XII. The values of g' contained in $g-g'$, Table I of (93) *Minerva*, however, do not correspond to the values of g' in Table A, since the value of g' used by Eichelberger in building the table $g-g'$ is the undisturbed mean anomaly of *Jupiter*. It can be obtained by multiplying Arg. I of Hill's Tables for the date $+6^d.6$ by the mean motion $299''.1283756$.

It should also be noted that the dates for which the values of g' and g are given in Tables A and I refer to Berlin mean time, except in case of (93) *Minerva*, for which Table I refers to Greenwich mean time.

TRAVERSE TABLES (TABLE B).

These tables are to facilitate the formation of the products of the form $a \sin A$ and $a \cos A$, which occur in the periodic parts of the perturbations, and are designated, at the foot of the

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[a] Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac. Vol. VII.

tables of each planet, by $a_i \sin ig$ and $b_i \cos ig$ or $a_i \sin i\varepsilon$ and $b_i \cos i\varepsilon$. They are to be entered with $a = a_i$ and $A = ig$ or $i\varepsilon$ as arguments. The products are tabulated for every degree of A from 1° to 90°, and for every unit of a from 1 to 100. For $a = 1$, the products are given to five decimals; from $a = 2$ to $a = 9$ to four decimals, and from $a = 11$ to $a = 100$ to one decimal. This latter part of the Traverse Tables has been copied from Table II of The American Navigator by Nathaniel Bowditch. The a_i and b_i coefficients are tabulated to one decimal of the adopted unit of 0°.001 for $n\delta z$ and $u/\cos i$, and to one decimal of 0.00001 for $\delta \log r$. The products may be taken directly from the tables by double interpolation for values a_i and b_i up to 100.0 units in each case, i. e., for coefficients not exceeding 0°.1 or 0.001, respectively. If the coefficients be larger, the products may be conveniently found in parts with the aid of that portion of the table which is given to four and five decimals. Example: Required the product—

$$a \sin A = -2479.6 \times \sin 306^\circ.38; \quad \text{Unit of } a = 0^\circ.001$$

Since the angle is in the fourth quadrant, the algebraical sign of the product is +. The numerical part may be taken from the Traverse Tables in the form:

$$(1000 \times 2 + 100 \times 4 + 79.6) \cos 36^\circ.38)$$

1000×2 cos 36°.38	=1610.1	Table B, page 218
100×4 cos 36.38	= 322.0	Table B, page 219
79.6 cos 36.38	= 64.1	Table B, page 230
−2479.6 sin 306.38	=1996.2 units=1°.9962	

With Bremiker's five-place tables the product is found to be 1996.3, which agrees with the former result within the accuracy of the computation.

ELEMENTS (TABLE C).

In this table are given the final elements of the twelve planets and the quantities m_0 and g for computing the magnitude at opposition, the latter being taken from the Berliner Astronomisches Jahrbuch.

SPECIAL TABLES FOR THE TWELVE PLANETS.

The *special tables* for the twelve planets are arranged in three groups.

The first group contains eight planets for which the argument of the developments is $(ig - i'g')$, and for which the perturbations are tabulated in the form:

$$\Sigma_i (a_i \sin ig + b_i \cos ig) + cT$$

where the coefficients a_i, b_i, and c are functions of coefficients of the original developments; a_i and b_i are also functions of g', while c is a function of g.

The second group contains three planets for which the argument of the developments is also $(ig - i'g')$, but in which all terms having $(ig - i'g')$ or a multiple of $(ig - i'g')$ as argument are combined in the tables for particular values of i and i' under a single argument $(ig - i'g')$.

If we denote the three components $n\delta z$, $\log (1 + \nu)$ and $\delta\beta$, by the symbol γ, then the perturbations are tabulated in the form

$$\gamma = \Sigma_i \gamma_i + \gamma_t T - c_\gamma$$

where i is the numerical designation of the various arguments and c_γ is a constant.

The third group contains but one planet, (93) *Minerva*, for which the argument of the developments is $(i - i'\mu)\varepsilon - i'(g' - \mu g)$, and for which the perturbations are tabulated in the form

$$\Sigma_i a_i \sin i\varepsilon + \Sigma_i b_i \cos i\varepsilon + (\Delta b_0)_t$$

where the a_i and b_i are functions of coefficients of the original developments and of the argument $N = \varepsilon - g' - \mu e \sin \varepsilon$, and where $(\Delta b_0)_t$ is the nontrigonometrical secular part of the perturbations. Explicit directions for the use of the tables and an example are given with each group.

The special tables for each planet are preceded by the adopted elements, a list of the auxiliary quantities needed in computing a geocentric position, and by the developments of $n\delta z$, ν, and $u/\cos i$.

The arrangement of the tables for the different planets has been rendered as uniform as seemed expedient, without too extensive transformation, considering the diversity of the original plans adopted by EICHELBERGER, RITTER, and the author. The angles throughout are expressed in decimals of a degree. Table I of every planet gives the mean anomaly. Tables II–IV give the nonsecular portion of the perturbations. In the tables these are designated as periodic terms. Table V gives the secular portion of the perturbations. Table VI gives the constants for the equator. For the first group, containing eight planets, the perturbation in the third component is tabulated in the form $u/\cos i$, for all others in the form $\delta\beta = au/\cos i$. The unit of the tabular values is printed at the head of each table.

For (93) *Minerva*, for which ε was kept explicit in the plan adopted for tabulation by EICHELBERGER, a Table VII is added, giving the reduction of the mean to the eccentric anomaly. This table also contains part of the argument N of Tables II–IV of *Minerva*. Table I of *Minerva* contains the other part of this argument.

Tables for the equation to the center and the logarithm of the radius-vector are not given, as BAUSCHINGER'S "Tafeln zur Theoretischen Astronomie" and TIETJEN'S "Tafel zur Berechnung der Wahren Anomalie" answer all requirements.

The perturbations of the first group, containing eight planets, were developed to the nearest second of arc, while the tables give the perturbations to one decimal of the adopted units $0\overset{\circ}{.}001$ and 0.00001. These tabular values were computed only to the last figure given in the tables. The last figure is, therefore, not exact, but was retained to insure greater exactness of the perturbations to the nearest $0\overset{\circ}{.}001$ and 0.00001. The tables, therefore, give the perturbations of the first order well within the originally contemplated limit of one minute of arc. For the remaining four planets the accuracy is still greater, the perturbations having been developed to the nearest tenth of a second of arc and the values in the tables having been computed to one more decimal than tabulated. The mean anomaly and the constants to the equator have been computed to one and two more places than tabulated to facilitate later correction of the elements.

ARGUMENTS g AND g' OF THE PERTURBATIONS.

The perturbations are based on the initially adopted elements of a minor planet and *Jupiter*. They are corrected only for the finally adopted mean mean motion of the planet. The values of the mean anomaly given in Table I for each planet are based on the finally adopted values of the mean mean motion and of the mean anomaly g_0 at the epoch, as deduced by the Method of Least Squares from the differences between the theoretical and observed positions.

In general the absolute corrections to g_0 and π can not be obtained with accuracy from the Least Squares reduction. When they are large they usually are numerically nearly equal and of opposite sign. The position, however, of the planet in its orbit does not depend so much on the absolute values of Δg_0 and $\Delta\pi$ as on their sum $\Delta\pi + \Delta g_0$, which is of greater accuracy.

Whatever uncertainty may remain in the tabulated values of g is therefore almost wholly eliminated in the undisturbed positions through the constants for the equator, which are based on the value of π resulting from the Least Squares solution. But, in general, this will not be the case for the perturbations, because their coefficients are based on the initial value of π for each planet.

Theoretically, for attaining the highest accuracy, the coefficients should have been corrected to correspond to the final value of π (and of the other elements), if the arguments were to be based directly on the g in Table I. But within the accuracy aimed at in these tables it is sufficient to correct the values of g in Table I by $\Delta\pi = \pi - \pi_0$ when they are to serve as arguments, and to use them as they stand when they are to serve as mean anomalies. This correction arises from the consideration that the perturbations depend in part on $\pi + g_0$, for which the initial and final values are

$$\pi_0 + (g_0)_0 \text{ and } \pi_0 + \Delta\pi + (g_0)_0 + \Delta g_0 = \pi_0 + [(g_0)_0 + \Delta g_0 + \Delta\pi].$$

Thus, since Δg_0 appears in Table I and since the coefficients of the perturbations depend on π_0, the correction $\Delta\pi$ may be allowed for in the main by adding the same to the values of g as given in Table I when the g are to serve as arguments. In cases where $\Delta\pi$ is small and the perturbations do not vary rapidly with g, the correction may be neglected. But with large values of $\Delta\pi$ and rapid variation of the perturbations the omission of this correction may introduce comparatively large errors of the second order in the residuals, through the consequent inaccuracy of the arguments of the perturbations.

TABLES OF EIGHT PLANETS.—(105) ARTEMIS, (115) THYRA, (128) NEMESIS, (133) CYRENE, (139) JUEWA, (161) ATHOR, (174) PHAEDRA, (179) KLYTAEMNESTRA.

The elements of these planets are mean elements.

.The expressions for $n\delta z$, ν, and $u/\cos i$ are developed in the following form:

$$\begin{aligned} n\delta z = nz - g_0 - nt &= \Sigma_i \Sigma_{i'} A^i_{i'} \sin (ig - i'g') + \Sigma_i \Sigma_{i'} B^i_{i'} \cos (ig - i'g') \\ &\quad + (t - t_0) \{ \Sigma_i C_i \sin ig + \Sigma_i D_i \cos ig \} \\ \nu &= B^0_0 + \Sigma_i \Sigma_{i'} A^i_{i'} \sin (ig - i'g') + \Sigma_i \Sigma_{i'} B^i_{i'} \cos (ig - i'g') \\ &\quad + (t - t_0) \{ D_0 + \Sigma_i C_i \sin ig + \Sigma_i D_i \cos ig \} \\ u/\cos i &= B^0_0 + \Sigma_i \Sigma_{i'} A^i_{i'} \sin (ig - i'g') + \Sigma_i \Sigma_{i'} B^i_{i'} \cos (ig - i'g') \\ &\quad + (t - t_0) \{ D_0 + \Sigma_i C_i \sin ig + \Sigma_i D_i \cos ig \} \end{aligned}$$

i varying from $-\infty$ to $+\infty$, and i' from 0 to ∞, except that the constants B^0_0 and D_0 are segregated from the sums. Before tabulation, the expression for ν was transformed into an expression for $\log (1+\nu) = \delta \log r$ by multiplying the expression for ν by Mod. sin 1″ and adding the higher powers of ν where they were appreciable.

For tabulation the perturbations are segregated into their nonsecular and their secular portions.

NONSECULAR PORTION OF THE PERTURBATION.

The nonsecular portion of the expression is:

$$B^0_0 + \Sigma_i \Sigma_{i'} A^i_{i'} \sin (ig - i'g') + \Sigma_i \Sigma_{i'} B^i_{i'} \cos (ig - i'g').$$

For $u\delta z$, $B^0_0 = D_0 = 0$, these constants being contained in the elements g and n, respectively. Let

$$A^i_{i'} = m^i_{i'} \cos M^i_{i'}$$
$$B^i_{i'} = m^i_{i'} \sin M^i_{i'}$$

where $m^i_{i'}$ may always be taken positive. Then the perturbations may be written in the form

$$B^0_0 + \Sigma_i \Sigma_{i'} \ M^i_{i'} \ m^i_{i'} \sin (ig - i'g' + M^i_{i'})$$

or also

$$\Sigma_i \Sigma_{i'} \ m^i_{i'} \sin ig \cos (M^i_{i'} - i'g') + \Sigma_i \Sigma_{i'} \ m^i_{i'} \cos ig \sin (M^i_{i'} - i'g')$$

if B^0_0 be omitted for the present.

As a first step in the construction of the tables each coefficient $m^i_{i'}$ and angle $M^i_{i'}$ were computed from the corresponding coefficients $A^i_{i'}$ and $B^i_{i'}$ of $\sin (ig - i'\mathrm{g}')$ and $\cos (ig - i'g')$.

For a particular value of i the foregoing double sum becomes

$$\sin ig \ \Sigma_{i'} m^i_{i'} \cos (M^i_{i'} - i'g') + \cos ig \ \Sigma_{i'} m^i_{i'} \sin (M^i_{i'} - i'g')$$

where i is to be taken both positive and negative, while i' is always positive.

Let

$a_{+(i)}$ represent the coefficient of $\sin ig$.
$a_{-(i)}$ represent the coefficient of $\sin (-ig)$.
$b_{+(i)}$ represent the coefficient of $\cos ig$.
$b_{-(i)}$ represent the coefficient of $\cos (-ig)$.

Then the nonsecular portion of the perturbations becomes for a particular numerical value of i, i now positive only,

$$\begin{aligned} n\delta z &= a_{+(i)} \sin ig + a_{-(i)} \sin(-ig) + b_{+(i)} \cos ig + b_{-(i)} \cos(-ig) \\ &= (a_{+(i)} - a_{-(i)}) \sin ig + (b_{+(i)} + b_{-(i)}) \cos ig \\ &= a_i \sin ig + b_i \cos ig \end{aligned}$$

where

$$\begin{aligned} a_i &= \Sigma_{i'} m^{+i}_{i} \cos(M^{+i}_{i'} - i'g') - \Sigma_{i'} m^{-i}_{i'} \cos(M^{-i}_{i'} - i'g') \\ b_i &= \Sigma_{i'} m^{+i}_{i'} \sin(M^{+i}_{i'} - i'g') + \Sigma_{i'} m^{-i}_{i'} \sin(M^{-i}_{i'} - i'g') \end{aligned}$$

if B^0_0 be again omitted in ν and $u/\cos i$.

The a_i and b_i are therefore functions of the original $A^i_{i'}$ and $B^i_{i'}$ coefficients and of the argument g'. They are tabulated for each positive value of i at intervals of 6° of g' from $g'=0$ to $g'=360°$, or where the perturbations vary rapidly at intervals of 3°. The difference in the a_i and b_i for one degree is also given, higher differences having been considered when necessary. The constant B^0_0 occurring in ν and $u/\cos i$ is included in b_0. It is not necessary to compute a_0 since this is multiplied by $\sin 0 \times g$.

SECULAR PORTION OF THE PERTURBATIONS.

This is of the form

$$T\{D_0 + \Sigma_i C_i \sin ig + \Sigma_i D_i \cos ig\}$$

where $T = t - t_0$ in Julian years, and may be written

$$Tc$$

where

$$c = D_0 + \Sigma_i C_i \sin ig + \Sigma_i D_i \cos ig.$$

c is a function of g and is tabulated for every 6° thereof in Table V.

g was kept explicit in preference to g', as more terms could thus be combined in the tabulated values of a_i and b_i. These coefficients were also found to converge more rapidly with g explicit.

The complete tabulation of the perturbations of this group of eight planets is, therefore, in the form

$$\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$$

for each of the components $n\delta z$, $\log(1+\nu) = \delta \log r$, and $u/\cos i$.

ARRANGEMENT OF THE TABLES.

Table I gives the values of the mean anomaly g for January 0.0 of every common year and for January 1.0 of every leap year from the date of discovery to 1930, and their changes for the different months and days.

Table II gives the coefficients a_i and b_i of the periodic parts of the perturbation $n\delta z$ with the argument g' in units of 0°.001 and one decimal thereof.

Table III gives the coefficients a_i and b_i of the periodic parts of the perturbation $\log(1+\nu) = \delta \log r$ with the argument g' in units of the fifth place and one decimal thereof.

Table IV gives the coefficients a_i and b_i of the periodic parts of the perturbation $u/\cos i$ with the argument g' in units of 0°.001 and one decimal thereof.

Table V gives the coefficients c of the secular parts of the perturbations for all three components with the argument g.

Table VI gives the constants for the equator for the beginning of every year from the date of discovery to 1930, inclusively of the logarithms of the quantities $\cos a$, $\cos b$, and $\cos c$, by which the perturbation $\delta\beta$ must be multiplied to obtain the corrections Δx, Δy, and Δz to the heliocentric equatorial coördinates x, y, and z.

DIRECTIONS FOR COMPUTING THE PERTURBATION $n\delta z$, $\delta \log r=\log(1+\nu)$, and $\delta\beta$.

The perturbations $n\delta z$, $\delta \log r$, and $u/\cos i$ are each of the form

$$\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$$

Hence the following directions apply alike to each of the three components:

Let t_0 be the epoch of the mean anomaly g_0, and let t be the date for which the perturbations are to be computed. Let g' be *Jupiter's* mean anomaly at the date. Let g be the planet's undisturbed mean anomaly at the date. For the date t take g' and g from tables A and I, respectively. To form the argument g of the perturbations in Tables II–IV, apply to Table I the correction $\varDelta\pi=\pi-\mathring{\pi}_0$. (See p. 203.)

Form as many multiples of the corrected g as there are subscripts i in the tables of a_i and b_i, Tables II–IV.

Express $T=t-t_0$ in Julian years and decimals thereof.

With argument g' take a_i and b_i, the coefficients of the periodic terms, from Tables II–IV.

With argument g take the secular terms c from Table V.

By means of the Traverse Tables B form the periodic terms:

$$a_i \sin ig \text{ and } a_i \cos ig$$

Form the secular terms $c(t-t_0)=cT$.

Sum the periodic terms and the secular terms for each component.

Compute $\delta\beta=\dfrac{a}{57.3}\,\dfrac{u}{\cos i}$.

The disturbed mean anomaly is

$$M=nz=g+n\delta z.$$

EXAMPLE.

As an example for the use of the tables of this group of eight planets, the perturbations of (179) *Klytaemnestra* will be computed for 1907, September 26.5, Berlin mean time.

	g, Table I	g', Table A.		
1907 .0	302°31498	78°06	$t-t_0$	+14. 1 years.
Sept. 0.0	46. 72370	20. 191	g	353°66
26.0	4. 99924	2. 161	2g	347. 32
0. 5	0. 09614	0. 042	3g	340. 99
g, g'	354. 1341	100. 454	4g	334. 65
$\varDelta\pi$	− 0. 4719		5g	328. 31
Arg. g, g'	353. 662	100. 454	6g	321. 97

PERTURBATIONS.

Arg. g'.	$n\delta z$		$\log(1+\nu)$		$u/\cos i$	
	Table II, Unit=$0\overset{\circ}{.}001$.		Table III, Unit=0. 00001.		Table IV, Unit=$0\overset{\circ}{.}001$.	
i	a_i	b_i	a_i	b_i	a_i	b_i
0		− 9. 3		+ 0. 1		+3. 1
1	−203. 2	+507. 5	+ 50. 3	+11. 4	+7. 5	+1. 9
2	−136. 7	+249. 1	+106. 6	+58. 4	+5. 8	−4. 2
3	− 24. 3	+ 17. 9	+ 10. 9	−12. 3	+1. 6	−3. 2
4	+ 1. 4	− 5. 3	− 2. 6	− 0. 8		
5	− 1. 5	+ 0. 7	+ 0. 4	+ 1. 0		
6	+ 0. 7	+ 0. 3				

Arg. g.—TABLE V

c	−2. 49	+0. 01	+0. 02

FROM TRAVERSE TABLES, TABLE B.

i	$n\delta z$		$\log(1+\nu)$		$u/\cos i$	
	$a_i \sin ig$	$b_i \cos ig$	$a_i \sin ig$	$b_i \cos ig$	$a_i \sin ig$	$b_i \cos ig$
0		− 9. 3		+ 0. 1		+3. 1
1	+22. 4	+504. 4	− 5. 5	+11. 3	−0. 8	+1. 9
2	+30. 0	+242. 9	−23. 4	+57. 0	−1. 3	−4. 1
3	+ 7. 9	+ 16. 9	− 3. 6	−11. 6	−0. 5	−3. 0
4	− 0. 6	− 4. 8	+ 1. 1	− 0. 7		
5	+ 0. 8	+ 0. 6	− 0. 2	+ 0. 8		
6	− 0. 4	+ 0. 2				
	+60. 1	+750. 9	−31. 6	+56. 9	−2. 6	−2. 1
Sum $c(t-t_0)$	+811. 0 − 35. 1		+ 25. 3 + 0. 1		−4. 7 +0. 3	
	+775. 9 $=+0\overset{\circ}{.}7759$ $=n\delta z$		+ 25. 4 =+0. 000254 $=\log(1+\nu)$		−4. 4 $=-0\overset{\circ}{.}0044$ $= u/\cos i$	

The perturbations are:

$$n\delta z = +0\overset{\circ}{.}7759;\ \log(1+\nu) = \delta \log r = +0.00025;\ \delta\beta = \frac{a}{57.3}\frac{u}{\cos i} = -0.00023$$

and

$$M = nz = g + n\delta z = 354\overset{\circ}{.}9100$$

As an example for the computation of a geocentric position with the aid of M, $\log(1+\nu) = \delta \log r$, and $\delta\beta$, the geocentric right ascension and declination of this planet, referred to the mean equinox and ecliptic 1907.0, are derived for the date of the perturbations on page 215.

TABLES OF THREE PLANETS.—(101) HELENA, (103) HERA, AND (119) ALTHAEA.

The elements of these planets are osculating[a] elements.

The perturbations are developed in sines and cosines of $(ig-i'g')$. The form of development is the same as for the foregoing group of eight planets, see page 202.

Before tabulation, the expression for ν was transformed into an expression for log $(1+\nu)=\partial \log r$ by multiplying the expression for ν by Mod. sin 1″ and adding the higher powers of ν wherever they were appreciable. Similarly the expression for $u/\cos i$ was transformed into an expression for $\partial\beta$ by multiplying the expression for $u/\cos i$ by a sin 1″.

For tabulation the perturbations are segregated into their nonsecular and their secular portions.

NONSECULAR PORTION OF THE PERTURBATIONS.

In accordance with the plan adopted by the original computers for tabulating the nonsecular perturbations of these planets, all terms having $(ig-i'g')$ or multiples thereof for particular values of i and i' as argument are tabulated under the single argument $(ig-i'g')$ for the three components in Tables II, III, and IV, respectively. The original numerical designation of the arguments $(ig-i'g')$ for particular values of i and i' has also been adhered to, and *differs* for the three planets. The numerical designation of the different arguments and the numbers added to make all quantities positive are given separately for each planet. In Tables II, III, and IV the headings of the terms depending on a particular argument i are $(n\partial z)_i$, $(\partial \log r)_i$, and $(\partial\beta)_i$.

SECULAR PORTION OF THE PERTURBATIONS.

This is tabulated in the same manner as for the preceding group of eight planets, in Table V, and is denoted by $(n\partial z)_t$, $(\partial \log r)_t$, and $(\partial\beta)_t$, respectively. The argument to be used for each planet is indicated in the table. $(n\partial z)_t$, $(\partial \log r)_t$, and $(\partial\beta)_t$, must be multiplied by $T=t-t_0$ in Julian years.

From the sum of the perturbations for each component taken from Tables II–V must be subtracted the sum of the constants added to make all quantities positive. The constant terms of the developments are not included in the tables and must also be applied. For each component the algebraic sum of the constants to be applied is given separately with the tables of each planet, and is designated by c_z, c_r, c_β for the three components, respectively.

Besides the constants introduced to make all the values of $\partial \log r$ positive, and the constant corresponding to the absolute term in the development of ν, c_r also contains the correction which it is necessary to apply to $\partial \log r$ when the geocentric places are computed with the value of the semimajor axis a which corresponds to the mean mean motion. It is to be observed that in HANSEN's theory the disturbed positions must be computed with constant elements. The constant in the development of ν corresponds to the value of the semimajor axis a, computed from the osculating mean motion. The value a, however, given with the elements and in the auxiliary quantities in these tables, corresponds to the mean mean motion. That part of c_r which is due to the introduction of the semimajor axis a, corresponding to the mean mean motion in place of the osculating value of a, is indicated for each planet.

Thus, in the tables for *Althaea*, page 348, the sum of the constants added to make all numbers of Table III positive is 107.5 units of the fifth decimal place. The constant term in ν, page 350, is $+27''.4$, and the correction of this constant necessitated by the use of the mean instead of the osculating value of the semimajor axis a is $-38''.4$. The algebraic sum of this latter correction and of the constant in ν is $-11''.0$, or $-11''.0 \sin 1''$ Mod. $=-2.3$ units of the fifth decimal place in $\partial \log r$. The total number of units of the fifth decimal place to be subtracted from $\partial \log r$ is, therefore, 110 units $=c_r$, as given on page 348, of the tables of (119) *Althaea*.

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[a] It is to be observed, however, that the elements g_0 and n contain the constant and the nontrigonometrical secular parts of $n\partial z$, respectively.

The complete tabulation of the perturbations of (101) *Helena*, (103) *Hera*, and (119) *Althaea*, is, therefore, as follows

$$\begin{aligned} n\delta z &= (n\delta z)_1 + (n\delta z)_2 + \text{etc} \ldots\ldots + (n\delta z)_t T - c_z \\ \delta \log r &= (\delta \log r)_1 + (\delta \log r)_2 + \text{etc} \ldots\ldots + (\delta \log r)_t T - c_r \\ \delta_i\beta &= (\delta_i\beta)_1 + (\delta_i\beta)_2 + \text{etc} \ldots\ldots + (\delta_i\beta)_t T - c_\beta \end{aligned}$$

ARRANGEMENT OF THE TABLES.

Table I gives the values of the mean anomaly g for January 0.0 of every common year, and for January 1.0 of every leap year from the year of discovery to 1930, and its variations for the different months and days.

Table II gives the periodic parts of the perturbations of the mean anomaly, designated by $(n\delta z)_1$, $(n\delta z)_2$, etc., for arguments 1, 2, etc., in units of 0°001 and one decimal thereof.

Table III gives the periodic parts of the perturbations of the radius vector, designated by $(\delta \log r)_1$, $(\delta \log r)_2$, etc., for arguments 1, 2, etc., in units of the fifth place and one decimal thereof.

Table IV gives the periodic parts of the perturbations u cos i multiplied by a sin $1''$, designated by $(\delta_i\beta)_1$, $(\delta_i\beta)_2$, etc., in units of the fifth decimal place and one decimal thereof.

Table V gives the perturbations of the mean anomaly, of the radius vector, and of the third coordinate, arising from the terms to be multiplied by T, the time from the epoch expressed in Julian years. These coefficients of the secular parts of the perturbations are designated by $(n\delta z)_t$, $(\delta \log r)_t$, and $(\delta_i\beta)_t$.

Table VI contains the constants for the equator for the beginning of every year from the date of discovery to 1930, inclusively of the logarithms of the quantities cos a and cos b and cos c, by which the perturbation $\delta_i\beta$ must be multiplied to obtain the corrections Δx, Δy, Δz to the heliocentric equatorial coordinates x, y, and z.

DIRECTIONS FOR COMPUTING THE PERTURBATIONS $n\delta z$, $\delta \log r = \log(1+\nu)$, AND $\delta\beta$.

Let t_0 be the epoch of the mean anomaly g_0, and let t be the date for which the perturbations are to be computed. Let g' be *Jupiter's* mean anomaly at the date. Let g be the planet's undisturbed mean anomaly at the date. For the date t take g' and g from the Tables A and I, respectively. To form the argument g of the perturbations in tables II–V, apply to Table I the correction $\Delta\pi = \pi - \pi_0$. (See p. 203.)

Form the necessary arguments $(ig - i'g')$ for Tables II to V as indicated on pages 327, 338, or 348.

Express $T = t - t_0$ in Julian years and decimals thereof.

From Tables II–IV take the periodic parts $(n\delta z)_i$, $(\delta \log r)_i$, and $(\delta_i\beta)_i$ of the perturbations with the arguments $(ig - i'g')$, in accordance with their designations on pages 327, 338, or 348.

From Table V take the values of $(n\delta z)_t$, $(\delta \log r)_t$, and $(\delta_i\beta)_t$, to be multiplied by $T = (t - t_0)$ in Julian years and perform the multiplication.

Form the sums $n\delta z$, $\delta \log r$, and $\delta_i\beta$, of the periodic and secular parts of the perturbations.

Subtract the constants c_z, c_r, and c_β, given on pages 327, 338, or 348.

The disturbed mean anomaly is:

$$M = nz = g + n\delta z.$$

EXAMPLE.

As an example of the use of the tables of (101) *Helena*, (103) *Hera*, and (119) *Althaea*, we shall compute the perturbations of (119) *Althaea* for 1907, December 2.7535, Berlin Mean Time.

	g, Table I.	g', Table A.		
1907.0	324°83910	78°06	t	1907. 922
Dec. 0.0	79. 36264	27. 752	t_0	1894. 643
2.0	0. 47523	0. 166	$t-t_0$	+13.28 Julian years.
0.7535	0. 17904	0. 063		
g, g'	44. 8560	106. 04		
$\Delta\pi$	− 0. 0261			
Arg. g, g'	44. 830	106. 04		

PERTURBATIONS.

Arguments.			$(n\partial z)_i$ Table II, Unit=0°001.	$(\partial \log r)_i$ Table III, Unit=0.00001.	$(\partial\beta)_i$ Table IV, Unit=0.00001.
g	44°83	1	217. 6	21. 5	25. 9
$g-\ g'$	298. 79	2	90. 6	71. 2	5. 7
$g-3\ g'$	86. 71	3	224. 6	3. 9	11. 4
$g-2\ g'$	192. 75	4	39. 0	18. 0	14. 2
$2\ g-3\ g'$	131. 54	5	1. 4	1. 7	28. 1
$2\ g-\ g'$	343. 62	6	2. 1	1. 6	4. 6
$3\ g-2\ g'$	282. 41	7	0. 0	1. 2	
$3\ g-4\ g'$	70. 33	8	0. 5	0. 0	3. 5
$4\ g-3\ g'$	221. 20	9	0. 1		
$-\ g'$	253. 96	10	0. 1	1. 3	27. 2
$-g-\ g'$	209. 13	11	0. 5		3. 9
		Sum	+ 576. 5	+120. 4	+124. 5
		$c\ (t-t_0)$	− 17. 8	− 2. 7	− 69. 5
		c_z, c_r, c_β	− 407. 2	−109. 8	−161. 4
			+ 151. 5	+ 7. 9	−106. 4
			= $(n\partial z)$	$=\partial \log r$	$=\partial\beta$

Arg. 1, c=$(n\partial z)_t$, etc., Table V.

$(n\partial z)_t$	$(\partial \log r)_t$	$(\partial\beta)_t$
−1. 34	−0. 20	−5. 23

The perturbations are

$$n\partial z = +0^\circ\!.1515;\ \partial \log r = +0.00008;\ \partial\beta = -0.00106$$

and

$$M = nz = g + n\partial z = 45^\circ\!.0075.$$

For an example for the computation of a geocentric position with the aid of M, $\partial \log r$, and $\partial\beta$, see the example of (179) *Klytaemnestra*, page 215.

TABLES OF (93) MINERVA.

The elements of *Minerva* are osculating[a] elements. The tables of *Minerva* are reproduced from a manuscript by EICHELBERGER. The original tables were merely abridged and rearranged to conform as much as possible to the general plan adopted for the tables of the minor planets discovered by WATSON.

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[a] It is to be observed, however, that the elements g_0 and n contain the constant and nontrigonometrical parts of $n\partial z$, respectively.

The tables are based upon the "General Perturbations of Minerva by Jupiter," published by **Eichelberger** in the Memoirs of the National Academy of Sciences, Volume III, Third Memoir.

Except for some minor changes, due mainly to the adoption of a different epoch and of a slightly different value of *Jupiter's* mass, the perturbations and elements given on pages 361, 362, and 363 are the same as those originally published by **Eichelberger**.

The expressions $n\delta z$, ν, and $u/\cos i$ are developed in the form:

$$\begin{aligned} n\delta z = nz - g_0 - nt = {} & \Sigma_i\Sigma_{i'}A^i_{i'} \sin\,[(i-i'\mu)\varepsilon - i'(g'-\mu g)] + \\ & \Sigma_i\Sigma_{i'}B^i_{i'} \cos\,[(i-i'\mu)\varepsilon - i'(g'-\mu g)] + \\ & (t-t_0)\{\Sigma_i C_i \sin i\varepsilon + \Sigma_i D_i \cos {}_i\varepsilon\} \end{aligned}$$

$$\begin{aligned} \nu = {} & B^0_0 + \Sigma_i\Sigma_{i'}A^i_{i'} \sin\,[(i-i'\mu)\varepsilon - i'(g'-\mu g)] + \\ & \Sigma_i\Sigma_{i'}B^i_{i'} \cos\,[(i-i'\mu)\varepsilon - i'(g'-\mu g)] + \\ & (t-t_0)\{D_0 + \Sigma_i C_i \sin i\varepsilon + \Sigma_i D_i \cos i\varepsilon\} \end{aligned}$$

$$\begin{aligned} u \cos i = {} & B^0_0 + \Sigma_i\Sigma_{i'}A^i_{i'} \sin\,[(i-i'\mu)\varepsilon - i'(g'-\mu g)] + \\ & \Sigma_i\Sigma_{i'}B^i_{i'} \cos\,[(i-i'\mu)\varepsilon - i'(g'-\mu g)] + \\ & (t-t_0)\{D_0 + \Sigma_i C_i \sin i\varepsilon + \Sigma_i D_i \cos i\varepsilon\} \end{aligned}$$

i varying from $-\infty$ to $+\infty$, and i' from 0 to ∞, except that the constants B^0_0 and D_0 are segregated from the double sums.

Before tabulation, the expression for ν was transformed into an expression for $\log(1+\nu) = \delta \log r$ by multiplying the expression for ν by Mod. sin 1″, the higher powers of ν being inappreciable within the accuracy of the tables. Similarly the expression for $u/\cos i$ was transformed into an expression for $\delta\beta$ by multiplying the expression for $u/\cos i$ by $a \sin 1''$.

For tabulation the perturbations are segregated into their secular and nonsecular portions. The long period term in $n\delta z$ is

$$+11''.1 \cos\,[5\varepsilon - 13(g' + \mu e \sin \varepsilon)] + 4''.0 \sin\,[5\varepsilon - 13(g' + \mu e \sin\varepsilon)]$$

and is also segregated from the periodic portion.

NONSECULAR PORTION OF THE PERTURBATIONS.

The nonsecular portion of the perturbations has the form

$$B^0_0 + \Sigma_i\Sigma_{i'}A^i_{i'} \sin\,[(i-i'\mu)\varepsilon - i'(g'-\mu g)] + \Sigma_i\Sigma_{i'}B^i_{i'} \cos\,[(i-i'\mu)\varepsilon - i'(g'-g)]$$

for all three components. For $n\delta z$, B^0_0 and $D_0 = 0$, these constants being contained in the elements g_0 and n, respectively.

By writing the argument

$$(i-i'\mu)\varepsilon - i'(g'-\mu g)$$

in the form

$$i'(\varepsilon - g' - \mu e \sin\varepsilon) + (i-i')\varepsilon = i'N + (i-i')\varepsilon$$

where

$$N = (g-g') + (\varepsilon - g - \mu e \sin\varepsilon) = (g-g') + \Delta(g-g')$$

and where

$$\Delta(g-g') = \varepsilon - g - \mu e \sin\varepsilon$$

we obtain for the nonsecular portion of the perturbations the expression

$$\Sigma_i\Sigma_{i'}A^i_{i'} \sin\,[i'N + (i-i')\varepsilon] + \Sigma_i\Sigma_{i'}B^i_{i'} \cos\,[i'N + (i-i')\varepsilon]$$

where B^0_0 is omitted for the present.

If we write (i) for $(i-i')$, and expand the sines and cosines, the expression becomes for a particular value of (i)

$$\begin{aligned} & \Sigma_{i'}A^{(i)+i'}_{i'} \sin i'N \cos (i)\varepsilon + \Sigma_{i'}A^{(i)+i'}_{i'} \cos i'N \sin (i)\varepsilon \\ & + \Sigma_{i'}B^{(i)+i'}_{i'} \cos i'N \cos (i)\varepsilon - \Sigma_i B^{(i)+i'}_{i'} \sin i'N \sin (i)\varepsilon \\ & = \cos (i)\varepsilon\,\Sigma_{i'}[A^{(i)+i'}_{i'} \sin i'N + B^{(i)+i'}_{i'} \cos i'N] + \sin (i)\varepsilon\,\Sigma_{i'}[A^{(i)+i'}_{i'} \cos i'N - B^{(i)+i'}_{i'} \sin i'N] \end{aligned}$$

where, as before, i' is always positive, and where $(i) = (i-i')$ may be either positive or negative.

Let, in the foregoing expression,

$a_{+(i)}$ represent the coefficient of sin $(+(i)\varepsilon)$.
$a_{-(i)}$ represent the coefficient of sin $(-(i)\varepsilon)$.
$b_{+(i)}$ represent the coefficient of cos $(+(i)\varepsilon)$.
$b_{-(i)}$ represent the coefficient of cos $(-(i)\varepsilon)$.

Then the nonsecular portion of the perturbations becomes for a particular value of (i)

$$(a_{+(i)}-a_{-(i)})\sin(i)\varepsilon+(b_{+(i)}+b_{-(i)})\cos(i)\varepsilon$$

where (i) is always positive.

Changing the notation by letting

$$a_i=(a_{+(i)}-a_{-(i)});\ b_i=(b_{+(i)}-b_{-(i)})$$

we obtain the following form for the nonsecular portion of the perturbations for a particular value of (i),

$$a_i\sin i\varepsilon+b_i\cos i\varepsilon$$

where

$$a_i=\Sigma_{i'}[A^{+(i)+i'}_{i'}\cos i'N-B^{+(i)+i'}_{i'}\sin i'N]-\Sigma_{i'}[A^{-(i)+i'}_{i'}\cos i'N-B^{-(i)+i'}_{i'}\sin i'N]$$
$$b_i=\Sigma_{i'}[A^{+(i)+i'}_{i'}\sin i'N+B^{+(i)+i'}_{i'}\cos i'N]+\Sigma_{i'}[A^{-(i)+i'}_{i'}\sin i'N+B^{-(i)+i'}_{i'}\cos i'N]$$

The nonsecular portion of the perturbations have thus been reduced to the form

$$\Sigma_i a_i\sin i\varepsilon+\Sigma_i b_i\cos i\varepsilon,\ i \text{ always positive.}$$

The a_i and b_i coefficients are functions of the original $A^{i}_{i'}$ and $B^{i}_{i'}$ coefficients, as given on pages 362, 363, and of the argument N, where

$$N=g-g'+\Delta(g-g')$$

and

$$\Delta(g-g')=\varepsilon-g-\mu e\sin\varepsilon.$$

The a_i and b_i coefficients are tabulated for the nonsecular parts of the perturbations with the argument N in Tables II, III, and IV for all three components, the intervals being so chosen as to facilitate interpolation. The difference for one degree is also given wherever necessary. The constant B^0_0 occurring in ν and $u/\cos i$, is included in b_0. It is not necessary to compute a_0 since this is multiplied by $\sin 0\times g$.

SECULAR PORTION OF THE PERTURBATIONS.

This is of the form

$$T\{D_0+\Sigma_i C_i\sin i\varepsilon+\Sigma_i D_i\cos i\varepsilon\}$$

where $T=t-t_0$, and may be written

$$(\Delta b_0)_t+\Sigma_i(\Delta a_i)_t\sin i\varepsilon+\Sigma_i(\Delta b_i)_t\cos i\varepsilon$$

where

$$(\Delta b_0)_t=TD_0;\ (\Delta a_i)_t=TC_i;\ (\Delta b_i)_t=TD_i.$$

The secular terms are thus reduced to the same form as the nonsecular terms. The values of $(\Delta b_0)_t$, $(\Delta a_i)_t$, and $(\Delta b_i)_t$ are tabulated in Table V for all three components for the beginning of every second year from 1865–1930, together with the changes for various intervals, to facilitate their computation for any date within the table. The term $(\Delta b_0)_t$ in $n\delta z$ is contained in the element n, and need not be tabulated. This heading has, therefore, been adopted for the long-period term.

THE LONG-PERIOD TERM IN $n\delta z$.

The long-periodic term in $n\delta z$ has been computed for every two years from 1865–1930, and is tabulated in Table V in the block $n\delta z$ under the heading $(\Delta b_0)_t$. Owing to its slow variation its changes are not given.

The complete tabulation of the perturbations of *Minerva* is, therefore, in the form

$$(\Delta b_0)_t+\Sigma_i[a_i+(\Delta a_i)_t]\sin i\varepsilon+\Sigma_i[b_i+(\Delta b_i)_t]\cos i\varepsilon$$

for each of the components $n\delta z$, $\log(1+\nu)=\delta\log r$, and $\delta\beta$.

ARRANGEMENT OF THE TABLES.

Table I gives the values of the mean anomaly g and of $(g-g')$ for January 0.0 of every common year and for January 1.0 of every leap year from 1865 to 1930, and their changes for the different months and days.

Table II gives the coefficients a_i and b_i of the periodic parts of the perturbations $n\delta z$, with the argument N, in units of 0°.001 and one decimal thereof, where

$$N=(g-g')+\Delta(g-g').$$

Table III gives the coefficients a_i and b_i of the periodic parts of the perturbations $\log(1+\nu)=\delta\log r$ with the argument N in units of the fifth decimal place and one decimal thereof.

Table IV gives the coefficients a_i and b_i of the periodic parts of the perturbations $\delta\beta$ with the argument N in units of the fifth place and one decimal thereof.

Table V gives the coefficients $(\Delta b_0)_t$, $(\Delta a_i)_t$, and $(\Delta b_i)_t$ of the secular parts of the perturbations for all three components for the beginning of every second year from 1865 to 1930, together with their changes for one year, thirty-one days, thirty days, twenty-eight days, and one day. The coefficient $(\Delta b_0)_t$ for $n\delta z$ represents the long-period term.

Table VI gives the constants for the equator for the beginning of every year from date of discovery to 1930, inclusively of $\cos a$, $\cos b$, $\cos c$, by which the perturbations $\delta\beta$ must be multiplied to obtain the corrections Δx, Δy, Δz to the heliocentric equatorial coordinates x, y, and z.

Table VII gives the values of $\Delta(g-g')=\varepsilon-g-\mu e\sin\varepsilon$ and the values of the reduction $(\varepsilon-g)$ from mean to eccentric anomaly for the argument g.

DIRECTIONS FOR COMPUTING THE PERTURBATIONS $n\delta z$, $\delta\log r=\log(1+\nu)$, and $\delta\beta$.

Let t be the date for which the perturbations are to be computed. Let g' be *Jupiter's* mean anomaly at the date. Let g be the planet's undisturbed mean anomaly at the date. For the date t take g and $g-g'$ from Table I. Greenwich mean time is used for this table.

With $g+\Delta\pi$ as argument take $\Delta(g-g')$ and $(\varepsilon-g)$ from Table VII.

Form the multiples of ε up to 5ε, where $\varepsilon=g+(\varepsilon-g)$.

With $N=(g-g')+\Delta(g-g')+\Delta\pi$ as argument take the coefficients a_i, b_i of the periodic part of the perturbations from Tables II, III, and IV, where i has every value from 0 to 5.

For the date t take the coefficients $(\Delta a_i)_t$, $(\Delta b_i)_t$ from Table V for each of the three components. Form the coefficients $(a)_i=a_i+(\Delta a_i)_t$ and $(b)_i=b_i+(\Delta b_i)_t$.

By means of the traverse tables, Tables B, form the products

$$[a_i+(\Delta a_i)_t]\sin i\varepsilon \text{ and } [b_i+(\Delta b_i)_t]\cos i\varepsilon.$$

Form the sum of the products for each component. The resulting sums are the desired values of $n\delta z$, $\delta\log r$, and $\delta\beta$. The disturbed mean anomaly is $M=nz=g+n\delta z$.

EXAMPLE.

As an example of the use of the tables, the perturbations of *Minerva* will be computed for 1874, January 15.0, Greenwich mean time.

	Table I.		Table VII.			
	g	$g-g'$	Argument g.			
1874.0	199°.86574	43°.455	$\Delta(g-g')$	−1°.717	g	203°.165
Jan. 0.0	0.00000	0.000	$(\varepsilon-g)$	−2.795	$(\varepsilon-g)$	−2.803
15 days	3.23301	1.987	$(g-g')$	45.442	ε	200.36
g. g′	203.09875	45.442	$\Delta(g-g')$	−1.717	2ε	40.72
$\Delta\pi$	+0.0666		$\Delta\pi$	+0.067	3ε	241.09
Arg. g	203.1654				4ε	81.45
			Arg. N	43.792	5ε	281.81

PERTURBATIONS.

Arg. N	$n\delta z$		$\log(1+\nu)$		$\delta\beta$	
	Table II, Unit=0°.001.		Table III, Unit=0.00001.		Table IV, Unit=0.00001.	
i	a_i	b_i	a_i	b_i	a_i	b_i
0		−69.8		+30.4		−31.4
1	+199.8	−329.5	−22.3	+70.0	+9.2	+21.2
2	−100.0	−34.0	−3.4	−6.0	+22.3	+51.9
3	−133.5	−13.6	+0.4	−7.8	−2.0	+9.3
4	−4.9	+1.6	+0.3	−2.4	+1.6	−2.6
5	+2.6	+3.9	+0.1	−0.2	−0.1	−0.9

TABLE V (T=1874, JAN. 15.0).

i	$(\Delta a_i)_t$	$(\Delta b_i)_t$	$(\Delta a_i)_t$	$(\Delta b_i)_t$	$(\Delta a_i)_t$	$(\Delta b_i)_t$
0		+2.9				+0.3
1	−0.7	+3.9	+1.5	+0.3	−11.9	−1.8
2		−0.1				

Applying these secular terms to the corresponding periodic coefficients just preceding, and then multiplying by the sines and cosines of the proper multiples of ε, we obtain the following perturbations by means of the Traverse Tables, Tables B:

FROM TRAVERSE TABLES, TABLE B.

i	$n\delta z$		$\log(1+\nu)$		$\delta\beta$	
	$a_i \sin i\varepsilon$	$b_i \cos i\varepsilon$	$a_i \sin i\varepsilon$	$b_i \cos i\varepsilon$	$a_i \sin i\varepsilon$	$b_i \cos i\varepsilon$
0		−66.8		+30.4		−31.1
1	−69.3	+305.4	+7.3	−66.0	+0.9	−17.8
2	−65.1	−25.9	−2.2	−4.6	+14.5	+39.4
3	+116.7	+6.6	−0.3	+3.8	+1.7	−4.5
4	−4.8	+0.3	+0.3	−0.4	+1.6	−0.4
5	−2.5	+0.8	−0.1		+0.1	−0.2
	−25.0	+220.4	+4.9	−36.8	+18.8	−14.6
Sum	+195.4		−31.9		+4.2	

The perturbations are

$$n\delta z = +0^\circ.1954;\quad \log(1+\nu) = -0.00032;\quad \delta\beta = +0.00004;$$

and

$$M = nz = g + n\delta z = 203^\circ.2942.$$

For an example for the computation of a geocentric position with the aid of M, $\log(1+\nu) = \delta \log r$, and $\delta\beta$, see the example of (179) *Klytaemnestra*, page 215.

DIRECTIONS FOR THE COMPUTATION OF A GEOCENTRIC POSITION REFERRED TO THE MEAN EQUINOX AND EQUATOR FOR THE BEGINNING OF THE YEAR, FROM M, δ log r, AND $\delta\beta$.

To the undisturbed g, *i. e.*, the value taken directly from Table I, the perturbations $n\delta z$ have been added to form the disturbed mean anomaly,

$$M = nz = g + n\delta z.$$

From M, the true anomaly $\bar{f}$ may be conveniently computed by means of TIETJEN's "Tafe zur Berechnung der Wahren Anomalie." [a]

Compute the radius vector corresponding to $\bar{f}$ by the formula

$$\bar{r} = \frac{p}{1 + e \cos \bar{f}}$$

where p and e are to be found with the Auxiliary Quantities.

Compute r, the disturbed radius vector by the formula

$$r = \bar{r}(1 + \nu).$$

Take from the table of the Constants for the Equator, Table VI, the values A', B', C', log sin a, log sin b, log sin c, for the beginning of the year and compute the heliocentric coordinates by the formulae,

$$x = r \sin a \sin (A' + \bar{f}).$$
$$y = r \sin b \sin (B' + \bar{f}).$$
$$z = r \sin c \sin (C' + \bar{f}).$$

Compute

$$\varDelta x = \cos a \ \delta\beta$$
$$\varDelta y = \cos b \ \delta\beta$$
$$\varDelta z = \cos c \ \delta\beta$$

where cos a, cos b, cos c, are given in Table VI.

Form the geocentric coordinates by the formulae,

$$\xi = x + \varDelta x + X$$
$$\eta = y + \varDelta y + Y$$
$$\zeta = z + \varDelta z + Z$$

in which X, Y, and Z are the solar coordinates at the date referred to the mean equator and equinox at the beginning of the year.

Compute α and δ for the beginning of the year in the usual way from

$$\rho \cos \delta \cos \alpha = \xi$$
$$\rho \cos \delta \sin \alpha = \eta$$
$$\rho \sin \delta = \zeta$$

EXAMPLE.

As an example, the geocentric right ascension and declination of (179) *Klytaemnestra* will be computed for September 26.5, 1907, Berlin mean time, referred to the mean equinox and ecliptic for the beginning of the year, with the aid of the perturbations derived on page 206, etc.

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[a] Veröffentlichungen des Königlichen Astronomischen Rechen-Instituts zu Berlin. No. 1.

		°				
g		354. 1341			$\log\cos\bar{f}$	9. 99728
$n\delta z$	+	0. 7759			$\log e\cos\bar{f}$	9. 04693
$g+n\delta z=M_1$		354. 9100			$\log(1+e\cos\bar{f})$	0. 04587
Arg. $M_1=2\pi-M_1$		5. 0900		Tietjen: "Tafel zur Berechnung der Wahren Anomalie."[a]	$\log r$	0. 42182
dM°	+	0. 0900			$\log(1+\nu)$	26
dM'	+		5. 40		$\log r$	0. 42208
ϕ		6. 4371				
$d\phi'$	+		6. 23			
$dv/d\phi$	+	0. 2320				
$(D\,dv/d\phi)dM'$	+	42			$\log\delta\beta$	6. 358n
$\Delta\phi\,d\phi'/20$	+	6				
$\Sigma d\phi'$	+		1. 48			
$d(v-M)/dM$	+	0. 2542				
$1/2\,D_m dM^\circ$		0			log e, log p, and log a from elements and auxiliary quantities, page 313.	
$\Sigma dM'$	+		1. 37			
$v-M$	+	1	16. 55			
v_1-M_1		1	19. 40			
		1. 3233				
$v_1=\bar{f}$		353. 5867				

[a] Veröffentlichungen des Königlichen Astronomischen Rechen-Instituts zu Berlin, No. 1.

	ξ	η	ζ	
A', B', C'	84°0995	351°2146	12°5988	Table VI.
$A'+\bar{f}$, etc.	77. 6862	344. 8013	6. 1855	
log sin a, etc.	9. 99630	9. 97007	9. 58154	Table VI.
log sin $(A'+\bar{f})$, etc.	9. 98989	9. 41857n	9. 03240	
log x, y, z	0. 40826	9. 81071n	9. 03601	
log cos a, etc.	9. 114n	9. 555n	9. 966	Table VI.
log Δx, Δy, Δz	5. 472	5. 913	6. 321n	
x, y, z	+ 2. 56012	− 0. 64674	+ 0. 10864	
Δx, Δy, Δz	+ 3	+ 8	− 21	
X, Y, Z	− 1. 00115	− 0. 04320	− 0. 01875	Berliner Astronomisches Jharbuch, 1907.
ξ, η, ζ	+ 1. 55900	− 0. 68986	+ 0. 08968	

log ξ	0. 19285	log ρ cos δ	0. 23167
log cos α	9. 96118	log cos δ	9. 99940
log sin α	9. 60706	log sin δ	8. 72043
log η	9. 83874n	log ζ	8. 95270
log tg α	9. 64589n	log tg δ	8. 72103
α, 1907.0	336°1319	δ 1907.0	3°0113
	$=22^{h}\ 24^{m}\ 31^{s}7$	log ρ	0. 23227

$$\left.\begin{array}{l} a=22^{h}\ 24^{m}\ 32^{s} \\ \delta=3^\circ\ 0'.7 \end{array}\right\}1907.0$$

TABLE A.—JUPITER'S MEAN ANOMALY. (g′)

Jan. 0.0 of common years; Jan. 1.0 of leap years

Year	g'	Year	g'
	°		°
1863	182. 91	1900	225. 68
B 4	213. 29	1	256. 01
5	243. 57	2	286. 36
6	273. 84	3	316. 71
7	304. 11	B 4	347. 12
B 8	334. 49	5	17. 44
9	4. 82	6	47. 75
1370	35. 18	7	78. 06
1	65. 58	B 8	108. 46
B 2	96. 04	9	138. 79
3	126. 43	1910	169. 12
4	156. 78	1	199. 46
5	187. 10	B 2	229. 88
B 6	217. 47	3	260. 22
7	247. 74	4	290. 54
8	278. 00	5	320. 86
9	303. 28	B 6	351. 26
B 1880	338. 68	7	21. 57
1	9. 02	8	51. 89
2	39. 41	9	82. 22
3	69. 80	B 1920	112. 65
B 4	100. 24	1	143. 01
5	130. 58	2	173. 36
6	160. 89	3	203. 69
7	191. 18	B 4	234. 06
B 8	221. 56	5	264. 33
9	251. 87	6	294. 60
1890	282. 19	7	324. 87
1	312. 53	B 8	355. 26
B 2	342. 97	9	25. 60
3	13. 34	1930	55. 97
4	43. 70	1	86. 36
5	74. 03	B 2	116. 83
B 6	104. 45	3	147. 21
7	134. 76	4	177. 56
8	165. 05	1935	207. 86
1899	195. 36		

Table for beginning of month

Month		g'
		°
Jan.	0.0 1.0	0. 000
Feb.	0.0 1.0	2. 576
Mar.	0.0	4. 902
Apr.	0.0	7. 478
May	0.0	9. 971
June	0.0	12. 547
July	0.0	15. 030
Aug.	0.0	17. 615
Sept.	0.0	20. 191
Oct.	0.0	22. 684
Nov.	0.0	25. 259
Dec.	0.0	27. 752

Change for n days[a]

n	g'	n	g'
	°		°
1	0. 083	16	1. 330
2	0. 166	17	1. 413
3	0. 249	18	1. 496
4	0. 332	19	1. 579
5	0. 416	20	1. 662
6	0. 499	21	1. 745
7	0. 582	22	1. 828
8	0. 665	23	1. 911
9	0. 748	24	1. 994
10	0. 831	25	2. 078
11	0. 914	26	2. 161
12	0. 997	27	2. 244
13	1. 080	28	2. 327
14	1. 163	29	2. 410
15	1. 247	30	2. 493

[a] For dates during January and February of leap years subtract one day before entering the table.

TABLE B.—TRAVERSE TABLES.

Giving the products $a \begin{smallmatrix}\sin\\ \cos\end{smallmatrix} A$ with the arguments a and A.

a	1				2				3				a
A	sin		cos		sin		cos		sin		cos		A
0°	0.00000		1.00000		0.0000		2.0000		0.0000		3.0000		90°
		1745		15		349		3		524		5	
1	0.01745		0.99985		0.0349		1.9997		0.0524		2.9995		89
		1745		46		349		9		523		13	
2	0.03490		0.99939		0.0698		1.9988		0.1047		2.9982		88
		1744		76		349		15		523		23	
3	0.05234		0.99863		0.1047		1.9973		0.1570		2.9959		87
		1742		107		348		22		523		32	
4	0.06976		0.99756		0.1395		1.9951		0.2093		2.9927		86
		1740		137		348		27		522		41	
5	0.08716		0.99619		0.1743		1.9924		0.2615		2.9886		85
		1737		167		348		34		521		50	
6	0.10453		0.99452		0.2091		1.9890		0.3136		2.9836		84
		1734		197		346		39		520		60	
7	0.12187		0.99255		0.2437		1.9851		0.3656		2.9776		83
		1730		228		346		46		519		68	
8	0.13917		0.99027		0.2783		1.9805		0.4175		2.9708		82
		1726		258		346		51		518		77	
9	0.15643		0.98769		0.3129		1.9754		0.4693		2.9631		81
		1722		288		344		58		516		87	
10	0.17365		0.98481		0.3473		1.9696		0.5209		2.9544		80
		1716		318		343		63		515		95	
11	0.19081		0.98163		0.3816		1.9633		0.5724		2.9449		79
		1710		348		342		70		513		105	
12	0.20791		0.97815		0.4158		1.9563		0.6237		2.9344		78
		1704		378		341		76		511		113	
13	0.22495		0.97437		0.4499		1.9487		0.6748		2.9231		77
		1697		407		339		81		510		122	
14	0.24192		0.97030		0.4838		1.9406		0.7258		2.9109		76
		1690		437		338		87		507		131	
15	0.25882		0.96593		0.5176		1.9319		0.7765		2.8978		75
		1682		467		337		94		504		140	
16	0.27564		0.96126		0.5513		1.9225		0.8269		2.8838		74
		1673		496		334		99		502		149	
17	0.29237		0.95630		0.5847		1.9126		0.8771		2.8689		73
		1665		524		333		105		500		157	
18	0.30902		0.95106		0.6180		1.9021		0.9271		2.8532		72
		1655		554		331		111		496		166	
19	0.32557		0.94552		0.6511		1.8910		0.9767		2.8366		71
		1645		583		329		116		494		175	
20	0.34202		0.93969		0.6840		1.8794		1.0261		2.8191		70
		1635		611		327		122		490		184	
21	0.35837		0.93358		0.7167		1.8672		1.0751		2.8007		69
		1624		640		325		128		487		191	
22	0.37461		0.92718		0.7492		1.8544		1.1238		2.7816		68
		1612		668		323		134		484		201	
23	0.39073		0.92050		0.7815		1.8410		1.1722		2.7615		67
		1601		696		320		139		480		209	
24	0.40674		0.91354		0.8135		1.8271		1.2202		2.7406		66
		1588		723		317		145		477		217	
25	0.42262		0.90631		0.8452		1.8126		1.2679		2.7189		65
		1575		752		315		150		472		225	
26	0.43837		0.89879		0.8767		1.7976		1.3151		2.6964		64
		1562		778		313		156		469		234	
27	0.45399		0.89101		0.9080		1.7820		1.3620		2.6730		63
		1548		806		309		161		464		242	
28	0.46947		0.88295		0.9389		1.7659		1.4084		2.6488		62
		1534		833		307		167		460		249	
29	0.48481		0.87462		0.9696		1.7492		1.4544		2.6239		61
		1519		859		304		171		456		258	
30	0.50000		0.86603		1.0000		1.7321		1.5000		2.5981		60
		1504		886		301		178		451		266	
31	0.51504		0.85717		1.0301		1.7143		1.5451		2.5715		59
		1488		912		297		182		447		274	
32	0.52992		0.84805		1.0598		1.6961		1.5898		2.5441		58
		1472		938		295		188		441		281	
33	0.54464		0.83867		1.0893		1.6773		1.6339		2.5160		57
		1455		963		291		192		437		289	
34	0.55919		0.82904		1.1184		1.6581		1.6776		2.4871		56
		1439		989		288		198		431		296	
35	0.57358		0.81915		1.1472		1.6383		1.7207		2.4575		55
		1421		1013		284		203		427		304	
36	0.58779		0.80902		1.1756		1.6180		1.7634		2.4271		54
		1403		1038		280		207		420		312	
37	0.60182		0.79864		1.2036		1.5973		1.8054		2.3959		53
		1384		1063		277		213		416		319	
38	0.61566		0.78801		1.2313		1.5760		1.8470		2.3640		52
		1366		1086		273		217		410		326	
39	0.62932		0.77715		1.2586		1.5543		1.8880		2.3314		51
		1347		1111		270		222		404		333	
40	0.64279		0.76604		1.2856		1.5321		1.9284		2.2981		50
		1327		1133		265		227		398		340	
41	0.65606		0.75471		1.3121		1.5094		1.9682		2.2641		49
		1307		1157		262		231		392		347	
42	0.66913		0.74314		1.3383		1.4863		2.0074		2.2294		48
		1286		1179		257		236		386		353	
43	0.68199		0.73135		1.3640		1.4627		2.0460		2.1941		47
		1267		1201		253		240		380		361	
44	0.69466		0.71934		1.3893		1.4387		2.0840		2.1580		46
		1245		1223		249		245		373		367	
45	0.70711		0.70711		1.4142		1.4142		2.1213		2.1213		45
A	cos		sin		cos		sin		cos		sin		A

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \frac{\sin}{\cos} A$ with the arguments *a* and *A*.

a	4				5				6				*a*
A	sin		cos		sin		cos		sin		cos		*A*
0°	0.0000		4.0000		0.0000		5.0000		0.0000		6.0000		90°
1	0.0698	698	3.9994	6	0.0873	873	4.9992	8	0.1047	1047	5.9991	9	89
2	0.1396	698	3.9976	18	0.1745	872	4.9970	22	0.2094	1047	5.9963	28	88
3	0.2093	697	3.9945	31	0.2617	872	4.9932	38	0.3140	1046	5.9918	45	87
4	0.2790	697	3.9902	43	0.3488	871	4.9878	54	0.4185	1045	5.9854	64	86
5	0.3486	696	3.9848	54	0.4358	870	4.9810	68	0.5229	1044	5.9772	82	85
6	0.4181	695	3.9781	67	0.5226	868	4.9726	84	0.6272	1043	5.9671	101	84
7	0.4875	694	3.9702	79	0.6093	867	4.9627	99	0.7312	1040	5.9553	118	83
8	0.5567	692	3.9611	91	0.6959	866	4.9513	114	0.8350	1038	5.9416	137	82
9	0.6257	690	3.9508	103	0.7822	863	4.9384	129	0.9386	1036	5.9261	155	81
10	0.6946	689	3.9392	116	0.8682	860	4.9240	144	1.0419	1033	5.9088	173	80
11	0.7632	686	3.9265	127	0.9540	858	4.9081	159	1.1449	1030	5.8898	190	79
12	0.8316	684	3.9126	139	1.0396	856	4.8907	174	1.2475	1026	5.8689	209	78
13	0.8998	682	3.8975	151	1.1248	852	4.8718	190	1.3497	1022	5.8462	227	77
14	0.9677	679	3.8812	163	1.2096	848	4.8515	203	1.4515	1018	5.8218	244	76
15	1.0353	676	3.8637	175	1.2941	845	4.8296	219	1.5529	1014	5.7956	262	75
16	1.1025	672	3.8450	187	1.3782	841	4.8063	233	1.6538	1009	5.7676	280	74
17	1.1695	670	3.8252	198	1.4618	836	4.7815	248	1.7542	1004	5.7378	298	73
18	1.2361	666	3.8042	210	1.5451	833	4.7553	262	1.8541	999	5.7063	315	72
19	1.3023	662	3.7821	221	1.6278	827	4.7276	277	1.9534	993	5.6731	332	71
20	1.3681	658	3.7588	233	1.7101	823	4.6985	291	2.0521	987	5.6382	349	70
21	1.4335	654	3.7343	245	1.7918	817	4.6679	306	2.1502	981	5.6015	367	69
22	1.4984	649	3.7087	256	1.8730	812	4.6359	320	2.2476	974	5.5631	384	68
23	1.5629	645	3.6820	267	1.9536	806	4.6025	334	2.3444	968	5.5230	401	67
24	1.6269	640	3.6542	278	2.0337	801	4.5677	348	2.4404	960	5.4813	417	66
25	1.6905	636	3.6252	290	2.1131	794	4.5315	362	2.5357	953	5.4378	435	65
26	1.7535	630	3.5952	300	2.1918	787	4.4940	375	2.6302	945	5.3928	450	64
27	1.8160	625	3.5640	312	2.2700	782	4.4550	390	2.7239	937	5.3461	467	63
28	1.8779	619	3.5318	322	2.3474	774	4.4147	403	2.8168	929	5.2977	484	62
29	1.9392	613	3.4985	333	2.4240	766	4.3731	416	2.9089	921	5.2477	500	61
30	2.0000	608	3.4641	344	2.5000	760	4.3301	430	3.0000	911	5.1962	515	60
31	2.0602	602	3.4287	354	2.5752	752	4.2858	443	3.0902	902	5.1430	532	59
32	2.1197	595	3.3922	365	2.6496	744	4.2402	456	3.1795	893	5.0883	547	58
33	2.1786	589	3.3547	375	2.7232	736	4.1934	468	3.2678	883	5.0320	563	57
34	2.2368	582	3.3162	385	2.7960	728	4.1452	482	3.3552	874	4.9742	578	56
35	2.2943	575	3.2766	396	2.8679	719	4.0958	494	3.4415	863	4.9149	593	55
36	2.3511	568	3.2361	405	2.9389	710	4.0451	507	3.5267	852	4.8541	608	54
37	2.4073	562	3.1945	414	3.0091	702	3.9932	519	3.6109	842	4.7918	623	53
38	2.4626	553	3.1520	425	3.0783	692	3.9401	531	3.6940	831	4.7281	637	52
39	2.5173	547	3.1086	434	3.1466	683	3.8858	543	3.7759	819	4.6629	653	51
40	2.5711	538	3.0642	444	3.2139	673	3.8302	556	3.8567	808	4.5963	666	50
41	2.6242	531	3.0188	454	3.2803	664	3.7736	566	3.9364	797	4.5283	680	49
42	2.6765	523	2.9726	462	3.3456	653	3.7157	579	4.0148	784	4.4589	694	48
43	2.7280	515	2.9254	472	3.4100	644	3.6568	589	4.0920	772	4.3881	708	47
44	2.7786	506	2.8774	480	3.4733	633	3.5967	601	4.1679	759	4.3160	721	46
45	2.8284	498	2.8284	490	3.5355	622	3.5355	612	4.2426	747	4.2426	734	45
A	cos		sin		cos		sin		cos		sin		*A*

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \begin{smallmatrix}\sin\\ \cos\end{smallmatrix} A$ with the arguments a and A.

a	7				8				9				*a*
A	sin		cos		sin		cos		sin		cos		*A*
0°	0. 0000	1222	7. 0000	11	0. 0000	1396	8. 0000	12	0. 0000	1571	9. 0000	14	90°
1	0. 1222	1221	6. 9989	32	0. 1396	1396	7. 9988	37	0. 1571	1570	8. 9986	41	89
2	0. 2443	1221	6. 9957	53	0. 2792	1395	7. 9951	61	0. 3141	1569	8. 9945	68	88
3	0. 3664	1219	6. 9904	75	0. 4187	1394	7. 9890	85	0. 4710	1568	8. 9877	96	87
4	0. 4883	1218	6. 9829	95	0. 5581	1391	7. 9805	109	0. 6278	1566	8. 9781	123	86
5	0. 6101	1216	6. 9734	118	0. 6972	1390	7. 9696	134	0. 7844	1564	8. 9658	151	85
6	0. 7317	1214	6. 9616	138	0. 8362	1388	7. 9562	158	0. 9408	1560	8. 9507	178	84
7	0. 8531	1211	6. 9478	159	0. 9750	1384	7. 9404	182	1. 0968	1558	8. 9329	205	83
8	0. 9742	1208	6. 9319	181	1. 1134	1381	7. 9222	207	1. 2526	1553	8. 9124	232	82
9	1. 0950	1205	6. 9138	202	1. 2515	1377	7. 9015	230	1. 4079	1549	8. 8892	259	81
10	1. 2155	1202	6. 8936	222	1. 3892	1373	7. 8785	255	1. 5628	1545	8. 8633	286	80
11	1. 3357	1197	6. 8714	244	1. 5265	1368	7. 8530	278	1. 7173	1539	8. 8347	314	79
12	1. 4554	1192	6. 8470	264	1. 6633	1363	7. 8252	302	1. 8712	1534	8. 8033	340	78
13	1. 5746	1188	6. 8206	285	1. 7996	1358	7. 7950	326	2. 0246	1527	8. 7693	366	77
14	1. 6934	1183	6. 7921	306	1. 9354	1352	7. 7624	350	2. 1773	1521	8. 7327	394	76
15	1. 8117	1178	6. 7615	327	2. 0706	1345	7. 7274	373	2. 3294	1513	8. 6933	419	75
16	1. 9295	1171	6. 7288	347	2. 2051	1339	7. 6901	397	2. 4807	1506	8. 6514	447	74
17	2. 0466	1165	6. 6941	367	2. 3390	1331	7. 6504	420	2. 6313	1499	8. 6067	472	73
18	2. 1631	1159	6. 6574	388	2. 4721	1324	7. 6084	442	2. 7812	1489	8. 5595	498	72
19	2. 2790	1151	6. 6186	408	2. 6045	1317	7. 5642	467	2. 9301	1481	8. 5097	525	71
20	2. 3941	1145	6. 5778	427	2. 7362	1307	7. 5175	489	3. 0782	1471	8. 4572	550	70
21	2. 5086	1136	6. 5351	448	2. 8669	1300	7. 4686	511	3. 2253	1462	8. 4022	576	69
22	2. 6222	1129	6. 4903	468	2. 9969	1289	7. 4175	535	3. 3715	1451	8. 3446	601	68
23	2. 7351	1121	6. 4435	487	3. 1258	1281	7. 3640	556	3. 5166	1440	8. 2845	626	67
24	2. 8472	1111	6. 3948	506	3. 2539	1270	7. 3084	579	3. 6606	1430	8. 2219	651	66
25	2. 9583	1103	6. 3442	526	3. 3809	1261	7. 2505	601	3. 8036	1417	8. 1568	677	65
26	3. 0686	1093	6. 2916	546	3. 5070	1249	7. 1904	623	3. 9453	1406	8. 0891	700	64
27	3. 1779	1084	6. 2370	564	3. 6319	1239	7. 1281	645	4. 0859	1393	8. 0191	725	63
28	3. 2863	1074	6. 1806	583	3. 7558	1227	7. 0636	666	4. 2252	1381	7. 9466	750	62
29	3. 3937	1063	6. 1223	601	3. 8785	1215	6. 9970	688	4. 3633	1367	7. 8716	774	61
30	3. 5000	1053	6. 0622	620	4. 0000	1203	6. 9282	708	4. 5000	1353	7. 7942	797	60
31	3. 6053	1041	6. 0002	639	4. 1203	1191	6. 8574	730	4. 6353	1340	7. 7145	821	59
32	3. 7094	1031	5. 9365	656	4. 2394	1177	6. 7844	750	4. 7693	1325	7. 6324	844	58
33	3. 8125	1019	5. 8707	674	4. 3571	1164	6. 7094	771	4. 9018	1309	7. 5480	867	57
34	3. 9144	1006	5. 8033	692	4. 4735	1151	6. 6323	791	5. 0327	1295	7. 4613	889	56
35	4. 0150	995	5. 7341	710	4. 5886	1137	6. 5532	811	5. 1622	1279	7. 3724	912	55
36	4. 1145	982	5. 6631	727	4. 7023	1122	6. 4721	830	5. 2901	1262	7. 2812	935	54
37	4. 2127	969	5. 5904	743	4. 8145	1108	6. 3891	850	5. 4163	1247	7. 1877	956	53
38	4. 3096	956	5. 5161	761	4. 9253	1093	6. 3041	869	5. 5410	1229	7. 0921	978	52
39	4. 4052	943	5. 4400	777	5. 0346	1077	6. 2172	888	5. 6639	1212	6. 9943	999	51
40	4. 4995	929	5. 3623	793	5. 1423	1062	6. 1284	907	5. 7851	1194	6. 8944	1020	50
41	4. 5924	915	5. 2830	810	5. 2485	1045	6. 0377	925	5. 9045	1177	6. 7924	1041	49
42	4. 6839	901	5. 2020	825	5. 3530	1030	5. 9452	944	6. 0222	1158	6. 6883	1061	48
43	4. 7740	886	5. 1195	841	5. 4560	1013	5. 8508	961	6. 1380	1139	6. 5822	1081	47
44	4. 8626	871	5. 0354	857	5. 5573	995	5. 7547	979	6. 2519	1121	6. 4741	1101	46
45	4. 9497		4. 9497		5. 6568		5. 6568		6. 3640		6. 3640		45
A	cos		sin		cos		sin		cos		sin		*A*

Table B.—*Traverse Tables*—Continued.

Giving the products $a \overset{\sin}{\underset{\cos}{}} A$ with the arguments a and A.

a	11		12		13		14		15		16		17		a
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	A
0°	0.0	11.0	0.0	12.0	0.0	13.0	0.0	14.0	0.0	15.0	0.0	16.0	0.0	17.0	90°
1	0.2	11.0	0.2	12.0	0.2	13.0	0.2	14.0	0.3	15.0	0.3	16.0	0.3	17.0	89
2	0.4	11.0	0.4	12.0	0.5	13.0	0.5	14.0	0.5	15.0	0.6	16.0	0.6	17.0	88
3	0.6	11.0	0.6	12.0	0.7	13.0	0.7	14.0	0.8	15.0	0.8	16.0	0.9	17.0	87
4	0.8	11.0	0.8	12.0	0.9	13.0	1.0	14.0	1.0	15.0	1.1	16.0	1.2	17.0	86
5	1.0	11.0	1.0	12.0	1.1	13.0	1.2	13.9	1.3	14.9	1.4	15.9	1.5	16.9	85
6	1.1	10.9	1.3	11.9	1.4	12.9	1.5	13.9	1.6	14.9	1.7	15.9	1.8	16.9	84
7	1.3	10.9	1.5	11.9	1.6	12.9	1.7	13.9	1.8	14.9	1.9	15.9	2.1	16.9	83
8	1.5	10.9	1.7	11.9	1.8	12.9	1.9	13.9	2.1	14.9	2.2	15.8	2.4	16.8	82
9	1.7	10.9	1.9	11.9	2.0	12.8	2.2	13.8	2.3	14.8	2.5	15.8	2.7	16.8	81
10	1.9	10.8	2.1	11.8	2.3	12.8	2.4	13.8	2.6	14.8	2.8	15.8	3.0	16.7	80
11	2.1	10.8	2.3	11.8	2.5	12.8	2.7	13.7	2.9	14.7	3.1	15.7	3.2	16.7	79
12	2.3	10.8	2.5	11.7	2.7	12.7	2.9	13.7	3.1	14.7	3.3	15.7	3.5	16.6	78
13	2.5	10.7	2.7	11.7	2.9	12.7	3.1	13.6	3.4	14.6	3.6	15.6	3.8	16.6	77
14	2.7	10.7	2.9	11.6	3.1	12.6	3.4	13.6	3.6	14.6	3.9	15.5	4.1	16.5	76
15	2.8	10.6	3.1	11.6	3.4	12.6	3.6	13.5	3.9	14.5	4.1	15.5	4.4	16.4	75
16	3.0	10.6	3.3	11.5	3.6	12.5	3.9	13.5	4.1	14.4	4.4	15.4	4.7	16.3	74
17	3.2	10.5	3.5	11.5	3.8	12.4	4.1	13.4	4.4	14.3	4.7	15.3	5.0	16.3	73
18	3.4	10.5	3.7	11.4	4.0	12.4	4.3	13.3	4.6	14.3	4.9	15.2	5.3	16.2	72
19	3.6	10.4	3.9	11.3	4.2	12.3	4.6	13.2	4.9	14.2	5.2	15.1	5.5	16.1	71
20	3.8	10.3	4.1	11.3	4.4	12.2	4.8	13.2	5.1	14.1	5.5	15.0	5.8	16.0	70
21	3.9	10.3	4.3	11.2	4.7	12.1	5.0	13.1	5.4	14.0	5.7	14.9	6.1	15.9	69
22	4.1	10.2	4.5	11.1	4.9	12.1	5.2	13.0	5.6	13.9	6.0	14.8	6.4	15.8	68
23	4.3	10.1	4.7	11.0	5.1	12.0	5.5	12.9	5.9	13.8	6.3	14.7	6.6	15.6	67
24	4.5	10.0	4.9	11.0	5.3	11.9	5.7	12.8	6.1	13.7	6.5	14.6	6.9	15.5	66
25	4.6	10.0	5.1	10.9	5.5	11.8	5.9	12.7	6.3	13.6	6.8	14.5	7.2	15.4	65
26	4.8	9.9	5.3	10.8	5.7	11.7	6.1	12.6	6.6	13.5	7.0	14.4	7.5	15.3	64
27	5.0	9.8	5.4	10.7	5.9	11.6	6.4	12.5	6.8	13.4	7.3	14.3	7.7	15.1	63
28	5.2	9.7	5.6	10.6	6.1	11.5	6.6	12.4	7.0	13.2	7.5	14.1	8.0	15.0	62
29	5.3	9.6	5.8	10.5	6.3	11.4	6.8	12.2	7.3	13.1	7.8	14.0	8.2	14.9	61
30	5.5	9.5	6.0	10.4	6.5	11.3	7.0	12.1	7.5	13.0	8.0	13.9	8.5	14.7	60
31	5.7	9.4	6.2	10.3	6.7	11.1	7.2	12.0	7.7	12.9	8.2	13.7	8.8	14.6	59
32	5.8	9.3	6.4	10.2	6.9	11.0	7.4	11.9	7.9	12.7	8.5	13.6	9.0	14.4	58
33	6.0	9.2	6.5	10.1	7.1	10.9	7.6	11.7	8.2	12.6	8.7	13.4	9.3	14.3	57
34	6.2	9.1	6.7	9.9	7.3	10.8	7.8	11.6	8.4	12.4	8.9	13.3	9.5	14.1	56
35	6.3	9.0	6.9	9.8	7.5	10.6	8.0	11.5	8.6	12.3	9.2	13.1	9.8	13.9	55
36	6.5	8.9	7.1	9.7	7.6	10.5	8.2	11.3	8.8	12.1	9.4	12.9	10.0	13.8	54
37	6.6	8.8	7.2	9.6	7.8	10.4	8.4	11.2	9.0	12.0	9.6	12.8	10.2	13.6	53
38	6.8	8.7	7.4	9.5	8.0	10.2	8.6	11.0	9.2	11.8	9.9	12.6	10.5	13.4	52
39	6.9	8.5	7.6	9.3	8.2	10.1	8.8	10.9	9.4	11.7	10.1	12.4	10.7	13.2	51
40	7.1	8.4	7.7	9.2	8.4	10.0	9.0	10.7	9.6	11.5	10.3	12.3	10.9	13.0	50
41	7.2	8.3	7.9	9.1	8.5	9.8	9.2	10.6	9.8	11.3	10.5	12.1	11.2	12.8	49
42	7.4	8.2	8.0	8.9	8.7	9.7	9.4	10.4	10.0	11.1	10.7	11.9	11.4	12.6	48
43	7.5	8.0	8.2	8.8	8.9	9.5	9.5	10.2	10.2	11.0	10.9	11.7	11.6	12.4	47
44	7.6	7.9	8.3	8.6	9.0	9.4	9.7	10.1	10.4	10.8	11.1	11.5	11.8	12.2	46
45	7.8	7.8	8.5	8.5	9.2	9.2	9.9	9.9	10.6	10.6	11.3	11.3	12.0	12.0	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	A

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a^{\sin}_{\cos}A$ with the arguments a and A.

a	18		19		20		21		22		23		24		*a*
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	*A*
0°	0.0	18.0	0.0	19.0	0.0	20.0	0.0	21.0	0.0	22.0	0.0	23.0	0.0	24.0	90°
1	0.3	18.0	0.3	19.0	0.3	20.0	0.4	21.0	0.4	22.0	0.4	23.0	0.4	24.0	89
2	0.6	18.0	0.7	19.0	0.7	20.0	0.7	21.0	0.8	22.0	0.8	23.0	0.8	24.0	88
3	0.9	18.0	1.0	19.0	1.0	20.0	1.1	21.0	1.2	22.0	1.2	23.0	1.3	24.0	87
4	1.3	18.0	1.3	19.0	1.4	20.0	1.5	20.9	1.5	21.9	1.6	22.9	1.7	23.9	86
5	1.6	17.9	1.7	18.9	1.7	19.9	1.8	20.9	1.9	21.9	2.0	22.9	2.1	23.9	85
6	1.9	17.9	2.0	18.9	2.1	19.9	2.2	20.9	2.3	21.9	2.4	22.9	2.5	23.9	84
7	2.2	17.9	2.3	18.9	2.4	19.9	2.6	20.8	2.7	21.8	2.8	22.8	2.9	23.8	83
8	2.5	17.8	2.6	18.8	2.8	19.8	2.9	20.8	3.1	21.8	3.2	22.8	3.3	23.8	82
9	2.8	17.8	3.0	18.8	3.1	19.8	3.3	20.7	3.4	21.7	3.6	22.7	3.8	23.7	81
10	3.1	17.7	3.3	18.7	3.5	19.7	3.6	20.7	3.8	21.7	4.0	22.7	4.2	23.6	80
11	3.4	17.7	3.6	18.7	3.8	19.6	4.0	20.6	4.2	21.6	4.4	22.6	4.6	23.6	79
12	3.7	17.6	4.0	18.6	4.2	19.6	4.4	20.5	4.6	21.5	4.8	22.5	5.0	23.5	78
13	4.0	17.5	4.3	18.5	4.5	19.5	4.7	20.5	4.9	21.4	5.2	22.4	5.4	23.4	77
14	4.4	17.5	4.6	18.4	4.8	19.4	5.1	20.4	5.3	21.3	5.6	22.3	5.8	23.3	76
15	4.7	17.4	4.9	18.4	5.2	19.3	5.4	20.3	5.7	21.3	6.0	22.2	6.2	23.2	75
16	5.0	17.3	5.2	18.3	5.5	19.2	5.8	20.2	6.1	21.1	6.3	22.1	6.6	23.1	74
17	5.3	17.2	5.6	18.2	5.8	19.1	6.1	20.1	6.4	21.0	6.7	22.0	7.0	23.0	73
18	5.6	17.1	5.9	18.1	6.2	19.0	6.5	20.0	6.8	20.9	7.1	21.9	7.4	22.8	72
19	5.9	17.0	6.2	18.0	6.5	18.9	6.8	19.9	7.2	20.8	7.5	21.7	7.8	22.7	71
20	6.2	16.9	6.5	17.9	6.8	18.8	7.2	19.7	7.5	20.7	7.9	21.6	8.2	22.6	70
21	6.5	16.8	6.8	17.7	7.2	18.7	7.5	19.6	7.9	20.5	8.2	21.5	8.6	22.4	69
22	6.7	16.7	7.1	17.6	7.5	18.5	7.9	19.5	8.2	20.4	8.6	21.3	9.0	22.3	68
23	7.0	16.6	7.4	17.5	7.8	18.4	8.2	19.3	8.6	20.3	9.0	21.2	9.4	22.1	67
24	7.3	16.4	7.7	17.4	8.1	18.3	8.5	19.2	8.9	20.1	9.4	21.0	9.8	21.9	66
25	7.6	16.3	8.0	17.2	8.5	18.1	8.9	19.0	9.3	19.9	9.7	20.8	10.1	21.8	65
26	7.9	16.2	8.3	17.1	8.8	18.0	9.2	18.9	9.6	19.8	10.1	20.7	10.5	21.6	64
27	8.2	16.0	8.6	16.9	9.1	17.8	9.5	18.7	10.0	19.6	10.4	20.5	10.9	21.4	63
28	8.5	15.9	8.9	16.8	9.4	17.7	9.9	18.5	10.3	19.4	10.8	20.3	11.3	21.2	62
29	8.7	15.7	9.2	16.6	9.7	17.5	10.2	18.4	10.7	19.2	11.2	20.1	11.6	21.0	61
30	9.0	15.6	9.5	16.5	10.0	17.3	10.5	18.2	11.0	19.1	11.5	19.9	12.0	20.8	60
31	9.3	15.4	9.8	16.3	10.3	17.1	10.8	18.0	11.3	18.9	11.8	19.7	12.4	20.6	59
32	9.5	15.3	10.1	16.1	10.6	17.0	11.1	17.8	11.7	18.7	12.2	19.5	12.7	20.4	58
33	9.8	15.1	10.3	15.9	10.9	16.8	11.4	17.6	12.0	18.5	12.5	19.3	13.1	20.1	57
34	10.1	14.9	10.6	15.8	11.2	16.6	11.7	17.4	12.3	18.2	12.9	19.1	13.4	19.9	56
35	10.3	14.7	10.9	15.6	11.5	16.4	12.0	17.2	12.6	18.0	13.2	18.8	13.8	19.7	55
36	10.6	14.6	11.2	15.4	11.8	16.2	12.3	17.0	12.9	17.8	13.5	18.6	14.1	19.4	54
37	10.8	14.4	11.4	15.2	12.0	16.0	12.6	16.8	13.2	17.6	13.8	18.4	14.4	19.2	53
38	11.1	14.2	11.7	15.0	12.3	15.8	12.9	16.5	13.5	17.3	14.2	18.1	14.8	18.9	52
39	11.3	14.0	12.0	14.8	12.6	15.5	13.2	16.3	13.8	17.1	14.5	17.9	15.1	18.7	51
40	11.6	13.8	12.2	14.6	12.9	15.3	13.5	16.1	14.1	16.9	14.8	17.6	15.4	18.4	50
41	11.8	13.6	12.5	14.3	13.1	15.1	13.8	15.8	14.4	16.6	15.1	17.4	15.7	18.1	49
42	12.0	13.4	12.7	14.1	13.4	14.9	14.1	15.6	14.7	16.3	15.4	17.1	16.1	17.8	48
43	12.3	13.2	13.0	13.9	13.6	14.6	14.3	15.4	15.0	16.1	15.7	16.8	16.4	17.6	47
44	12.5	12.9	13.2	13.7	13.9	14.4	14.6	15.1	15.3	15.8	16.0	16.5	16.7	17.3	46
45	12.7	12.7	13.4	13.4	14.1	14.1	14.8	14.8	15.6	15.6	16.3	16.3	17.0	17.0	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	*A*

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \genfrac{}{}{0pt}{}{\sin}{\cos} A$ with the arguments a and A.

a	25		26		27		28		29		30		31		*a*
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	*A*
0°	0.0	25.0	0.0	26.0	0.0	27.0	0.0	28.0	0.0	29.0	0.0	30.0	0.0	31.0	90°
1	0.4	25.0	0.5	26.0	0.5	27.0	0.5	28.0	0.5	29.0	0.5	30.0	0.5	31.0	89
2	0.9	25.0	0.9	26.0	0.9	27.0	1.0	28.0	1.0	29.0	1.0	30.0	1.1	31.0	88
3	1.3	25.0	1.4	26.0	1.4	27.0	1.5	28.0	1.5	29.0	1.6	30.0	1.6	31.0	87
4	1.7	24.9	1.8	25.9	1.9	26.9	2.0	27.9	2.0	28.9	2.1	29.9	2.2	30.9	86
5	2.2	24.9	2.3	25.9	2.4	26.9	2.4	27.9	2.5	28.9	2.6	29.9	2.7	30.9	85
6	2.6	24.9	2.7	25.9	2.8	26.9	2.9	27.8	3.0	28.8	3.1	29.8	3.2	30.8	84
7	3.0	24.8	3.2	25.8	3.3	26.8	3.4	27.8	3.5	28.8	3.7	29.8	3.8	30.8	83
8	3.5	24.8	3.6	25.7	3.8	26.7	3.9	27.7	4.0	28.7	4.2	29.7	4.3	30.7	82
9	3.9	24.7	4.1	25.7	4.2	26.7	4.4	27.7	4.5	28.6	4.7	29.6	4.8	30.6	81
10	4.3	24.6	4.5	25.6	4.7	26.6	4.9	27.6	5.0	28.6	5.2	29.5	5.4	30.5	80
11	4.8	24.5	5.0	25.5	5.2	26.5	5.3	27.5	5.5	28.5	5.7	29.4	5.9	30.4	79
12	5.2	24.5	5.4	25.4	5.6	26.4	5.8	27.4	6.0	28.4	6.2	29.3	6.4	30.3	78
13	5.6	24.4	5.8	25.3	6.1	26.3	6.3	27.3	6.5	28.3	6.7	29.2	7.0	30.2	77
14	6.0	24.3	6.3	25.2	6.5	26.2	6.8	27.2	7.0	28.1	7.3	29.1	7.5	30.1	76
15	6.5	24.1	6.7	25.1	7.0	26.1	7.2	27.0	7.5	28.0	7.8	29.0	8.0	29.9	75
16	6.9	24.0	7.2	25.0	7.4	26.0	7.7	26.9	8.0	27.9	8.3	28.8	8.5	29.8	74
17	7.3	23.9	7.6	24.9	7.9	25.8	8.2	26.8	8.5	27.7	8.8	28.7	9.1	29.6	73
18	7.7	23.8	8.0	24.7	8.3	25.7	8.7	26.6	9.0	27.6	9.3	28.5	9.6	29.5	72
19	8.1	23.6	8.5	24.6	8.8	25.5	9.1	26.5	9.4	27.4	9.8	28.4	10.1	29.3	71
20	8.6	23.5	8.9	24.4	9.2	25.4	9.6	26.3	9.9	27.3	10.3	28.2	10.6	29.1	70
21	9.0	23.3	9.3	24.3	9.7	25.2	10.0	26.1	10.4	27.1	10.8	28.0	11.1	28.9	69
22	9.4	23.2	9.7	24.1	10.1	25.0	10.5	26.0	10.9	26.9	11.2	27.8	11.6	28.7	68
23	9.8	23.0	10.2	23.9	10.5	24.9	10.9	25.8	11.3	26.7	11.7	27.6	12.1	28.5	67
24	10.2	22.8	10.6	23.8	11.0	24.7	11.4	25.6	11.8	26.5	12.2	27.4	12.6	28.3	66
25	10.6	22.7	11.0	23.6	11.4	24.5	11.8	25.4	12.3	26.3	12.7	27.2	13.1	28.1	65
26	11.0	22.5	11.4	23.4	11.8	24.3	12.3	25.2	12.7	26.1	13.2	27.0	13.6	27.9	64
27	11.3	22.3	11.8	23.2	12.3	24.1	12.7	24.9	13.2	25.8	13.6	26.7	14.1	27.6	63
28	11.7	22.1	12.2	23.0	12.7	23.8	13.1	24.7	13.6	25.6	14.1	26.5	14.6	27.4	62
29	12.1	21.9	12.6	22.7	13.1	23.6	13.6	24.5	14.1	25.4	14.5	26.2	15.0	27.1	61
30	12.5	21.7	13.0	22.5	13.5	23.4	14.0	24.2	14.5	25.1	15.0	26.0	15.5	26.8	60
31	12.9	21.4	13.4	22.3	13.9	23.1	14.4	24.0	14.9	24.9	15.5	25.7	16.0	26.6	59
32	13.2	21.2	13.8	22.0	14.3	22.9	14.8	23.7	15.4	24.6	15.9	25.4	16.4	26.3	58
33	13.6	21.0	14.2	21.8	14.7	22.6	15.2	23.5	15.8	24.3	16.3	25.2	16.9	26.0	57
34	14.0	20.7	14.5	21.6	15.1	22.4	15.7	23.2	16.2	24.0	16.8	24.9	17.3	25.7	56
35	14.3	20.5	14.9	21.3	15.5	22.1	16.1	22.9	16.6	23.8	17.2	24.6	17.8	25.4	55
36	14.7	20.2	15.3	21.0	15.9	21.8	16.5	22.7	17.0	23.5	17.6	24.3	18.2	25.1	54
37	15.0	20.0	15.6	20.8	16.2	21.6	16.9	22.4	17.5	23.2	18.1	24.0	18.7	24.8	53
38	15.4	19.7	16.0	20.5	16.6	21.3	17.2	22.1	17.9	22.9	18.5	23.6	19.1	24.4	52
39	15.7	19.4	16.4	20.2	17.0	21.0	17.6	21.8	18.3	22.5	18.9	23.3	19.5	24.1	51
40	16.1	19.2	16.7	19.9	17.4	20.7	18.0	21.4	18.6	22.2	19.3	23.0	19.9	23.7	50
41	16.4	18.9	17.1	19.6	17.7	20.4	18.4	21.1	19.0	21.9	19.7	22.6	20.3	23.4	49
42	16.7	18.6	17.4	19.3	18.1	20.1	18.7	20.8	19.4	21.6	20.1	22.3	20.7	23.0	48
43	17.0	18.3	17.7	19.0	18.4	19.7	19.1	20.5	19.8	21.2	20.5	21.9	21.1	22.7	47
44	17.4	18.0	18.1	18.7	18.8	19.4	19.5	20.1	20.1	20.9	20.8	21.6	21.5	22.3	46
45	17.7	17.7	18.4	18.4	19.1	19.1	19.8	19.8	20.5	20.5	21.2	21.2	21.9	21.9	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	*A*

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \begin{smallmatrix}\sin\\ \cos\end{smallmatrix} A$ with the arguments a and A.

a	32		33		34		35		36		37		38		*a*
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	*A*
0°	0.0	32.0	0.0	33.0	0.0	34.0	0.0	35.0	0.0	36.0	0.0	37.0	0.0	38.0	90°
1	0.6	32.0	0.6	33.0	0.6	34.0	0.6	35.0	0.6	36.0	0.6	37.0	0.7	38.0	89
2	1.1	32.0	1.2	33.0	1.2	34.0	1.2	35.0	1.3	36.0	1.3	37.0	1.3	38.0	88
3	1.7	32.0	1.7	33.0	1.8	34.0	1.8	35.0	1.9	36.0	1.9	36.9	2.0	37.9	87
4	2.2	31.9	2.3	32.9	2.4	33.9	2.4	34.9	2.5	35.9	2.6	36.9	2.7	37.9	86
5	2.8	31.9	2.9	32.9	3.0	33.9	3.1	34.9	3.1	35.9	3.2	36.9	3.3	37.9	85
6	3.3	31.8	3.4	32.8	3.6	33.8	3.7	34.8	3.8	35.8	3.9	36.8	4.0	37.8	84
7	3.9	31.8	4.0	32.8	4.1	33.7	4.3	34.7	4.4	35.7	4.5	36.7	4.6	37.7	83
8	4.5	31.7	4.6	32.7	4.7	33.7	4.9	34.7	5.0	35.6	5.1	36.6	5.3	37.6	82
9	5.0	31.6	5.2	32.6	5.3	33.6	5.5	34.6	5.6	35.6	5.8	36.5	5.9	37.5	81
10	5.6	31.5	5.7	32.5	5.9	33.5	6.1	34.5	6.3	35.5	6.4	36.4	6.6	37.4	80
11	6.1	31.4	6.3	32.4	6.5	33.4	6.7	34.4	6.9	35.3	7.1	36.3	7.3	37.3	79
12	6.7	31.3	6.9	32.3	7.1	33.3	7.3	34.2	7.5	35.2	7.7	36.2	7.9	37.2	78
13	7.2	31.2	7.4	32.2	7.6	33.1	7.9	34.1	8.1	35.1	8.3	36.1	8.5	37.0	77
14	7.7	31.0	8.0	32.0	8.2	33.0	8.5	34.0	8.7	34.9	9.0	35.9	9.2	36.9	76
15	8.3	30.9	8.5	31.9	8.8	32.8	9.1	33.8	9.3	34.8	9.6	35.7	9.8	36.7	75
16	8.8	30.8	9.1	31.7	9.4	32.7	9.6	33.6	9.9	34.6	10.2	35.6	10.5	36.5	74
17	9.4	30.6	9.6	31.6	9.9	32.5	10.2	33.5	10.5	34.4	10.8	35.4	11.1	36.3	73
18	9.9	30.4	10.2	31.4	10.5	32.3	10.8	33.3	11.1	34.2	11.4	35.2	11.7	36.1	72
19	10.4	30.3	10.7	31.2	11.1	32.1	11.4	33.1	11.7	34.0	12.0	35.0	12.4	35.9	71
20	10.9	30.1	11.3	31.0	11.6	31.9	12.0	32.9	12.3	33.8	12.7	34.8	13.0	35.7	70
21	11.5	29.9	11.8	30.8	12.2	31.7	12.5	32.7	12.9	33.6	13.3	34.5	13.6	35.5	69
22	12.0	29.7	12.4	30.6	12.7	31.5	13.1	32.5	13.5	33.4	13.9	34.3	14.2	35.2	68
23	12.5	29.5	12.9	30.4	13.3	31.3	13.7	32.2	14.1	33.1	14.5	34.1	14.8	35.0	67
24	13.0	29.2	13.4	30.1	13.8	31.1	14.2	32.0	14.6	32.9	15.0	33.8	15.5	34.7	66
25	13.5	29.0	13.9	29.9	14.4	30.8	14.8	31.7	15.2	32.6	15.6	33.5	16.1	34.4	65
26	14.0	28.8	14.5	29.7	14.9	30.6	15.3	31.5	15.8	32.4	16.2	33.3	16.7	34.2	64
27	14.5	28.5	15.0	29.4	15.4	30.3	15.9	31.2	16.3	32.1	16.8	33.0	17.3	33.9	63
28	15.0	28.3	15.5	29.1	16.0	30.0	16.4	30.9	16.9	31.8	17.4	32.7	17.8	33.6	62
29	15.5	28.0	16.0	28.9	16.5	29.7	17.0	30.6	17.5	31.5	17.9	32.4	18.4	33.2	61
30	16.0	27.7	16.5	28.6	17.0	29.4	17.5	30.3	18.0	31.2	18.5	32.0	19.0	32.9	60
31	16.5	27.4	17.0	28.3	17.5	29.1	18.0	30.0	18.5	30.9	19.1	31.7	19.6	32.6	59
32	17.0	27.1	17.5	28.0	18.0	28.8	18.5	29.7	19.1	30.5	19.6	31.4	20.1	32.2	58
33	17.4	26.8	18.0	27.7	18.5	28.5	19.1	29.4	19.6	30.2	20.2	31.0	20.7	31.9	57
34	17.9	26.5	18.5	27.4	19.0	28.2	19.6	29.0	20.1	29.8	20.7	30.7	21.2	31.5	56
35	18.4	26.2	18.9	27.0	19.5	27.9	20.1	28.7	20.6	29.5	21.2	30.3	21.8	31.1	55
36	18.8	25.9	19.4	26.7	20.0	27.5	20.6	28.3	21.2	29.1	21.7	29.9	22.3	30.7	54
37	19.3	25.6	19.9	26.4	20.5	27.2	21.1	28.0	21.7	28.8	22.3	29.5	22.9	30.3	53
38	19.7	25.2	20.3	26.0	20.9	26.8	21.5	27.6	22.2	28.4	22.8	29.2	23.4	29.9	52
39	20.1	24.9	20.8	25.6	21.4	26.4	22.0	27.2	22.7	28.0	23.3	28.8	23.9	29.5	51
40	20.6	24.5	21.2	25.3	21.9	26.0	22.5	26.8	23.1	27.6	23.8	28.3	24.4	29.1	50
41	21.0	24.2	21.6	24.9	22.3	25.7	23.0	26.4	23.6	27.2	24.3	27.9	24.9	28.7	49
42	21.4	23.8	22.1	24.5	22.8	25.3	23.4	26.0	24.1	26.8	24.8	27.5	25.4	28.2	48
43	21.8	23.4	22.5	24.1	23.2	24.9	23.9	25.6	24.6	26.3	25.2	27.1	25.9	27.8	47
44	22.2	23.0	22.9	23.7	23.6	24.5	24.3	25.2	25.0	25.9	25.7	26.6	26.4	27.3	46
45	22.6	22.6	23.3	23.3	24.0	24.0	24.7	24.7	25.5	25.5	26.2	26.2	26.9	26.9	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	*A*

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \frac{\sin}{\cos} A$ with the arguments a and A.

a	39		40		41		42		43		44		45		*a*
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	*A*
0°	0.0	39.0	0.0	40.0	0.0	41.0	0.0	42.0	0.0	43.0	0.0	44.0	0.0	45.0	90°
1	0.7	39.0	0.7	40.0	0.7	41.0	0.7	42.0	0.8	43.0	0.8	44.0	0.8	45.0	89
2	1.4	39.0	1.4	40.0	1.4	41.0	1.5	42.0	1.5	43.0	1.5	44.0	1.6	45.0	88
3	2.0	38.9	2.1	39.9	2.1	40.9	2.2	41.9	2.3	42.9	2.3	43.9	2.4	44.9	87
4	2.7	38.9	2.8	39.9	2.9	40.9	2.9	41.9	3.0	42.9	3.1	43.9	3.1	44.9	86
5	3.4	38.9	3.5	39.8	3.6	40.8	3.7	41.8	3.7	42.8	3.8	43.8	3.9	44.8	85
6	4.1	38.8	4.2	39.8	4.3	40.8	4.4	41.8	4.5	42.8	4.6	43.8	4.7	44.8	84
7	4.8	38.7	4.9	39.7	5.0	40.7	5.1	41.7	5.2	42.7	5.4	43.7	5.5	44.7	83
8	5.4	38.6	5.6	39.6	5.7	40.6	5.8	41.6	6.0	42.6	6.1	43.6	6.3	44.6	82
9	6.1	38.5	6.3	39.5	6.4	40.5	6.6	41.5	6.7	42.5	6.9	43.5	7.0	44.4	81
10	6.8	38.4	6.9	39.4	7.1	40.4	7.3	41.4	7.5	42.3	7.6	43.3	7.8	44.3	80
11	7.4	38.3	7.6	39.3	7.8	40.2	8.0	41.2	8.2	42.2	8.4	43.2	8.6	44.2	79
12	8.1	38.1	8.3	39.1	8.5	40.1	8.7	41.1	8.9	42.1	9.1	43.0	9.4	44.0	78
13	8.8	38.0	9.0	39.0	9.2	39.9	9.4	40.9	9.7	41.9	9.9	42.9	10.1	43.8	77
14	9.4	37.8	9.7	38.8	9.9	39.8	10.2	40.8	10.4	41.7	10.6	42.7	10.9	43.7	76
15	10.1	37.7	10.4	38.6	10.6	39.6	10.9	40.6	11.1	41.5	11.4	42.5	11.6	43.5	75
16	10.7	37.5	11.0	38.5	11.3	39.4	11.6	40.4	11.9	41.3	12.1	42.3	12.4	43.3	74
17	11.4	37.3	11.7	38.3	12.0	39.2	12.3	40.2	12.6	41.1	12.9	42.1	13.2	43.0	73
18	12.1	37.1	12.4	38.0	12.7	39.0	13.0	39.9	13.3	40.9	13.6	41.8	13.9	42.8	72
19	12.7	36.9	13.0	37.8	13.3	38.8	13.7	39.7	14.0	40.7	14.3	41.6	14.7	42.5	71
20	13.3	36.6	13.7	37.6	14.0	38.5	14.4	39.5	14.7	40.4	15.0	41.3	15.4	42.3	70
21	14.0	36.4	14.3	37.3	14.7	38.3	15.1	39.2	15.4	40.1	15.8	41.1	16.1	42.0	69
22	14.6	36.2	15.0	37.1	15.4	38.0	15.7	38.9	16.1	39.9	16.5	40.8	16.9	41.7	68
23	15.2	35.9	15.6	36.8	16.0	37.7	16.4	38.7	16.8	39.6	17.2	40.5	17.6	41.4	67
24	15.9	35.6	16.3	36.5	16.7	37.5	17.1	38.4	17.5	39.3	17.9	40.2	18.3	41.1	66
25	16.5	35.3	16.9	36.3	17.3	37.2	17.7	38.1	18.2	39.0	18.6	39.9	19.0	40.8	65
26	17.1	35.1	17.5	36.0	18.0	36.9	18.4	37.7	18.8	38.6	19.3	39.5	19.7	40.4	64
27	17.7	34.7	18.2	35.6	18.6	36.5	19.1	37.4	19.5	38.3	20.0	39.2	20.4	40.1	63
28	18.3	34.4	18.8	35.3	19.2	36.2	19.7	37.1	20.2	38.0	20.7	38.8	21.1	39.7	62
29	18.9	34.1	19.4	35.0	19.9	35.9	20.4	36.7	20.8	37.6	21.3	38.5	21.8	39.4	61
30	19.5	33.8	20.0	34.6	20.5	35.5	21.0	36.4	21.5	37.2	22.0	38.1	22.5	39.0	60
31	20.1	33.4	20.6	34.3	21.1	35.1	21.6	36.0	22.1	36.9	22.7	37.7	23.2	38.6	59
32	20.7	33.1	21.2	33.9	21.7	34.8	22.3	35.6	22.8	36.5	23.3	37.3	23.8	38.2	58
33	21.2	32.7	21.8	33.5	22.3	34.4	22.9	35.2	23.4	36.1	24.0	36.9	24.5	37.7	57
34	21.8	32.3	22.4	33.2	22.9	34.0	23.5	34.8	24.0	35.6	24.6	36.5	25.2	37.3	56
35	22.4	31.9	22.9	32.8	23.5	33.6	24.1	34.4	24.7	35.2	25.2	36.0	25.8	36.9	55
36	22.9	31.6	23.5	32.4	24.1	33.2	24.7	34.0	25.3	34.8	25.9	35.6	26.5	36.4	54
37	23.5	31.1	24.1	31.9	24.7	32.7	25.3	33.5	25.9	34.3	26.5	35.1	27.1	35.9	53
38	24.0	30.7	24.6	31.5	25.2	32.3	25.9	33.1	26.5	33.9	27.1	34.7	27.7	35.5	52
39	24.5	30.3	25.2	31.1	25.8	31.9	26.4	32.6	27.1	33.4	27.7	34.2	28.3	35.0	51
40	25.1	29.9	25.7	30.6	26.4	31.4	27.0	32.2	27.6	32.9	28.3	33.7	28.9	34.5	50
41	25.6	29.4	26.2	30.2	26.9	30.9	27.6	31.7	28.2	32.5	28.9	33.2	29.5	34.0	49
42	26.1	29.0	26.8	29.7	27.4	30.5	28.1	31.2	28.8	32.0	29.4	32.7	30.1	33.4	48
43	26.6	28.5	27.3	29.3	28.0	30.0	28.6	30.7	29.3	31.4	30.0	32.2	30.7	32.9	47
44	27.1	28.1	27.8	28.8	28.5	29.5	29.2	30.2	29.9	30.9	30.6	31.7	31.3	32.4	46
45	27.6	27.6	28.3	28.3	29.0	29.0	29.7	29.7	30.4	30.4	31.1	31.1	31.8	31.8	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	*A*

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \frac{\sin}{\cos} A$ with the arguments a and A.

a	46		47		48		49		50		51		52		*a*
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	*A*
0°	0.0	46.0	0.0	47.0	0.0	48.0	0.0	49.0	0.0	50.0	0.0	51.0	0.0	52.0	90°
1	0.8	46.0	0.8	47.0	0.8	48.0	0.9	49.0	0.9	50.0	0.9	51.0	0.9	52.0	89
2	1.6	46.0	1.6	47.0	1.7	48.0	1.7	49.0	1.7	50.0	1.8	51.0	1.8	52.0	88
3	2.4	45.9	2.5	46.9	2.5	47.9	2.6	48.9	2.6	49.9	2.7	50.9	2.7	51.9	87
4	3.2	45.9	3.3	46.9	3.3	47.9	3.4	48.9	3.5	49.9	3.6	50.9	3.6	51.9	86
5	4.0	45.8	4.1	46.8	4.2	47.8	4.3	48.8	4.4	49.8	4.4	50.8	4.5	51.8	85
6	4.8	45.7	4.9	46.7	5.0	47.7	5.1	48.7	5.2	49.7	5.3	50.7	5.4	51.7	84
7	5.6	45.7	5.7	46.6	5.8	47.6	6.0	48.6	6.1	49.6	6.2	50.6	6.3	51.6	83
8	6.4	45.6	6.5	46.5	6.7	47.5	6.8	48.5	7.0	49.5	7.1	50.5	7.2	51.5	82
9	7.2	45.4	7.4	46.4	7.5	47.4	7.7	48.4	7.8	49.4	8.0	50.4	8.1	51.4	81
10	8.0	45.3	8.2	46.3	8.3	47.3	8.5	48.3	8.7	49.2	8.9	50.2	9.0	51.2	80
11	8.8	45.2	9.0	46.1	9.2	47.1	9.3	48.1	9.5	49.1	9.7	50.1	9.9	51.0	79
12	9.6	45.0	9.8	46.0	10.0	47.0	10.2	47.9	10.4	48.9	10.6	49.9	10.8	50.9	78
13	10.3	44.8	10.6	45.8	10.8	46.8	11.0	47.7	11.2	48.7	11.5	49.7	11.7	50.7	77
14	11.1	44.6	11.4	45.6	11.6	46.6	11.9	47.5	12.1	48.5	12.3	49.5	12.6	50.5	76
15	11.9	44.4	12.2	45.4	12.4	46.4	12.7	47.3	12.9	48.3	13.2	49.3	13.5	50.2	75
16	12.7	44.2	13.0	45.2	13.2	46.1	13.5	47.1	13.8	48.1	14.1	49.0	14.3	50.0	74
17	13.4	44.0	13.7	44.9	14.0	45.9	14.3	46.9	14.6	47.8	14.9	48.8	15.2	49.7	73
18	14.2	43.7	14.5	44.7	14.8	45.7	15.1	46.6	15.5	47.6	15.8	48.5	16.1	49.5	72
19	15.0	43.5	15.3	44.4	15.6	45.4	16.0	46.3	16.3	47.3	16.6	48.2	16.9	49.2	71
20	15.7	43.2	16.1	44.2	16.4	45.1	16.8	46.0	17.1	47.0	17.4	47.9	17.8	48.9	70
21	16.5	42.9	16.8	43.9	17.2	44.8	17.6	45.7	17.9	46.7	18.3	47.6	18.6	48.5	69
22	17.2	42.7	17.6	43.6	18.0	44.5	18.4	45.4	18.7	46.4	19.1	47.3	19.5	48.2	68
23	18.0	42.3	18.4	43.3	18.8	44.2	19.1	45.1	19.5	46.0	19.9	46.9	20.3	47.9	67
24	18.7	42.0	19.1	42.9	19.5	43.9	19.9	44.8	20.3	45.7	20.7	46.6	21.2	47.5	66
25	19.4	41.7	19.9	42.6	20.3	43.5	20.7	44.4	21.1	45.3	21.6	46.2	22.0	47.1	65
26	20.2	41.3	20.6	42.2	21.0	43.1	21.5	44.0	21.9	44.9	22.4	45.8	22.8	46.7	64
27	20.9	41.0	21.3	41.9	21.8	42.8	22.2	43.7	22.7	44.6	23.2	45.4	23.6	46.3	63
28	21.6	40.6	22.1	41.5	22.5	42.4	23.0	43.3	23.5	44.1	23.9	45.0	24.4	45.9	62
29	22.3	40.2	22.8	41.1	23.3	42.0	23.8	42.9	24.2	43.7	24.7	44.6	25.2	45.5	61
30	23.0	39.8	23.5	40.7	24.0	41.6	24.5	42.4	25.0	43.3	25.5	44.2	26.0	45.0	60
31	23.7	39.4	24.2	40.3	24.7	41.1	25.2	42.0	25.8	42.9	26.3	43.7	26.8	44.6	59
32	24.4	39.0	24.9	39.9	25.4	40.7	26.0	41.6	26.5	42.4	27.0	43.3	27.6	44.1	58
33	25.1	38.6	25.6	39.4	26.1	40.3	26.7	41.1	27.2	41.9	27.8	42.8	28.3	43.6	57
34	25.7	38.1	26.3	39.0	26.8	39.8	27.4	40.6	28.0	41.5	28.5	42.3	29.1	43.1	56
35	26.4	37.7	27.0	38.5	27.5	39.3	28.1	40.1	28.7	41.0	29.3	41.8	29.8	42.6	55
36	27.0	37.2	27.6	38.0	28.2	38.8	28.8	39.6	29.4	40.5	30.0	41.3	30.6	42.1	54
37	27.7	36.7	28.3	37.5	28.9	38.3	29.5	39.1	30.1	39.9	30.7	40.7	31.3	41.5	53
38	28.3	36.2	28.9	37.0	29.6	37.8	30.2	38.6	30.8	39.4	31.4	40.2	32.0	41.0	52
39	28.9	35.7	29.6	36.5	30.2	37.3	30.8	38.1	31.5	38.9	32.1	39.6	32.7	40.4	51
40	29.6	35.2	30.2	36.0	30.9	36.8	31.5	37.5	32.1	38.3	32.8	39.1	33.4	39.8	50
41	30.2	34.7	30.8	35.5	31.5	36.2	32.1	37.0	32.8	37.7	33.5	38.5	34.1	39.2	49
42	30.8	34.2	31.4	34.9	32.1	35.7	32.8	36.4	33.5	37.2	34.1	37.9	34.8	38.6	48
43	31.4	33.6	32.1	34.4	32.7	35.1	33.4	35.8	34.1	36.6	34.8	37.3	35.5	38.0	47
44	32.0	33.1	32.6	33.8	33.3	34.5	34.0	35.2	34.7	36.0	35.4	36.7	36.1	37.4	46
45	32.5	32.5	33.2	33.2	33.9	33.9	34.6	34.6	35.4	35.4	36.1	36.1	36.8	36.8	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	*A*

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \genfrac{}{}{0pt}{}{\sin}{\cos} A$ with the arguments a and A.

a	53		54		55		56		57		58		59		*a*
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	*A*
0°	0.0	53.0	0.0	54.0	0.0	55.0	0.0	56.0	0.0	57.0	0.0	58.0	0.0	59.0	90°
1	0.9	53.0	0.9	54.0	1.0	55.0	1.0	56.0	1.0	57.0	1.0	58.0	1.0	59.0	89
2	1.8	53.0	1.9	54.0	1.9	55.0	2.0	56.0	2.0	57.0	2.0	58.0	2.1	59.0	88
3	2.8	52.9	2.8	53.9	2.9	54.9	2.9	55.9	3.0	56.9	3.0	57.9	3.1	58.9	87
4	3.7	52.9	3.8	53.9	3.8	54.9	3.9	55.9	4.0	56.9	4.0	57.9	4.1	58.9	86
5	4.6	52.8	4.7	53.8	4.8	54.8	4.9	55.8	5.0	56.8	5.1	57.8	5.1	58.8	85
6	5.5	52.7	5.6	53.7	5.7	54.7	5.9	55.7	6.0	56.7	6.1	57.7	6.2	58.7	84
7	6.5	52.6	6.6	53.6	6.7	54.6	6.8	55.6	6.9	56.6	7.1	57.6	7.2	58.6	83
8	7.4	52.5	7.5	53.5	7.7	54.5	7.8	55.5	7.9	56.4	8.1	57.4	8.2	58.4	82
9	8.3	52.3	8.4	53.3	8.6	54.3	8.8	55.3	8.9	56.3	9.1	57.3	9.2	58.3	81
10	9.3	52.2	9.4	53.2	9.6	54.2	9.7	55.1	9.9	56.1	10.1	57.1	10.2	58.1	80
11	10.1	52.0	10.3	53.0	10.5	54.0	10.7	55.0	10.9	56.0	11.1	56.9	11.3	57.9	79
12	11.0	51.8	11.2	52.8	11.4	53.8	11.6	54.8	11.9	55.8	12.1	56.7	12.3	57.7	78
13	11.9	51.6	12.1	52.6	12.4	53.6	12.6	54.6	12.8	55.5	13.0	56.5	13.3	57.5	77
14	12.8	51.4	13.1	52.4	13.3	53.4	13.5	54.3	13.8	55.3	14.0	56.3	14.3	57.2	76
15	13.7	51.2	14.0	52.2	14.2	53.1	14.5	54.1	14.8	55.1	15.0	56.0	15.3	57.0	75
16	14.6	50.9	14.9	51.9	15.2	52.9	15.4	53.8	15.7	54.8	16.0	55.8	16.3	56.7	74
17	15.5	50.7	15.8	51.6	16.1	52.6	16.4	53.6	16.7	54.5	17.0	55.5	17.2	56.4	73
18	16.4	50.4	16.7	51.4	17.0	52.3	17.3	53.3	17.6	54.2	17.9	55.2	18.2	56.1	72
19	17.3	50.1	17.6	51.1	17.9	52.0	18.2	52.9	18.6	53.9	18.9	54.8	19.2	55.8	71
20	18.1	49.8	18.5	50.7	18.8	51.7	19.2	52.6	19.5	53.6	19.8	54.5	20.2	55.4	70
21	19.0	49.5	19.4	50.4	19.7	51.3	20.1	52.3	20.4	53.2	20.8	54.1	21.1	55.1	69
22	19.9	49.1	20.2	50.1	20.6	51.0	21.0	51.9	21.4	52.8	21.7	53.8	22.1	54.7	68
23	20.7	48.8	21.1	49.7	21.5	50.6	21.9	51.5	22.3	52.5	22.7	53.4	23.1	54.3	67
24	21.6	48.4	22.0	49.3	22.4	50.2	22.8	51.2	23.2	52.1	23.6	53.0	24.0	53.9	66
25	22.4	48.0	22.8	48.9	23.2	49.8	23.7	50.8	24.1	51.7	24.5	52.6	24.9	53.5	65
26	23.2	47.6	23.7	48.5	24.1	49.4	24.5	50.3	25.0	51.2	25.4	52.1	25.9	53.0	64
27	24.1	47.2	24.5	48.1	25.0	49.0	25.4	49.9	25.9	50.8	26.3	51.7	26.8	52.6	63
28	24.9	46.8	25.4	47.7	25.8	48.6	26.3	49.4	26.8	50.3	27.2	51.2	27.7	52.1	62
29	25.7	46.4	26.2	47.2	26.7	48.1	27.1	49.0	27.6	49.9	28.1	50.7	28.6	51.6	61
30	26.5	45.9	27.0	46.8	27.5	47.6	28.0	48.5	28.5	49.4	29.0	50.2	29.5	51.1	60
31	27.3	45.4	27.8	46.3	28.3	47.1	28.8	48.0	29.4	48.9	29.9	49.7	30.4	50.6	59
32	28.1	44.9	28.6	45.8	29.1	46.6	29.7	47.5	30.2	48.3	30.7	49.2	31.3	50.0	58
33	28.9	44.4	29.4	45.3	30.0	46.1	30.5	47.0	31.0	47.8	31.6	48.6	32.1	49.5	57
34	29.6	43.9	30.2	44.8	30.8	45.6	31.3	46.4	31.9	47.3	32.4	48.1	33.0	48.9	56
35	30.4	43.4	31.0	44.2	31.5	45.1	32.1	45.9	32.7	46.7	33.3	47.5	33.8	48.3	55
36	31.2	42.9	31.7	43.7	32.3	44.5	32.9	45.3	33.5	46.1	34.1	46.9	34.7	47.7	54
37	31.9	42.3	32.5	43.1	33.1	43.9	33.7	44.7	34.3	45.5	34.9	46.3	35.5	47.1	53
38	32.6	41.8	33.2	42.6	33.9	43.3	34.5	44.1	35.1	44.9	35.7	45.7	36.3	46.5	52
39	33.4	41.2	34.0	42.0	34.6	42.7	35.2	43.5	35.9	44.3	36.5	45.1	37.1	45.9	51
40	34.1	40.6	34.7	41.4	35.4	42.1	36.0	42.9	36.6	43.7	37.3	44.4	37.9	45.2	50
41	34.8	40.0	35.4	40.8	36.1	41.5	36.7	42.3	37.4	43.0	38.1	43.8	38.7	44.5	49
42	35.5	39.4	36.1	40.1	36.8	40.9	37.5	41.6	38.1	42.4	38.8	43.1	39.5	43.8	48
43	36.1	38.8	36.8	39.5	37.5	40.2	38.2	41.0	38.9	41.7	39.6	42.4	40.2	43.1	47
44	36.8	38.1	37.5	38.8	38.2	39.6	38.9	40.3	39.6	41.0	40.3	41.7	41.0	42.4	46
45	37.5	37.5	38.2	38.2	38.9	38.9	39.6	39.6	40.3	40.3	41.0	41.0	41.7	41.7	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	*A*

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \begin{smallmatrix}\sin\\ \cos\end{smallmatrix} A$ with the arguments a and A.

a	60		61		62		63		64		65		66		*a*
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	*A*
0°	0.0	60.0	0.0	61.0	0.0	62.0	0.0	63.0	0.0	64.0	0.0	65.0	0.0	66.0	90°
1	1.0	60.0	1.1	61.0	1.1	62.0	1.1	63.0	1.1	64.0	1.1	65.0	1.2	66.0	89
2	2.1	60.0	2.1	61.0	2.2	62.0	2.2	63.0	2.2	64.0	2.3	65.0	2.3	66.0	88
3	3.1	59.9	3.2	60.9	3.2	61.9	3.3	62.9	3.3	63.9	3.4	64.9	3.5	65.9	87
4	4.2	59.9	4.3	60.9	4.3	61.8	4.4	62.8	4.5	63.8	4.5	64.8	4.6	65.8	86
5	5.2	59.8	5.3	60.8	5.4	61.8	5.5	62.8	5.6	63.8	5.7	64.8	5.8	65.7	85
6	6.3	59.7	6.4	60.7	6.5	61.7	6.6	62.7	6.7	63.6	6.8	64.6	6.9	65.6	84
7	7.3	59.6	7.4	60.5	7.6	61.5	7.7	62.5	7.8	63.5	7.9	64.5	8.0	65.5	83
8	8.4	59.4	8.5	60.4	8.6	61.4	8.8	62.4	8.9	63.4	9.0	64.4	9.2	65.4	82
9	9.4	59.3	9.5	60.2	9.7	61.2	9.9	62.2	10.0	63.2	10.2	64.2	10.3	65.2	81
10	10.4	59.1	10.6	60.1	10.8	61.1	10.9	62.0	11.1	63.0	11.3	64.0	11.5	65.0	80
11	11.4	58.9	11.6	59.9	11.8	60.9	12.0	61.8	12.2	62.8	12.4	63.8	12.6	64.8	79
12	12.5	58.7	12.7	59.7	12.9	60.6	13.1	61.6	13.3	62.6	13.5	63.6	13.7	64.6	78
13	13.5	58.5	13.7	59.4	13.9	60.4	14.2	61.4	14.4	62.4	14.6	63.3	14.8	64.3	77
14	14.5	58.2	14.8	59.2	15.0	60.2	15.2	61.1	15.5	62.1	15.7	63.1	16.0	64.0	76
15	15.5	58.0	15.8	58.9	16.0	59.9	16.3	60.9	16.6	61.8	16.8	62.8	17.1	63.8	75
16	16.5	57.7	16.8	58.6	17.1	59.6	17.4	60.6	17.6	61.5	17.9	62.5	18.2	63.4	74
17	17.5	57.4	17.8	58.3	18.1	59.3	18.4	60.2	18.7	61.2	19.0	62.2	19.3	63.1	73
18	18.5	57.1	18.9	58.0	19.2	59.0	19.5	59.9	19.8	60.9	20.1	61.8	20.4	62.8	72
19	19.5	56.7	19.9	57.7	20.2	58.6	20.5	59.6	20.8	60.5	21.2	61.5	21.5	62.4	71
20	20.5	56.4	20.9	57.3	21.2	58.3	21.5	59.2	21.9	60.1	22.2	61.1	22.6	62.0	70
21	21.5	56.0	21.9	56.9	22.2	57.9	22.6	58.8	22.9	59.7	23.3	60.7	23.7	61.6	69
22	22.5	55.6	22.9	56.6	23.2	57.5	23.6	58.4	24.0	59.3	24.3	60.3	24.7	61.2	68
23	23.4	55.2	23.8	56.2	24.2	57.1	24.6	58.0	25.0	58.9	25.4	59.8	25.8	60.8	67
24	24.4	54.8	24.8	55.7	25.2	56.6	25.6	57.6	26.0	58.5	26.4	59.4	26.8	60.3	66
25	25.4	54.4	25.8	55.3	26.2	56.2	26.6	57.1	27.0	58.0	27.5	58.9	27.9	59.8	65
26	26.3	53.9	26.7	54.8	27.2	55.7	27.6	56.6	28.1	57.5	28.5	58.4	28.9	59.3	64
27	27.2	53.5	27.7	54.4	28.1	55.2	28.6	56.1	29.1	57.0	29.5	57.9	30.0	58.8	63
28	28.2	53.0	28.6	53.9	29.1	54.7	29.6	55.6	30.0	56.5	30.5	57.4	31.0	58.3	62
29	29.1	52.5	29.6	53.4	30.1	54.2	30.5	55.1	31.0	56.0	31.5	56.9	32.0	57.7	61
30	30.0	52.0	30.5	52.8	31.0	53.7	31.5	54.6	32.0	55.4	32.5	56.3	33.0	57.2	60
31	30.9	51.4	31.4	52.3	31.9	53.1	32.4	54.0	33.0	54.9	33.5	55.7	34.0	56.6	59
32	31.8	50.9	32.3	51.7	32.9	52.6	33.4	53.4	33.9	54.3	34.4	55.1	35.0	56.0	58
33	32.7	50.3	33.2	51.2	33.8	52.0	34.3	52.8	34.9	53.7	35.4	54.5	35.9	55.4	57
34	33.6	49.7	34.1	50.6	34.7	51.4	35.2	52.2	35.8	53.1	36.3	53.9	36.9	54.7	56
35	34.4	49.1	35.0	50.0	35.6	50.8	36.1	51.6	36.7	52.4	37.3	53.2	37.9	54.1	55
36	35.3	48.5	35.9	49.4	36.4	50.2	37.0	51.0	37.6	51.8	38.2	52.6	38.8	53.4	54
37	36.1	47.9	36.7	48.7	37.3	49.5	37.9	50.3	38.5	51.1	39.1	51.9	39.7	52.7	53
38	36.9	47.3	37.6	48.1	38.2	48.9	38.8	49.6	39.4	50.4	40.0	51.2	40.6	52.0	52
39	37.8	46.6	38.4	47.4	39.0	48.2	39.6	49.0	40.3	49.7	40.9	50.5	41.5	51.3	51
40	38.6	46.0	39.2	46.7	39.9	47.5	40.5	48.3	41.1	49.0	41.8	49.8	42.4	50.6	50
41	39.4	45.3	40.0	46.0	40.7	46.8	41.3	47.5	42.0	48.3	42.6	49.1	43.3	49.8	49
42	40.1	44.6	40.8	45.3	41.5	46.1	42.2	46.8	42.8	47.6	43.5	48.3	44.2	49.0	48
43	40.9	43.9	41.6	44.6	42.3	45.3	43.0	46.1	43.6	46.8	44.3	47.5	45.0	48.3	47
44	41.7	43.2	42.4	43.9	43.1	44.6	43.8	45.3	44.5	46.0	45.2	46.8	45.8	47.5	46
45	42.4	42.4	43.1	43.1	43.8	43.8	44.5	44.5	45.3	45.3	46.0	46.0	46.7	46.7	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	*A*

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \begin{smallmatrix}\sin\\ \cos\end{smallmatrix} A$ with the arguments a and A.

a	67		68		69		70		71		72		73		*a*
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	*A*
0°	0.0	67.0	0.0	68.0	0.0	69.0	0.0	70.0	0.0	71.0	0.0	72.0	0.0	73.0	90°
1	1.2	67.0	1.2	68.0	1.2	69.0	1.2	70.0	1.2	71.0	1.3	72.0	1.3	73.0	89
2	2.3	67.0	2.4	68.0	2.4	69.0	2.4	70.0	2.5	71.0	2.5	72.0	2.5	73.0	88
3	3.5	66.9	3.6	67.9	3.6	68.9	3.7	69.9	3.7	70.9	3.8	71.9	3.8	72.9	87
4	4.7	66.8	4.7	67.8	4.8	68.8	4.9	69.8	5.0	70.8	5.0	71.8	5.1	72.8	86
5	5.8	66.7	5.9	67.7	6.0	68.7	6.1	69.7	6.2	70.7	6.3	71.7	6.4	72.7	85
6	7.0	66.6	7.1	67.6	7.2	68.6	7.3	69.6	7.4	70.6	7.5	71.6	7.6	72.6	84
7	8.2	66.5	8.3	67.5	8.4	68.5	8.5	69.5	8.7	70.5	8.8	71.5	8.9	72.5	83
8	9.3	66.3	9.5	67.3	9.6	68.3	9.7	69.3	9.9	70.3	10.0	71.3	10.2	72.3	82
9	10.5	66.2	10.6	67.2	10.8	68.2	11.0	69.1	11.1	70.1	11.3	71.1	11.4	72.1	81
10	11.6	66.0	11.8	67.0	12.0	68.0	12.2	68.9	12.3	69.9	12.5	70.9	12.7	71.9	80
11	12.8	65.8	13.0	66.8	13.2	67.7	13.4	68.7	13.5	69.7	13.7	70.7	13.9	71.7	79
12	13.9	65.5	14.1	66.5	14.3	67.5	14.6	68.5	14.8	69.4	15.0	70.4	15.2	71.4	78
13	15.1	65.3	15.3	66.3	15.5	67.2	15.7	68.2	16.0	69.2	16.2	70.2	16.4	71.1	77
14	16.2	65.0	16.5	66.0	16.7	67.0	16.9	67.9	17.2	68.9	17.4	69.9	17.7	70.8	76
15	17.3	64.7	17.6	65.7	17.9	66.6	18.1	67.6	18.4	68.6	18.6	69.5	18.9	70.5	75
16	18.5	64.4	18.7	65.4	19.0	66.3	19.3	67.3	19.6	68.2	19.8	69.2	20.1	70.2	74
17	19.6	64.1	19.9	65.0	20.2	66.0	20.5	66.9	20.8	67.9	21.1	68.9	21.3	69.8	73
18	20.7	63.7	21.0	64.7	21.3	65.6	21.6	66.6	21.9	67.5	22.2	68.5	22.6	69.4	72
19	21.8	63.3	22.1	64.3	22.5	65.2	22.8	66.2	23.1	67.1	23.4	68.1	23.8	69.0	71
20	22.9	63.0	23.3	63.9	23.6	64.8	23.9	65.8	24.3	66.7	24.6	67.7	25.0	68.6	70
21	24.0	62.5	24.4	63.5	24.7	64.4	25.1	65.4	25.4	66.3	25.8	67.2	26.2	68.2	69
22	25.1	62.1	25.5	63.0	25.8	64.0	26.2	64.9	26.6	65.8	27.0	66.8	27.3	67.7	68
23	26.2	61.7	26.6	62.6	27.0	63.5	27.4	64.4	27.7	65.4	28.1	66.3	28.5	67.2	67
24	27.3	61.2	27.7	62.1	28.1	63.0	28.5	63.9	28.9	64.9	29.3	65.8	29.7	66.7	66
25	28.3	60.7	28.7	61.6	29.2	62.5	29.6	63.4	30.0	64.3	30.4	65.3	30.9	66.2	65
26	29.4	60.2	29.8	61.1	30.2	62.0	30.7	62.9	31.1	63.8	31.6	64.7	32.0	65.6	64
27	30.4	59.7	30.9	60.6	31.3	61.5	31.8	62.4	32.2	63.3	32.7	64.2	33.1	65.0	63
28	31.5	59.2	31.9	60.0	32.4	60.9	32.9	61.8	33.3	62.7	33.8	63.6	34.3	64.5	62
29	32.5	58.6	33.0	59.5	33.5	60.3	33.9	61.2	34.4	62.1	34.9	63.0	35.4	63.8	61
30	33.5	58.0	34.0	58.9	34.5	59.8	35.0	60.6	35.5	61.5	36.0	62.4	36.5	63.2	60
31	34.5	57.4	35.0	58.3	35.5	59.1	36.1	60.0	36.6	60.9	37.1	61.7	37.6	62.6	59
32	35.5	56.8	36.0	57.7	36.6	58.5	37.1	59.4	37.6	60.2	38.2	61.1	38.7	61.9	58
33	36.5	56.2	37.0	57.0	37.6	57.9	38.1	58.7	38.7	59.5	39.2	60.4	39.8	61.2	57
34	37.5	55.5	38.0	56.4	38.6	57.2	39.1	58.0	39.7	58.9	40.3	59.7	40.8	60.5	56
35	38.4	54.9	39.0	55.7	39.6	56.5	40.2	57.3	40.7	58.2	41.3	59.0	41.9	59.8	55
36	39.4	54.2	40.0	55.0	40.6	55.8	41.1	56.6	41.7	57.4	42.3	58.2	42.9	59.1	54
37	40.3	53.5	40.9	54.3	41.5	55.1	42.1	55.9	42.7	56.7	43.3	57.5	43.9	58.3	53
38	41.2	52.8	41.9	53.6	42.5	54.4	43.1	55.2	43.7	55.9	44.3	56.7	44.9	57.5	52
39	42.2	52.1	42.8	52.8	43.4	53.6	44.1	54.4	44.7	55.2	45.3	56.0	45.9	56.7	51
40	43.1	51.3	43.7	52.1	44.4	52.9	45.0	53.6	45.6	54.4	46.3	55.2	46.9	55.9	50
41	44.0	50.6	44.6	51.3	45.3	52.1	45.9	52.8	46.6	53.6	47.2	54.3	47.9	55.1	49
42	44.8	49.8	45.5	50.5	46.2	51.3	46.8	52.0	47.5	52.8	48.2	53.5	48.8	54.2	48
43	45.7	49.0	46.4	49.7	47.1	50.5	47.7	51.2	48.4	51.9	49.1	52.7	49.8	53.4	47
44	46.5	48.2	47.2	48.9	47.9	49.6	48.6	50.4	49.3	51.1	50.0	51.8	50.7	52.5	46
45	47.4	47.4	48.1	48.1	48.8	48.8	49.5	49.5	50.2	50.2	50.9	50.9	51.6	51.6	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	*A*

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \frac{\sin}{\cos} A$ with the arguments a and A.

a	74		75		76		77		78		79		80		*a*
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	*A*
0°	0.0	74.0	0.0	75.0	0.0	76.0	0.0	77.0	0.0	78.0	0.0	79.0	0.0	80.0	90°
1	1.3	74.0	1.3	75.0	1.3	76.0	1.3	77.0	1.4	78.0	1.4	79.0	1.4	80.0	89
2	2.6	74.0	2.6	75.0	2.7	76.0	2.7	77.0	2.7	78.0	2.8	79.0	2.8	80.0	88
3	3.9	73.9	3.9	74.9	4.0	75.9	4.0	76.9	4.1	77.9	4.1	78.9	4.2	79.9	87
4	5.2	73.8	5.2	74.8	5.3	75.8	5.4	76.8	5.4	77.8	5.5	78.8	5.6	79.8	86
5	6.4	73.7	6.5	74.7	6.6	75.7	6.7	76.7	6.8	77.7	6.9	78.7	7.0	79.7	85
6	7.7	73.6	7.8	74.6	7.9	75.6	8.0	76.6	8.2	77.6	8.3	78.6	8.4	79.6	84
7	9.0	73.4	9.1	74.4	9.3	75.4	9.4	76.4	9.5	77.4	9.6	78.4	9.7	79.4	83
8	10.3	73.3	10.4	74.3	10.6	75.3	10.7	76.3	10.9	77.2	11.0	78.2	11.1	79.2	82
9	11.6	73.1	11.7	74.1	11.9	75.1	12.0	76.1	12.2	77.0	12.4	78.0	12.5	79.0	81
10	12.8	72.9	13.0	73.9	13.2	74.8	13.4	75.8	13.5	76.8	13.7	77.8	13.9	78.8	80
11	14.1	72.6	14.3	73.6	14.5	74.6	14.7	75.6	14.9	76.6	15.1	77.5	15.3	78.5	79
12	15.4	72.4	15.6	73.4	15.8	74.3	16.0	75.3	16.2	76.3	16.4	77.3	16.6	78.3	78
13	16.6	72.1	16.9	73.1	17.1	74.1	17.3	75.0	17.5	76.0	17.8	77.0	18.0	77.9	77
14	17.9	71.8	18.1	72.8	18.4	73.7	18.6	74.7	18.9	75.7	19.1	76.7	19.4	77.6	76
15	19.2	71.5	19.4	72.4	19.7	73.4	19.9	74.4	20.2	75.3	20.4	76.3	20.7	77.3	75
16	20.4	71.1	20.7	72.1	20.9	73.1	21.2	74.0	21.5	75.0	21.8	75.9	22.1	76.9	74
17	21.6	70.8	21.9	71.7	22.2	72.7	22.5	73.6	22.8	74.6	23.1	75.5	23.4	76.5	73
18	22.9	70.4	23.2	71.3	23.5	72.3	23.8	73.2	24.1	74.2	24.4	75.1	24.7	76.1	72
19	24.1	70.0	24.4	70.9	24.7	71.9	25.1	72.8	25.4	73.8	25.7	74.7	26.0	75.6	71
20	25.3	69.5	25.7	70.5	26.0	71.4	26.3	72.4	26.7	73.3	27.0	74.2	27.4	75.2	70
21	26.5	69.1	26.9	70.0	27.2	71.0	27.6	71.9	28.0	72.8	28.3	73.8	28.7	74.7	69
22	27.7	68.6	28.1	69.5	28.5	70.5	28.8	71.4	29.2	72.3	29.6	73.2	30.0	74.2	68
23	28.9	68.1	29.3	69.0	29.7	70.0	30.1	70.9	30.5	71.8	30.9	72.7	31.3	73.6	67
24	30.1	67.6	30.5	68.5	30.9	69.4	31.3	70.3	31.7	71.3	32.1	72.2	32.5	73.1	66
25	31.3	67.1	31.7	68.0	32.1	68.9	32.5	69.8	33.0	70.7	33.4	71.6	33.8	72.5	65
26	32.4	66.5	32.9	67.4	33.3	68.3	33.8	69.2	34.2	70.1	34.6	71.0	35.1	71.9	64
27	33.6	65.9	34.0	66.8	34.5	67.7	35.0	68.6	35.4	69.5	35.9	70.7	36.3	71.3	63
28	34.7	65.3	35.2	66.2	35.7	67.1	36.1	68.0	36.6	68.9	37.1	69.8	37.6	70.6	62
29	35.9	64.7	36.4	65.6	36.8	66.5	37.3	67.3	37.8	68.2	38.3	69.1	38.8	70.0	61
30	37.0	64.1	37.5	65.0	38.0	65.8	38.5	66.7	39.0	67.5	39.5	68.4	40.0	69.3	60
31	38.1	63.4	38.6	64.3	39.1	65.1	39.7	66.0	40.2	66.9	40.7	67.7	41.2	68.6	59
32	39.2	62.8	39.7	63.6	40.3	64.5	40.8	65.3	41.3	66.1	41.9	67.0	42.4	67.8	58
33	40.3	62.1	40.8	62.9	41.4	63.7	41.9	64.6	42.5	65.4	43.0	66.3	43.6	67.1	57
34	41.4	61.3	41.9	62.2	42.5	63.0	43.1	63.8	43.6	64.7	44.2	65.5	44.7	66.3	56
35	42.4	60.6	43.0	61.4	43.6	62.3	44.2	63.1	44.7	63.9	45.3	64.7	45.9	65.5	55
36	43.5	59.9	44.1	60.7	44.7	61.5	45.3	62.3	45.8	63.1	46.4	63.9	47.0	64.7	54
37	44.5	59.1	45.1	59.9	45.7	60.7	46.3	61.5	46.9	62.3	47.5	63.1	48.1	63.9	53
38	45.6	58.3	46.2	59.1	46.8	59.9	47.4	60.7	48.0	61.5	48.6	62.3	49.3	63.0	52
39	46.6	57.5	47.2	58.3	47.8	59.1	48.5	59.8	49.1	60.6	49.7	61.4	50.3	62.2	51
40	47.6	56.7	48.2	57.5	48.9	58.2	49.5	59.0	50.1	59.8	50.8	60.5	51.4	61.3	50
41	48.5	55.8	49.2	56.6	49.9	57.4	50.5	58.1	51.2	58.9	51.8	59.6	52.5	60.4	49
42	49.5	55.0	50.2	55.7	50.9	56.5	51.5	57.2	52.2	58.0	52.9	58.7	53.5	59.5	48
43	50.5	54.1	51.1	54.9	51.8	55.6	52.5	56.3	53.2	57.0	53.9	57.8	54.6	58.5	47
44	51.4	53.2	52.1	54.0	52.8	54.7	53.5	55.4	54.2	56.1	54.9	56.8	55.6	57.5	46
45	52.3	52.3	53.0	53.0	53.7	53.7	54.4	54.4	55.2	55.2	55.9	55.9	56.6	56.6	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	*A*

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a\,\genfrac{}{}{0pt}{}{\sin}{\cos}\,A$ with the arguments a and A.

a	81		82		83		84		85		86		87		a
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	A
0°	0.0	81.0	0.0	82.0	0.0	83.0	0.0	84.0	0.0	85.0	0.0	86.0	0.0	87.0	90°
1	1.4	81.0	1.4	82.0	1.4	83.0	1.5	84.0	1.5	85.0	1.5	86.0	1.5	87.0	89
2	2.8	81.0	2.9	82.0	2.9	82.9	2.9	83.9	3.0	84.9	3.0	85.9	3.0	86.9	88
3	4.2	80.9	4.3	81.9	4.3	82.9	4.4	83.9	4.4	84.9	4.5	85.9	4.6	86.9	87
4	5.7	80.8	5.7	81.8	5.8	82.8	5.9	83.8	5.9	84.8	6.0	85.8	6.1	86.8	86
5	7.1	80.7	7.1	81.7	7.2	82.7	7.3	83.7	7.4	84.7	7.5	85.7	7.6	86.7	85
6	8.5	80.6	8.6	81.6	8.7	82.5	8.8	83.5	8.9	84.5	9.0	85.5	9.1	86.5	84
7	9.9	80.4	10.0	81.4	10.1	82.4	10.2	83.4	10.4	84.4	10.5	85.4	10.6	86.4	83
8	11.3	80.2	11.4	81.2	11.6	82.2	11.7	83.2	11.8	84.2	12.0	85.2	12.1	86.2	82
9	12.7	80.0	12.8	81.0	13.0	82.0	13.1	83.0	13.3	84.0	13.5	84.9	13.6	85.9	81
10	14.1	79.8	14.2	80.8	14.4	81.7	14.6	82.7	14.8	83.7	14.9	84.7	15.1	85.7	80
11	15.5	79.5	15.6	80.5	15.8	81.5	16.0	82.5	16.2	83.4	16.4	84.4	16.6	85.4	79
12	16.8	79.2	17.0	80.2	17.3	81.2	17.5	82.2	17.7	83.1	17.9	84.1	18.1	85.1	78
13	18.2	78.9	18.4	79.9	18.7	80.9	18.9	81.8	19.1	82.8	19.3	83.8	19.6	84.8	77
14	19.6	78.6	19.8	79.6	20.1	80.5	20.3	81.5	20.6	82.5	20.8	83.4	21.0	84.4	76
15	21.0	78.2	21.2	79.2	21.5	80.2	21.7	81.1	22.0	82.1	22.3	83.1	22.5	84.0	75
16	22.3	77.9	22.6	78.8	22.9	79.8	23.2	80.7	23.4	81.7	23.7	82.7	24.0	83.6	74
17	23.7	77.5	24.0	78.4	24.3	79.4	24.6	80.3	24.9	81.3	25.1	82.2	25.4	83.2	73
18	25.0	77.0	25.3	78.0	25.6	78.9	26.0	79.9	26.3	80.8	26.6	81.8	26.9	82.7	72
19	26.4	76.6	26.7	77.5	27.0	78.5	27.3	79.4	27.7	80.4	28.0	81.3	28.3	82.3	71
20	27.7	76.1	28.0	77.1	28.4	78.0	28.7	78.9	29.1	79.9	29.4	80.8	29.8	81.8	70
21	29.0	75.6	29.4	76.6	29.7	77.5	30.1	78.4	30.5	79.4	30.8	80.3	31.2	81.2	69
22	30.3	75.1	30.7	76.0	31.1	77.0	31.5	77.9	31.8	78.8	32.2	79.7	32.6	80.7	68
23	31.6	74.6	32.0	75.5	32.4	76.4	32.8	77.3	33.2	78.2	33.6	79.2	34.0	80.1	67
24	32.9	74.0	33.4	74.9	33.8	75.8	34.2	76.7	34.6	77.7	35.0	78.6	35.4	79.5	66
25	34.2	73.4	34.7	74.3	35.1	75.2	35.5	76.1	35.9	77.0	36.3	77.9	36.8	78.8	65
26	35.5	72.8	35.9	73.7	36.4	74.6	36.8	75.5	37.3	76.4	37.7	77.3	38.1	78.2	64
27	36.8	72.2	37.2	73.1	37.7	74.0	38.1	74.8	38.6	75.7	39.0	76.6	39.5	77.5	63
28	38.0	71.5	38.5	72.4	39.0	73.3	39.4	74.2	39.9	75.1	40.4	75.9	40.8	76.8	62
29	39.3	70.8	39.8	71.7	40.2	72.6	40.7	73.5	41.2	74.3	41.7	75.2	42.2	76.1	61
30	40.5	70.1	41.0	71.0	41.5	71.9	42.0	72.7	42.5	73.6	43.0	74.5	43.5	75.3	60
31	41.7	69.4	42.2	70.3	42.7	71.1	43.3	72.0	43.8	72.9	44.3	73.7	44.8	74.6	59
32	42.9	68.7	43.5	69.5	44.0	70.4	44.5	71.2	45.0	72.1	45.6	72.9	46.1	73.8	58
33	44.1	67.9	44.7	68.8	45.2	69.6	45.7	70.4	46.3	71.3	46.8	72.1	47.4	73.0	57
34	45.3	67.2	45.9	68.0	46.4	68.8	47.0	69.6	47.5	70.5	48.1	71.3	48.6	72.1	56
35	46.5	66.4	47.0	67.2	47.6	68.0	48.2	68.8	48.8	69.6	49.3	70.4	49.9	71.3	55
36	47.6	65.5	48.2	66.3	48.8	67.1	49.4	68.0	50.0	68.8	50.5	69.6	51.1	70.4	54
37	48.7	64.7	49.3	65.5	50.0	66.3	50.6	67.1	51.2	67.9	51.8	68.7	52.4	69.5	53
38	49.9	63.8	50.5	64.6	51.1	65.4	51.7	66.2	52.3	67.0	52.9	67.8	53.6	68.6	52
39	51.0	62.9	51.6	63.7	52.2	64.5	52.9	65.3	53.5	66.1	54.1	66.8	54.8	67.6	51
40	52.1	62.0	52.7	62.8	53.4	63.6	54.0	64.3	54.6	65.1	55.3	65.9	55.9	66.6	50
41	53.1	61.1	53.8	61.9	54.5	62.6	55.1	63.4	55.8	64.2	56.4	64.9	57.1	65.7	49
42	54.2	60.2	54.9	60.9	55.5	61.7	56.2	62.4	56.9	63.2	57.5	63.9	58.2	64.7	48
43	55.2	59.2	55.9	60.0	56.6	60.7	57.3	61.4	58.0	62.2	58.7	62.9	59.3	63.6	47
44	56.3	58.3	57.0	59.0	57.7	59.7	58.4	60.4	59.0	61.1	59.7	61.9	60.4	62.6	46
45	57.3	57.3	58.0	58.0	58.7	58.7	59.4	59.4	60.1	60.1	60.8	60.8	61.5	61.5	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	A

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \frac{\sin}{\cos} A$ with the arguments a and A.

a	88		89		90		91		92		93		94		a
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	A
0°	0. 0	88. 0	0. 0	89. 0	0. 0	90. 0	0. 0	91. 0	0. 0	92. 0	0. 0	93. 0	0. 0	94. 0	90°
1	1. 5	88. 0	1. 6	89. 0	1. 6	90. 0	1. 6	91. 0	1. 6	92. 0	1. 6	93. 0	1. 6	94. 0	89
2	3. 1	87. 9	3. 1	88. 9	3. 1	89. 9	3. 2	90. 9	3. 2	91. 9	3. 2	92. 9	3. 3	93. 9	88
3	4. 6	87. 9	4. 7	88. 9	4. 7	89. 9	4. 8	90. 9	4. 8	91. 9	4. 9	92. 9	4. 9	93. 9	87
4	6. 1	87. 8	6. 2	88. 8	6. 3	89. 8	6. 3	90. 8	6. 4	91. 8	6. 5	92. 8	6. 6	93. 8	86
5	7. 7	87. 7	7. 8	88. 7	7. 8	89. 7	7. 9	90. 7	8. 0	91. 6	8. 1	92. 6	8. 2	93. 6	85
6	9. 2	87. 5	9. 3	88. 5	9. 4	89. 5	9. 5	90. 5	9. 6	91. 5	9. 7	92. 5	9. 8	93. 5	84
7	10. 7	87. 3	10. 8	88. 3	11. 0	89. 3	11. 1	90. 3	11. 2	91. 3	11. 3	92. 3	11. 5	93. 3	83
8	12. 2	87. 1	12. 4	88. 1	12. 5	89. 1	12. 7	90. 1	12. 8	91. 1	12. 9	92. 1	13. 1	93. 1	82
9	13. 8	86. 9	13. 9	87. 9	14. 1	88. 9	14. 2	89. 9	14. 4	90. 9	14. 5	91. 9	14. 7	92. 8	81
10	15. 3	86. 7	15. 5	87. 6	15. 6	88. 6	15. 8	89. 6	16. 0	90. 6	16. 1	91. 6	16. 3	92. 6	80
11	16. 8	86. 4	17. 0	87. 4	17. 2	88. 3	17. 4	89. 3	17. 6	90. 3	17. 7	91. 3	17. 9	92. 3	79
12	18. 3	86. 1	18. 5	87. 1	18. 7	88. 0	18. 9	89. 0	19. 1	90. 0	19. 3	91. 0	19. 5	91. 9	78
13	19. 8	85. 7	20. 0	86. 7	20. 2	87. 7	20. 5	88. 7	20. 7	89. 6	20. 9	90. 6	21. 1	91. 6	77
14	21. 3	85. 4	21. 5	86. 4	21. 8	87. 3	22. 0	88. 3	22. 3	89. 3	22. 5	90. 2	22. 7	91. 2	76
15	22. 8	85. 0	23. 0	86. 0	23. 3	86. 9	23. 6	87. 9	23. 8	88. 9	24. 1	89. 8	24. 3	90. 8	75
16	24. 3	84. 6	24. 5	85. 6	24. 8	86. 5	25. 1	87. 5	25. 4	88. 4	25. 6	89. 4	25. 9	90. 4	74
17	25. 7	84. 2	26. 0	85. 1	26. 3	86. 1	26. 6	87. 0	26. 9	88. 0	27. 2	88. 9	27. 5	89. 9	73
18	27. 2	83. 7	27. 5	84. 6	27. 8	85. 6	28. 1	86. 5	28. 4	87. 5	28. 7	88. 4	29. 0	89. 4	72
19	28. 7	83. 2	29. 0	84. 2	29. 3	85. 1	29. 6	86. 0	30. 0	87. 0	30. 3	87. 9	30. 6	88. 9	71
20	30. 1	82. 7	30. 4	83. 6	30. 8	84. 6	31. 1	85. 5	31. 5	86. 5	31. 8	87. 4	32. 1	88. 3	70
21	31. 5	82. 2	31. 9	83. 1	32. 3	84. 0	32. 6	85. 0	33. 0	85. 9	33. 3	86. 8	33. 7	87. 8	69
22	33. 0	81. 6	33. 3	82. 5	33. 7	83. 4	34. 1	84. 4	34. 5	85. 3	34. 8	86. 2	35. 2	87. 2	68
23	34. 4	81. 0	34. 8	81. 9	35. 2	82. 8	35. 6	83. 8	35. 9	84. 7	36. 3	85. 6	36. 7	86. 5	67
24	35. 8	80. 4	36. 2	81. 3	36. 6	82. 2	37. 0	83. 1	37. 4	84. 0	37. 8	85. 0	38. 2	85. 9	66
25	37. 2	79. 8	37. 6	80. 7	38. 0	81. 6	38. 5	82. 5	38. 9	83. 4	39. 3	84. 3	39. 7	85. 2	65
26	38. 6	79. 1	39. 0	80. 0	39. 5	80. 9	39. 9	81. 8	40. 3	82. 7	40. 8	83. 6	41. 2	84. 5	64
27	40. 0	78. 4	40. 4	79. 3	40. 9	80. 2	41. 3	81. 1	41. 8	82. 0	42. 2	82. 9	42. 7	83. 8	63
28	41. 3	77. 7	41. 8	78. 6	42. 3	79. 5	42. 7	80. 3	43. 2	81. 2	43. 7	82. 1	44. 1	83. 0	62
29	42. 7	77. 0	43. 1	77. 8	43. 6	78. 7	44. 1	79. 6	44. 6	80. 5	45. 1	81. 3	45. 6	82. 2	61
30	44. 0	76. 2	44. 5	77. 1	45. 0	77. 9	45. 5	78. 8	46. 0	79. 7	46. 5	80. 5	47. 0	81. 4	60
31	45. 3	75. 4	45. 8	76. 3	46. 4	77. 1	46. 9	78. 0	47. 4	78. 9	47. 9	79. 7	48. 4	80. 6	59
32	46. 6	74. 6	47. 2	75. 5	47. 7	76. 3	48. 2	77. 2	48. 8	78. 0	49. 3	78. 9	49. 8	79. 7	58
33	47. 9	73. 8	48. 5	74. 6	49. 0	75. 5	49. 6	76. 3	50. 1	77. 2	50. 7	78. 0	51. 2	78. 8	57
34	49. 2	73. 0	49. 8	73. 8	50. 3	74. 6	50. 9	75. 4	51. 4	76. 3	52. 0	77. 1	52. 6	77. 9	56
35	50. 5	72. 1	51. 0	72. 9	51. 6	73. 7	52. 2	74. 5	52. 8	75. 4	53. 3	76. 2	53. 9	77. 0	55
36	51. 7	71. 2	52. 3	72. 0	52. 9	72. 8	53. 5	73. 6	54. 1	74. 4	54. 7	75. 2	55. 3	76. 0	54
37	53. 0	70. 3	53. 6	71. 1	54. 2	71. 9	54. 8	72. 7	55. 4	73. 5	56. 0	74. 3	56. 6	75. 1	53
38	54. 2	69. 3	54. 8	70. 1	55. 4	70. 9	56. 0	71. 7	56. 6	72. 5	57. 3	73. 3	57. 9	74. 1	52
39	55. 4	68. 4	56. 0	69. 2	56. 6	69. 9	57. 3	70. 7	57. 9	71. 5	58. 5	72. 3	59. 2	73. 1	51
40	56. 6	67. 4	57. 2	68. 2	57. 9	68. 9	58. 5	69. 7	59. 1	70. 5	59. 8	71. 2	60. 4	72. 0	50
41	57. 7	66. 4	58. 4	67. 2	59. 0	67. 9	59. 7	68. 7	60. 4	69. 4	61. 0	70. 2	61. 7	70. 9	49
42	58. 9	65. 4	59. 6	66. 1	60. 2	66. 9	60. 9	67. 6	61. 6	68. 4	62. 2	69. 1	62. 9	69. 9	48
43	60. 0	64. 4	60. 7	65. 1	61. 4	65. 8	62. 1	66. 6	62. 7	67. 3	63. 4	68. 0	64. 1	68. 7	47
44	61. 1	63. 3	61. 8	64. 0	62. 5	64. 7	63. 2	65. 5	63. 9	66. 2	64. 6	66. 9	65. 3	67. 6	46
45	62. 2	62. 2	62. 9	62. 9	63. 6	63. 6	64. 3	64. 3	65. 1	65. 1	65. 8	65. 8	66. 5	66. 5	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	A

TABLE B.—*Traverse Tables*—Continued.

Giving the products $a \frac{\sin}{\cos} A$ with the arguments a and A.

a	95		96		97		98		99		100		a
A	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	A
0°	0.0	95.0	0.0	96.0	0.0	97.0	0.0	98.0	0.0	99.0	0.0	100.0	90°
1	1.7	95.0	1.7	96.0	1.7	97.0	1.7	98.0	1.7	99.0	1.7	100.0	89
2	3.3	94.9	3.4	95.9	3.4	96.9	3.4	97.9	3.5	98.9	3.5	99.9	88
3	5.0	94.9	5.0	95.9	5.1	96.9	5.1	97.9	5.2	98.9	5.2	99.9	87
4	6.6	94.8	6.7	95.8	6.8	96.8	6.8	97.8	6.9	98.8	7.0	99.8	86
5	8.3	94.6	8.4	95.6	8.5	96.6	8.5	97.6	8.6	98.6	8.7	99.6	85
6	9.9	94.5	10.0	95.5	10.1	96.5	10.2	97.5	10.3	98.5	10.5	99.5	84
7	11.6	94.3	11.7	95.3	11.8	96.3	11.9	97.3	12.1	98.3	12.2	99.3	83
8	13.2	94.1	13.4	95.1	13.5	96.1	13.6	97.0	13.8	98.0	13.9	99.0	82
9	14.9	93.8	15.0	94.8	15.2	95.8	15.3	96.8	15.5	97.8	15.6	98.8	81
10	16.5	93.6	16.7	94.5	16.8	95.5	17.0	96.5	17.2	97.5	17.4	98.5	80
11	18.1	93.3	18.3	94.2	18.5	95.2	18.7	96.2	18.9	97.2	19.1	98.2	79
12	19.8	92.9	20.0	93.9	20.2	94.9	20.4	95.9	20.6	96.8	20.8	97.8	78
13	21.4	92.6	21.6	93.5	21.8	94.5	22.0	95.5	22.3	96.5	22.5	97.4	77
14	23.0	92.2	23.2	93.1	23.5	94.1	23.7	95.1	24.0	96.1	24.2	97.0	76
15	24.6	91.8	24.8	92.7	25.1	93.7	25.4	94.7	25.6	95.6	25.9	96.6	75
16	26.2	91.3	26.5	92.3	26.7	93.2	27.0	94.2	27.3	95.2	27.6	96.1	74
17	27.8	90.8	28.1	91.8	28.4	92.8	28.7	93.7	28.9	94.7	29.2	95.6	73
18	29.4	90.4	29.7	91.3	30.0	92.3	30.3	93.2	30.6	94.2	30.9	95.1	72
19	30.9	89.8	31.3	90.8	31.6	91.7	31.9	92.7	32.2	93.6	32.6	94.6	71
20	32.5	89.3	32.8	90.2	33.2	91.2	33.5	92.1	33.9	93.0	34.2	94.0	70
21	34.0	88.7	34.4	89.6	34.8	90.6	35.1	91.5	35.5	92.4	35.8	93.4	69
22	35.6	88.1	36.0	89.0	36.3	89.9	36.7	90.9	37.1	91.8	37.5	92.7	68
23	37.1	87.4	37.5	88.4	37.4	89.3	38.3	90.2	38.7	91.1	39.1	92.1	67
24	38.6	86.8	39.0	87.7	39.5	88.6	39.9	89.5	40.3	90.4	40.7	91.4	66
25	40.1	86.1	40.6	87.0	41.0	87.9	41.4	88.8	41.8	89.7	42.3	90.6	65
26	41.6	85.4	42.1	86.3	42.5	87.2	43.0	88.1	43.4	89.0	43.8	89.9	64
27	43.1	84.6	43.6	85.5	44.0	86.4	44.5	87.3	44.9	88.2	45.4	89.1	63
28	44.6	83.9	45.1	84.8	45.5	85.6	46.0	86.5	46.5	87.4	46.9	88.3	62
29	46.1	83.1	46.5	84.0	47.0	84.8	47.5	85.7	48.0	86.6	48.5	87.5	61
30	47.5	82.3	48.0	83.1	48.5	84.0	49.0	84.9	49.5	85.7	50.0	86.6	60
31	48.9	81.4	49.4	82.3	50.0	83.1	50.5	84.0	51.0	84.9	51.5	85.7	59
32	50.3	80.6	50.9	81.4	51.4	82.3	51.9	83.1	52.5	84.0	53.0	84.8	58
33	51.7	79.7	52.3	80.5	52.8	81.4	53.4	82.2	53.9	83.0	54.5	83.9	57
34	53.1	78.8	53.7	79.6	54.2	80.4	54.8	81.2	55.4	82.1	55.9	82.9	56
35	54.5	77.8	55.1	78.6	55.6	79.5	56.2	80.3	56.8	81.1	57.4	81.9	55
36	55.8	76.9	56.4	77.7	57.0	78.5	57.6	79.3	58.2	80.1	58.8	80.9	54
37	57.2	75.9	57.8	76.7	58.4	77.5	59.0	78.3	59.6	79.1	60.2	79.9	53
38	58.5	74.9	59.1	75.6	59.7	76.4	60.3	77.2	61.0	78.0	61.6	78.8	52
39	59.8	73.8	60.4	74.6	61.0	75.4	61.7	76.2	62.3	76.9	62.9	77.7	51
40	61.1	72.8	61.7	73.5	62.4	74.3	63.0	75.1	63.6	75.8	64.3	76.6	50
41	62.3	71.7	63.0	72.5	63.6	73.2	64.3	74.0	64.9	74.7	65.6	75.5	49
42	63.6	70.6	64.2	71.3	64.9	72.1	65.6	72.8	66.2	73.6	66.9	74.3	48
43	64.8	69.5	65.5	70.2	66.2	70.9	66.8	71.7	67.5	72.4	68.2	73.1	47
44	66.0	68.3	66.7	69.1	67.4	69.8	68.1	70.5	68.8	71.2	69.5	71.9	46
45	67.2	67.2	67.9	67.9	68.6	68.6	69.3	69.3	70.0	70.0	70.7	70.7	45
A	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	cos	sin	A

TABLE C.—ELEMENTS.

Minor planet.	Magnitude.		Epoch.	M. T. Berlin.	Mean equinox and ecliptic.	g_0	π	☊	i	φ	n
	m_0	g									
						° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	″
(93) **Minerva*	10.8	7.4	1875	Jan. 0.0372	1875.0	278 32 8	274 51 42	5 7 8	8 36 20	8 4 54	775.9214
(101) **Helena*	10.7	7.6	1877	Dec. 10.0	1880.0	99 46 33	327 36 50	343 39 43	10 9 51	7 55 16	854.4377
(103) **Hera*	10.2	6.9	1895	Nov. 26.0	1895.0	76 9 2	321 27 48	136 12 23	5 24 39	4 34 6	798.6939
(105) *Artemis*	11.1	8.5	1896	Nov. 20.0	1900.0	353 58 22	242 56 43	188 7 11	21 29 57	10 6 9	970.4299
(115) *Thyra*	10.4	7.8	1890	Jan. 0.0372	1900.0	299 32 18	43 27 39	309 12 2	11 35 8	11 6 59	966.3084
(119) **Althaea*	10.6	7.5	1894	Aug. 23.0	1894.0	332 43 50	11 56 27	203 54 3	5 43 54	4 36 2	855.4057
(128) *Nemesis*	10.6	7.2	1896	July 3.0	1900.0	101 41 9	16 36 2	76 39 30	6 15 18	7 16 50	777.8761
(133) *Cyrene*	11.3	7.3	1896	Dec. 10.0	1900.0	204 8 9	246 30 32	321 10 39	7 13 53	7 49 26	661.6605
(139) *Juewa*	10.9	7.4	1897	Jan. 29.0	1900.0	155 29 57	164 40 12	2 27 38	10 55 12	10 2 40	764.1684
(161) *Athor*	11.0	8.4	1896	Apr. 14.0	1900.0	72 49 13	310 26 18	18 39 54	9 3 26	7 57 47	966.6573
(174) *Phaedra*	11.6	8.0	1893	Nov. 16.0	1900.0	201 5 28	254 46 6	328 42 26	12 7 3	8 18 11	733.4324
(179) *Klytaemnestra*	11.5	7.7	1893	Sept. 17.0	1900.0	89 22 45	354 8 53	253 17 5	7 47 18	6 26 14	692.2030

NOTE.—For planets marked with an asterisk (*) the elements are osculating for the epoch, excepting the elements g_0 and n, which contain the constant part and the nontrigonometrical secular term in $n\delta z$, respectively. The columns headed m_0 and g are taken from the Berliner Astronomisches Jahrbuch and serve for the computation of the magnitude at opposition. The magnitude at opposition is $g+5$ ($\log \rho + \log r$), where ρ and r are the geocentric and heliocentric distances, respectively.

TABLES

OF

(105) ARTEMIS.
(115) THYRA.
(128) NEMESIS.
(133) CYRENE.
(139) JUEWA.
(161) ATHOR.
(174) PHAEDRA.
(179) KLYTAEMNESTRA.

$n\delta z$, $\delta \log r$, and $u/\cos i$ are tabulated in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.

TABLES OF (105) ARTEMIS.

MEAN ELEMENTS.

Epoch, 1896, Nov. 20.0, M. T. Berlin=1896.887, M. T. Berlin.

	°	′	″	°	
g_0 =	353	59	41	=353.9948	
ω =	54	48	51	= 54.8142	Mean equinox and ecliptic 1900.0
☊ =	188	7	15	=188.1208	
i =	21	30	0	= 21.5000	
φ =	10	6	12	= 10.1032	
n =	970″.4380			= 0.26956611	

The elements are based on oppositions extending from 1868 to 1900 and on the perturbations of the first order by *Jupiter*, as given on page 237.

AUXILIARY QUANTITIES.

$\log a=0.37536$ $\log 57.296\,e=1.00221$ $\log\sqrt{\frac{1-e}{1+e}}=9.92302$

$\log e=9.24408$ $\log p=0.36178$

TABLE I.—MEAN ANOMALY (g).

Jan. 0.0 of common years; Jan. 1.0 of leap years

Year	g	Year	g
	°		°
B 1868	29.80279	1899	201.83028
69	128.19442	1900	300.22191
1870	226.58605	1	38.61354
71	324.97768	2	137.00517
B 72	63.63888	3	235.39680
73	162.03051	B 4	334.05800
74	260.42214	1905	72.44963
1875	358.81377	6	170.84126
B 76	97.47496	7	269.23289
77	195.86659	B 8	7.89409
78	294.25822	9	106.28572
79	32.64985	1910	204.67735
B 1880	131.31105	1	303.06898
81	229.70268	B 2	41.73017
82	328.09431	3	140.12180
83	66.48594	4	238.51343
B 84	165.14714	1915	336.90506
1885	263.53877	B 6	75.56626
86	1.93040	7	173.95789
87	100.32203	8	272.34952
B 88	198.98322	9	10.74115
89	297.37485	B 1920	109.40234
1890	35.76648	1	207.79397
91	134.15811	2	306.18560
B 92	232.81931	3	44.57723
93	331.21094	B 4	143.23843
94	69.60257	1925	241.63006
1895	167.99420	6	340.02169
B 96	266.65539	7	78.41332
97	5.04702	B 8	177.07452
98	103.43865	9	275.46615
99	201.83028	1930	13.85778

Note.—When g is used as an argument of the perturbations add to the g of this table $\Delta\pi=\pi-\pi_0=+0^{\circ}.1631$. For explanation see page 203.

Table for beginning of month

Month	g
	°
Jan. 0.0 Jan. 1.0	0.00000
Feb. 0.0 Feb. 1.0	8.35655
Mar. 0.0	15.90440
Apr. 0.0	24.26095
May 0.0	32.34793
June 0.0	40.70448
July 0.0	48.79146
Aug. 0.0	57.14801
Sept. 0.0	65.50456
Oct. 0.0	73.59154
Nov. 0.0	81.94809
Dec. 0.0	90.03508

Change for n days[a]

n	g	n	g
	°		°
1	0.26957	16	4.31306
2	0.53913	17	4.58262
3	0.80870	18	4.85219
4	1.07826	19	5.12175
5	1.34783	20	5.39132
6	1.61740	21	5.66089
7	1.88696	22	5.93045
8	2.15653	23	6.20002
9	2.42609	24	6.46958
10	2.69566	25	6.73915
11	2.96523	26	7.00872
12	3.23479	27	7.27828
13	3.50436	28	7.54785
14	3.77392	29	7.81742
15	4.04349	30	8.08698

[a] For days during January and February of leap years, substract one day before entering this table.

Tables of (105) Artemis—Continued.

PERTURBATIONS.

Arg. $ig-i'g'$		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	0				− 4		+ 3
0	0				− 0.14nt		− 1.05nt
+1	0			− 2	+ 4		
+1		+ 4.14nt	− 4.38nt	− 2.19nt	− 2.07nt	− 6.23nt	+ 3.94nt
+2			+ 3	+ 2			− 1
+2		+ 0.18nt	− 0.19nt	− 0.19nt	− 0.18nt	− 0.54nt	+ 0.34nt
+3		+ 0.02nt	− 0.02nt	− 0.02nt	− 0.02nt	− 0.07nt	+ 0.04nt
+4	0					− 0.01nt	+ 0.01nt
−2	+1					− 1	− 1
−1		+ 8	− 9	+ 5	+ 4	− 7	+ 3
0		+ 21	+ 2	+ 1	+ 3	− 9	+ 4
+1		+ 43	− 53	+ 20	− 16	+ 7	− 8
+2		− 1	+ 2	+ 2		+ 2	− 5
+3	+1	+ 1			− 1		
−1	+2	+ 2	1		+ 1	− 3	− 1
0		+ 23	− 7	+ 4	+ 7	−13	− 9
+1		− 18	+ 239	+ 64	+ 7	+14	+13
+2		− 20	+ 120	+ 74	+ 13	+ 6	+ 1
+3			+ 8	+ 8	+ 1		+ 1
+4	+2		+ 1	+ 1			
−1	+3	+ 2			+ 1	− 1	− 2
0		+ 27		− 1	+ 12	14	19
+1		−256	+1356	+ 81	+ 28	+ 5	− 2
+2		−272	+ 312	+162	+139	− 3	+50
+3		− 2	+ 10	+ 11	+ 5	− 1	+ 5
+4	+3		+ 1	+ 1			+ 1
0	+4	− 2			− 1	1	+ 3
+1		− 22	+ 21	− 5	− 5	− 2	+ 2
+2		+ 69	− 39	− 17	− 30	+ 5	− 9
+3		− 14	− 2	− 1	− 10	+ 1	− 3
+4	+4		− 1	− 1			
0	+5			− 1			
+1		− 3	− 5	+ 1	− 1	− 1	
+2		+ 31	− 3		− 10	+ 2	− 1
+3		+ 11	+ 5	+ 3	− 8	+ 3	
+4	+5		− 2	− 1		1	
+1	+6	− 1	1			− 1	− 1
+2		+ 9	− 6	1	− 3	− 1	
+3		+ 3	+ 3	+ 9	− 10	4	+ 1
+4			1				1
+5	+6			1			

Tables of (105) Artemis—Continued.

TABLE II.—$n\delta z$.

PERIODIC TERMS.

Unit of a and b=0°.001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	− 1.4	−0.67	− 73.6	+22.36	+454.5	+ 4.01	− 50.8	+4.64	+107.6	+1.82
6	− 5.4	−0.64	+ 62.4	+22.71	+458.5	− 2.72	− 22.4	+4.71	+114.8	+0.68
12	− 9.1	−0.55	+194.8	+21.01	+421.9	− 9.41	+ 5.7	+4.62	+115.8	−0.31
18	−12.0	−0.44	+310.6	+17.30	+347.2	−15.26	+ 33.0	+4.44	+111.1	−1.24
24	−14.4	−0.33	+399.3	+12.01	+241.5	−19.71	+ 59.0	+4.16	+100.9	−2.18
30	−16.0	−0.17	+452.4	+ 5.47	+114.3	−22.31	+ 82.9	+3.72	+ 85.0	−3.16
36	−16.4	0.00	+464.9	− 1.36	− 22.1	−22.83	+103.7	+3.05	+ 63.0	−4.17
42	−16.0	+0.14	+436.1	− 8.16	−155.3	−21.16	+119.5	+2.01	+ 35.0	−5.07
48	−14.7	+0.28	+368.6	−14.10	−272.1	−17.48	+127.8	+0.58	+ 2.2	−5.72
54	−12.6	+0.40	+269.8	−18.61	−361.9	−12.26	+126.4	−1.12	− 33.6	−5.97
60	− 9.9	+0.48	+149.3	−21.19	−417.0	− 5.85	+114.3	−2.93	− 69.4	−5.62
66	− 6.8	+0.51	+ 19.6	−21.71	−432.1	+ 0.83	+ 91.2	−4.66	−101.0	−4.65
72	− 3.8	+0.50	−107.1	−20.13	−407.0	+ 7.36	+ 58.4	−6.02	−125.2	−3.10
78	− 0.8	+0.46	−218.2	−16.63	−345.4	+13.00	+ 19.0	−6.82	−138.2	−1.08
84	+ 1.7	+0.37	−303.8	−11.69	−253.8	+17.22	− 23.4	−6.94	−138.2	+1.12
90	+ 3.6	+0.24	−356.5	− 5.64	−142.4	+19.60	− 64.3	−6.29	−124.8	+3.25
96	+ 4.6	+0.12	−371.5	+ 0.61	− 22.5	+20.01	− 98.9	−4.96	− 99.2	+5.08
102	+ 5.0	0.00	−349.2	+ 6.72	+ 93.9	+18.46	−123.8	−3.12	− 63.8	+6.40
108	+ 4.6	−0.14	−292.5	+11.94	+195.5	+15.15	−136.4	−0.93	− 22.4	+7.02
114	+ 3.3	−0.24	−208.5	+15.82	+272.9	+10.43	−135.0	+1.33	+ 20.4	+6.90
120	+ 1.7	−0.30	−106.0	+17.97	+318.9	+ 4.76	−120.4	+3.42	+ 60.4	+6.10
126	− 0.3	−0.34	+ 3.6	+18.29	+333.0	− 1.06	− 93.9	+5.16	+ 93.6	+4.64
132	− 2.4	−0.32	+109.9	+16.77	+306.1	− 6.75	− 58.5	+6.29	+116.0	+2.71
138	− 4.2	−0.29	+201.5	+13.51	+250.6	−11.59	− 18.4	+6.74	+126.1	+0.52
144	− 5.9	−0.22	+269.9	+ 9.06	+169.6	−15.15	+ 22.4	+6.48	+122.4	−1.70
150	− 6.8	−0.11	+308.6	+ 3.68	+ 72.0	−17.09	+ 59.4	+5.50	+105.7	−3.69
156	− 7.2	+0.01	+314.1	− 1.87	− 31.9	−17.23	+ 88.4	+3.90	+ 78.1	−5.29
162	− 6.7	+0.12	+286.2	− 7.27	−131.3	−15.61	+106.2	+1.90	+ 42.2	−6.13
168	− 5.7	+0.21	+228.4	−11.83	−216.2	−12.47	+111.2	−0.29	+ 4.5	−6.25
174	− 4.2	+0.26	+146.6	−15.19	−278.4	− 8.04	+102.7	−2.40	− 32.8	−5.74
180	− 2.6	+0.30	+ 49.2	−16.94	−311.3	− 2.78	+ 82.4	−4.12	− 64.4	−4.48
186	− 0.6	+0.31	− 53.4	−17.00	−311.7	+ 2.63	+ 53.2	−5.31	− 86.6	−2.74
192	+ 1.1	+0.27	−151.5	−15.35	−279.7	+ 7.91	+ 18.7	−5.82	− 97.3	−0.73
198	+ 2.6	+0.21	−234.6	−12.14	−218.4	+12.33	− 16.8	−5.61	− 95.4	+1.27
204	+ 3.6	+0.12	−294.7	− 7.91	−134.1	+15.57	− 48.6	−4.76	− 82.1	+3.05
210	+ 4.0	+0.02	−325.6	− 2.43	− 34.6	+17.26	− 73.9	−3.41	− 58.8	+4.42
216	+ 3.8	−0.08	−323.9	+ 3.02	+ 69.7	+17.22	− 89.5	−1.72	− 29.0	+5.23
222	+ 3.0	−0.11	−289.3	+ 8.40	+168.7	+15.49	− 94.5	+0.12	+ 4.0	+5.48
228	+ 2.5	−0.18	−224.7	+12.92	+252.5	+12.18	− 88.0	+1.91	+ 36.7	+5.15
234	+ 0.8	−0.23	−136.6	+16.25	+312.3	+ 7.57	− 71.6	+3.49	+ 65.8	+4.27
240	− 0.3	−0.17	− 32.8	+17.99	+341.7	+ 2.05	− 46.1	+4.77	+ 88.0	+2.93
246	− 1.2	−0.12	+ 75.8	+17.96	+336.9	− 3.64	− 14.4	+5.56	+101.0	+1.28
252	− 1.8	−0.03	+179.1	+16.11	+298.0	− 9.22	+ 20.6	+5.82	+103.3	−0.62
258	− 1.6	+0.08	+265.8	+12.54	+227.8	−13.97	+ 55.4	+5.45	+ 93.6	−2.56
264	− 0.9	+0.17	+327.0	+ 7.64	+133.0	−17.36	+ 86.0	+4.44	+ 72.6	−4.33
270	+ 0.4	+0.26	+356.1	+ 1.86	+ 22.4	−19.15	+108.7	+2.84	+ 41.6	−5.75
276	+ 2.2	+0.35	+349.3	− 4.15	− 93.1	−19.02	+120.1	+0.79	+ 3.6	−6.57
282	+ 4.6	+0.42	+306.3	−10.01	−202.1	−19.01	+118.2	−1.49	− 37.2	−6.60
288	+ 7.2	+0.44	+230.9	−14.95	−293.7	−13.20	+102.2	−3.72	− 75.6	−5.83
294	+ 9.9	+0.42	+129.5	−18.58	−357.9	− 8.05	+ 73.6	−5.57	−107.2	−4.33
300	+12.3	+0.38	+ 11.6	−20.36	−388.6	− 1.98	+ 35.4	−6.76	−127.6	−2.21
306	+14.5	+0.29	−111.0	−20.23	−381.6	+ 4.29	− 7.5	−7.11	−133.7	+0.20
312	+15.8	+0.16	−227.4	−18.21	−337.1	+10.39	− 49.9	−6.59	−125.2	+2.53
318	+16.4	+0.02	−325.9	−14.33	−258.6	+15.54	− 86.6	−5.29	−103.3	+4.50
324	+16.1	−0.12	−396.6	− 9.06	−153.2	+19.37	−113.4	−3.45	− 71.2	+5.82
330	+15.0	−0.28	−432.7	− 2.78	− 29.7	+21.42	−128.0	−1.38	− 33.5	+6.38
336	+12.8	−0.42	−429.9	+ 3.74	+ 99.9	+21.47	−130.0	+0.62	+ 5.3	+6.21
342	+ 9.9	−0.52	−387.8	+10.18	+224.1	+19.57	−120.6	+2.32	+ 41.0	+5.47
348	+ 6.5	−0.61	−309.4	+15.72	+331.0	+15.77	−102.2	+3.54	+ 70.9	+4.33
354	+ 2.6	−0.66	−201.8	+19.95	+410.4	+10.47	− 78.1	+4.28	+ 93.0	+3.06
360	− 1.4	−0.67	− 73.6	+22.36	+454.5	+ 4.01	− 50.8	+4.64	+107.6	+1.82

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (105) Artemis—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS. Unit of a and b=0°.001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	+7.5	+0.38	+6.4	−0.58	−0.1	−0.07	−0.6	+0.01
6	+8.9	+0.06	+2.6	−0.64	−0.5	−0.06	−0.3	+0.05
12	+8.2	−0.25	−1.3	−0.58	−0.8	−0.02	0.0	+0.07
18	+5.9	−0.47	−4.3	−0.36	−0.8	+0.02	+0.5	+0.08
24	+2.6	−0.52	−5.6	−0.08	−0.5	+0.08	+0.9	+0.06
30	−0.4	−0.45	−5.2	+0.21	+0.1	+0.10	+1.2	+0.02
36	−2.8	−0.26	−3.1	+0.40	+0.7	+0.08	+1.1	−0.04
42	−3.5	+0.02	−0.4	+0.45	+1.1	+0.07	+0.7	−0.08
48	−2.5	+0.27	+2.3	+0.35	+1.5	+0.02	+0.2	−0.09
54	−0.3	+0.41	+3.8	+0.12	+1.4	−0.03	−0.4	−0.10
60	+2.4	+0.42	+3.8	−0.12	+1.1	−0.08	−1.0	−0.08
66	+4.8	+0.32	+2.4	−0.33	+0.5	−0.10	−1.3	−0.02
72	+6.3	+0.12	−0.2	−0.48	−0.1	−0.09	−1.3	+0.01
78	+6.2	−0.14	−3.4	−0.48	−0.6	−0.07	−1.2	+0.04
84	+4.6	−0.36	−6.0	−0.35	−0.9	−0.03	−0.8	+0.08
90	+1.9	−0.51	−7.6	−0.17	−1.0	0.00	−0.3	+0.08
96	−1.5	−0.52	−8.0	+0.07	−0.9	+0.03	+0.1	+0.06
102	−4.4	−0.41	−6.8	+0.28	−0.6	+0.04	+0.4	+0.03
108	−6.4	−0.23	−4.6	+0.42	−0.4	+0.04	+0.5	0.00
114	−7.2	−0.06	−1.7	+0.47	−0.1	+0.03	+0.4	−0.02
120	−7.1	+0.12	+1.0	+0.42	0.0	+0.01	+0.3	−0.01
126	−5.8	+0.28	+3.3	+0.32	0.0	+0.01	+0.3	−0.02
132	−3.8	+0.32	+4.7	+0.15	+0.1	+0.01	+0.1	−0.02
138	−1.9	+0.32	+5.1	+0.01	+0.1	−0.01	0.0	−0.01
144	+0.1	+0.29	+4.8	−0.10	0.0	−0.01	0.0	+0.01
150	+1.6	+0.21	+3.9	−0.16	0.0	0.00	+0.1	−0.01
156	+2.6	+0.11	+2.9	−0.19	0.0	−0.01	−0.1	−0.02
162	+2.9	+0.03	+1.6	−0.21	−0.1	0.00	−0.1	+0.01
168	+3.0	−0.02	+0.4	−0.18	0.0	0.00	0.0	+0.01
174	+2.6	−0.09	−0.6	−0.17	−0.1	−0.01	0.0	0.00
180	+1.9	−0.12	−1.6	−0.12	−0.1	0.00	0.0	+0.01
186	+1.1	−0.16	−2.0	−0.04	−0.1	−0.01	+0.1	+0.02
192	0.0	−0.17	−2.1	0.00	−0.2	+0.01	+0.2	0.00
198	−0.9	−0.15	−2.0	+0.06	0.0	+0.01	+0.1	−0.01
204	−1.8	−0.11	−1.4	+0.13	−0.1	+0.01	+0.1	+0.01
210	−2.2	−0.05	−0.4	+0.16	+0.1	+0.02	+0.2	0.00
216	−2.4	+0.01	+0.5	+0.13	+0.1	0.00	+0.1	−0.01
222	−2.1	+0.08	+1.2	+0.13	+0.1	0.00	+0.1	−0.01
228	−1.5	+0.12	+2.1	+0.12	+0.1	−0.01	0.0	+0.01
234	−0.7	+0.12	+2.6	+0.03	0.0	0.00	+0.2	+0.02
240	0.0	+0.14	+2.5	+0.02	+0.1	+0.01	+0.2	+0.01
246	+1.0	+0.16	+2.8	+0.01	+0.1	+0.02	+0.3	+0.01
252	+1.9	+0.13	+2.6	−0.05	+0.3	+0.02	+0.3	−0.01
258	+2.6	+0.14	+2.2	−0.10	+0.4	+0.03	+0.2	−0.02
264	+3.6	+0.14	+1.4	−0.15	+0.7	+0.03	0.0	−0.04
270	+4.3	+0.09	+0.4	−0.20	+0.8	0.00	−0.3	−0.06
276	+4.7	+0.04	−1.0	−0.25	+0.7	−0.03	−0.7	−0.06
282	+4.8	−0.04	−2.6	−0.30	+0.4	−0.06	−1.0	−0.03
288	+4.2	−0.18	−4.6	−0.32	0.0	−0.08	−1.1	−0.01
294	+2.6	−0.34	−6.5	−0.26	−0.5	−0.08	−1.1	+0.02
300	+0.1	−0.47	−7.7	−0.12	−1.0	−0.07	−0.9	+0.07
306	−3.0	−0.52	−8.0	+0.08	−1.3	−0.02	−0.3	+0.10
312	−6.2	−0.49	−6.7	+0.30	−1.3	+0.03	+0.3	+0.08
318	−8.9	−0.34	−4.4	+0.52	−0.9	+0.06	+0.6	+0.06
324	−10.3	−0.08	−0.4	+0.69	−0.6	+0.08	+1.0	+0.04
330	−9.9	+0.21	+3.9	+0.66	0.0	+0.09	+1.1	−0.02
336	−7.8	+0.47	+7.5	+0.51	+0.5	+0.06	+0.7	−0.07
342	−4.3	+0.67	+10.0	+0.28	+0.7	+0.01	+0.3	−0.08
348	+0.2	+0.72	+10.8	−0.03	+0.6	−0.03	−0.2	−0.06
354	+4.4	+0.61	+9.6	−0.37	+0.3	−0.06	−0.4	−0.03
360	+7.5	+0.38	+6.4	−0.58	−0.1	−0.07	−0.6	+0.01

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (105) Artemis—Continued.

TABLE III.—δ log r.

PERIODIC TERMS.

Unit of a and b=0.00001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	+3.6	−0.05	+32.4	+0.18	+ 4.8	−1.40	+47.1	+0.94	+23.0	−2.06
6	+3.1	−0.08	+32.4	+0.18	− 3.7	−1.41	+51.0	+0.38	+10.2	−2.18
12	+2.6	−0.12	+30.3	−0.52	−12.1	−1.32	+51.7	−0.16	− 3.2	−2.18
18	+1.7	−0.15	+26.1	−0.85	−19.6	−1.15	+49.1	−0.67	−15.9	−2.03
24	+0.8	−0.18	+20.1	−1.10	−25.9	−0.91	+43.7	−1.12	−27.6	−1.82
30	−0.4	−0.19	+12.9	−1.24	−30.5	−0.60	+35.6	−1.55	−37.7	−1.53
36	−1.5	−0.18	+ 5.2	−1.32	−33.1	−0.28	+25.1	−1.91	−46.0	−1.15
42	−2.5	−0.15	− 3.0	−1.33	−33.8	+0.06	+12.7	−2.21	−51.5	−0.64
48	−3.3	−0.12	−10.8	−1.22	−32.4	+0.40	− 1.4	−2.38	−53.7	−0.03
54	−4.0	−0.09	−17.7	−1.06	−29.0	+0.70	−15.9	−2.38	−51.9	+0.63
60	−4.4	−0.05	−23.5	−0.82	−24.0	+0.94	−29.9	−2.18	−46.1	+1.31
66	−4.6	0.00	−27.6	−0.53	−17.7	+1.12	−42.0	−1.75	−36.2	+1.92
72	−4.4	+0.05	−29.9	−0.22	−10.5	+1.20	−50.9	−1.14	−23.0	+2.42
78	−4.0	+0.09	−30.2	+0.13	− 3.3	+1.19	−55.7	−0.37	− 7.2	+2.69
84	−3.3	+0.13	−28.3	+0.45	+ 3.8	+1.10	−55.3	+0.48	+ 9.3	+2.70
90	−2.4	+0.15	−24.8	+0.70	+ 9.9	+0.92	−49.9	+1.28	+25.2	+2.45
96	−1.5	+0.15	−19.9	+0.89	+14.8	+0.68	−39.9	+1.99	+38.7	+1.94
102	−0.6	+0.14	−14.1	+1.02	+18.0	+0.37	−26.0	+2.49	+48.5	+1.22
108	+0.2	+0.12	− 7.7	+1.03	+19.2	+0.05	−10.0	+2.72	+53.4	+0.38
114	+0.8	+0.10	− 1.7	+0.94	+18.6	−0.24	+ 6.7	+2.68	+53.1	−0.48
120	+1.4	+0.06	+ 3.6	+0.78	+16.3	−0.49	+22.1	+2.35	+47.6	−1.29
126	+1.5	0.00	+ 7.7	+0.55	+12.7	−0.69	+34.9	+1.81	+37.6	−1.94
132	+1.4	−0.03	+10.2	+0.28	+ 8.0	−0.79	+43.8	+1.08	+24.3	−2.38
138	+1.1	−0.08	+11.1	−0.02	+ 3.2	−0.78	+47.9	+0.25	+ 9.1	−2.56
144	+0.5	−0.10	+10.0	−0.28	− 1.3	−0.68	+46.8	−0.57	− 6.4	−2.46
150	−0.1	−0.11	+ 7.7	−0.48	− 5.0	−0.50	+41.1	−1.31	−20.4	−2.09
156	−0.8	−0.11	+ 4.2	−0.60	− 7.3	−0.27	+31.1	−1.91	−31.5	−1.53
162	−1.4	−0.10	+ 0.5	−0.61	− 8.2	−0.01	+18.2	−2.27	−38.8	−0.80
168	−2.0	−0.09	− 3.1	−0.58	− 7.4	+0.25	+ 3.9	−2.35	−41.1	+0.02
174	−2.5	−0.06	− 6.4	−0.43	− 5.2	+0.46	−10.0	−2.17	−38.6	+0.79
180	−2.7	−0.02	− 8.3	−0.22	− 1.9	+0.58	−22.1	−1.73	−31.6	+1.48
186	−2.7	+0.02	− 9.1	+0.01	+ 1.7	+0.63	−30.8	−1.12	−20.9	+1.94
192	−2.4	+0.06	− 8.2	+0.24	+ 5.7	+0.62	−35.6	−0.38	− 8.3	+2.18
198	−2.0	+0.08	− 6.2	+0.45	+ 9.2	+0.50	−35.3	+0.42	+ 5.3	+2.16
204	−1.5	+0.10	− 2.8	+0.62	+11.7	+0.31	−30.5	+1.12	+17.6	+1.86
210	−0.8	+0.09	+ 1.2	+0.67	+12.9	+0.08	−21.8	+1.69	+27.6	+1.33
216	−0.4	+0.08	+ 5.2	+0.65	+12.7	−0.17	−10.2	+2.05	+33.6	+0.66
222	+0.1	+0.06	+ 9.0	+0.58	+10.9	−0.39	+ 2.8	+2.15	+35.5	−0.09
228	+0.3	+0.02	+12.1	+0.40	+ 8.0	−0.58	+15.6	+1.97	+32.5	−0.83
234	+0.4	0.00	+13.8	+0.15	+ 3.9	−0.71	+26.4	+1.58	+25.5	−1.44
240	+0.3	−0.05	+13.9	−0.10	− 0.5	−0.74	+34.6	+1.02	+15.2	−1.92
246	−0.2	−0.08	+12.6	−0.35	− 5.0	−0.70	+38.7	+0.32	+ 2.5	−2.18
252	−0.6	−0.08	+ 9.7	−0.58	− 8.9	−0.58	+38.4	−0.42	−10.9	−2.19
258	−1.2	−0.10	+ 5.6	−0.77	−11.9	−0.38	+33.6	−1.15	−23.8	−1.98
264	−1.8	−0.10	+ 0.5	−0.89	−13.5	−0.12	+24.6	−1.76	−34.6	−1.52
270	−2.4	−0.09	− 5.1	−0.91	−13.3	+0.18	+12.5	−2.20	−42.1	−0.88
276	−2.9	−0.07	−10.4	−0.84	−11.3	+0.47	− 1.8	−2.43	−45.2	−0.12
282	−3.2	−0.03	−15.2	−0.68	− 7.7	+0.73	−16.7	−2.39	−43.5	+0.68
288	−3.3	+0.01	−18.6	−0.44	− 2.5	+0.93	−30.5	−2.09	−37.1	+1.44
294	−3.1	+0.06	−20.5	−0.15	+ 3.5	+1.08	−41.8	−1.54	−26.2	+2.08
300	−2.6	+0.09	−20.4	+0.18	+10.4	+1.12	−49.0	−0.79	−12.1	+2.50
306	−2.0	+0.12	−18.3	+0.52	+16.9	+1.02	−51.3	+0.02	+ 3.8	+2.65
312	−1.1	+0.15	−14.2	+0.81	+22.7	+0.87	−48.7	+0.87	+19.7	+2.51
318	−0.2	+0.15	− 8.6	+1.03	+27.3	+0.62	−40.9	+1.63	+33.9	+2.11
324	+0.7	+0.16	− 1.8	+1.20	+30.2	+0.30	−29.1	+2.18	+45.0	+1.48
330	+1.7	+0.15	+ 5.8	+1.28	+30.9	−0.07	−14.7	+2.48	+51.6	+0.72
336	+2.5	+0.12	+13.5	+1.22	+29.4	−0.42	+ 0.6	+2.55	+53.7	−0.03
342	+3.1	+0.09	+20.5	+1.07	+25.8	−0.77	+15.9	+2.38	+51.2	−0.76
348	+3.6	+0.05	+26.3	+0.81	+20.2	−1.06	+29.1	+1.98	+44.6	−1.36
354	+3.7	0.00	+30.2	+0.51	+13.1	−1.28	+39.7	+1.50	+34.9	−1.80
360	+3.6	−0.05	+32.4	+0.18	+ 4.8	−1.40	+47.1	+0.94	+23.0	−2.06

[$n\delta z$ δ log r, and u/cos i are to be computed in the form $\Sigma_i\, a_i \sin ig+\Sigma_i\, b_i \cos ig+cT$.]

Tables of (105) Artemis—Continued.

TABLE III.—δ log r—Continued.

PERIODIC TERMS. Unit of a and b=0.00001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	+6.3	−0.41	−4.7	−0.39	0.0	0.00	0.0	+0.02
6	+3.3	−0.54	−6.4	−0.13	0.0	+0.01	+0.1	+0.02
12	−0.2	−0.49	−6.3	+0.15	+0.1	+0.02	+0.2	+0.01
18	−2.6	−0.28	−4.6	+0.37	+0.2	+0.02	+0.2	−0.01
24	−3.6	−0.03	−1.9	+0.42	+0.4	+0.02	+0.1	−0.02
30	−3.0	+0.21	+0.5	+0.32	+0.5	0.00	−0.1	−0.03
36	−1.1	+0.35	+2.0	+0.12	+0.4	−0.02	−0.3	−0.03
42	+1.2	+0.34	+2.0	−0.12	+0.3	−0.02	−0.5	−0.03
48	+3.0	+0.18	+0.5	−0.33	+0.2	−0.04	−0.7	−0.02
54	+3.4	−0.06	−2.0	−0.39	−0.2	−0.05	−0.7	0.00
60	+2.3	−0.29	−4.2	−0.32	−0.4	−0.03	−0.7	+0.02
66	−0.1	−0.43	−5.8	−0.12	−0.6	−0.02	−0.5	+0.04
72	−2.9	−0.45	−5.6	+0.14	−0.6	−0.02	−0.2	+0.05
78	−5.5	−0.32	−4.1	+0.35	−0.8	−0.01	+0.1	+0.04
84	−6.8	−0.09	−1.4	+0.47	−0.7	+0.02	+0.3	+0.03
90	−6.6	+0.13	+1.5	+0.45	−0.5	+0.04	+0.5	+0.02
96	−5.2	+0.31	+4.0	+0.32	−0.2	+0.04	+0.6	0.00
102	−2.9	+0.40	+5.3	+0.12	0.0	+0.03	+0.5	−0.01
108	−0.4	+0.36	+5.5	−0.08	+0.2	+0.02	+0.5	−0.02
114	+1.4	+0.22	+4.4	−0.21	+0.3	+0.02	+0.3	−0.02
120	+2.3	+0.09	+3.0	−0.24	+0.4	0.00	+0.2	−0.02
126	+2.5	−0.02	+1.5	−0.20	+0.3	−0.02	+0.1	−0.02
132	+2.0	−0.09	+0.6	−0.10	+0.2	−0.01	−0.1	−0.02
138	+1.4	−0.08	+0.3	0.00	+0.2	−0.01	−0.2	−0.01
144	+1.1	0.00	+0.6	+0.04	+0.1	−0.01	−0.2	+0.01
150	+1.4	+0.08	+0.8	0.00	+0.1	−0.02	−0.1	+0.02
156	+2.0	+0.10	+0.6	−0.08	−0.1	−0.02	0.0	+0.01
162	+2.6	+0.03	−0.2	−0.17	−0.1	+0.02	0.0	0.00
168	+2.4	−0.07	−1.4	−0.20	+0.1	+0.01	0.0	+0.01
174	+1.8	−0.17	−2.6	−0.16	0.0	−0.01	+0.1	0.00
180	+0.4	−0.27	−3.3	−0.06	0.0	0.00	0.0	−0.02
186	−1.4	−0.28	−3.3	+0.09	0.0	+0.01	−0.1	0.00
192	−3.0	−0.21	−2.2	+0.24	+0.1	−0.01	0.0	+0.01
198	−3.9	−0.05	−0.4	+0.34	−0.1	−0.02	0.0	+0.01
204	−3.6	+0.13	+1.9	+0.32	−0.1	+0.02	+0.1	+0.01
210	−2.3	+0.28	+3.5	+0.21	+0.1	+0.02	+0.1	+0.01
216	−0.2	+0.37	+4.4	+0.04	+0.1	+0.01	+0.2	+0.01
222	+2.1	+0.32	+4.0	−0.14	+0.2	+0.01	+0.2	−0.01
228	+3.7	+0.20	+2.7	−0.28	+0.2	+0.01	+0.1	−0.02
234	+4.5	+0.03	+0.6	−0.34	+0.3	+0.02	−0.1	−0.02
240	+4.1	−0.12	−1.4	−0.29	+0.4	0.00	−0.2	−0.02
246	+3.0	−0.22	−2.9	−0.18	+0.3	−0.02	−0.3	−0.02
252	+1.4	−0.24	−3.5	−0.02	+0.2	−0.02	−0.5	−0.02
258	+0.1	−0.18	−3.2	+0.08	0.0	−0.03	−0.5	−0.01
264	−0.8	−0.09	−2.6	+0.10	−0.2	−0.04	−0.6	0.00
270	−1.0	0.00	−2.0	+0.08	−0.5	−0.04	−0.5	+0.02
276	−0.8	+0.01	−1.6	0.00	−0.7	−0.02	−0.3	+0.03
282	−0.9	−0.04	−2.0	−0.06	−0.8	+0.01	−0.1	+0.04
288	−1.3	−0.12	−2.3	−0.05	−0.6	+0.02	+0.2	+0.05
294	−2.4	−0.22	−2.6	+0.02	−0.6	+0.02	+0.5	+0.04
300	−4.0	−0.25	−2.0	+0.17	−0.4	+0.03	+0.7	+0.02
306	−5.4	−0.18	−0.6	+0.32	−0.2	+0.05	+0.7	0.00
312	−6.1	0.00	+1.8	+0.44	+0.2	+0.04	+0.7	−0.02
318	−5.4	+0.23	+4.7	+0.44	+0.3	+0.02	+0.5	−0.03
324	−3.3	+0.46	+7.1	+0.30	+0.4	+0.02	+0.3	−0.03
330	+0.1	+0.58	+8.3	+0.07	+0.5	0.00	+0.1	−0.03
336	+3.6	+0.55	+7.9	−0.22	+0.4	−0.02	−0.1	−0.02
342	+6.7	+0.41	+5.6	−0.47	+0.2	−0.02	−0.2	−0.01
348	+8.5	+0.12	+2.3	−0.61	+0.1	−0.02	−0.2	+0.01
354	+8.2	−0.18	−1.7	−0.58	0.0	−0.01	−0.1	+0.02
360	+6.3	−0.41	−4.7	−0.39	0.0	0.00	0.0	+0.02

[$n\delta z$, δ log r, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (*105*) *Artemis*—Continued.

TABLE IV.—u/cos i.

PERIODIC TERMS. Unit of a and b=0″.001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	− 5.0	+0.35	+ 9.6	+0.17	+1.9	−0.12	+ 4.5	+0.52	+ 9.6	−0.20
6	− 2.8	+0.42	+10.4	+0.12	+1.1	−0.16	+ 7.4	+0.42	+ 8.0	−0.35
12	0.0	+0.47	+11.0	+0.06	0.0	−0.20	+ 9.5	+0.30	+ 5.4	−0.45
18	+ 2.8	+0.47	+11.1	−0.07	−1.3	−0.22	+11.0	+0.18	+ 2.6	−0.50
24	+ 5.6	+0.47	+10.2	−0.19	−2.7	−0.22	+11.6	+0.03	− 0.6	−0.53
30	+ 8.4	+0.40	+ 8.8	−0.29	−4.0	−0.20	+11.4	−0.10	− 3.8	−0.53
36	+10.4	+0.32	+ 6.7	−0.35	−5.1	−0.12	+10.4	−0.25	− 7.0	−0.49
42	+12.3	+0.24	+ 4.6	−0.40	−5.5	−0.02	+ 8.4	−0.38	− 9.7	−0.42
48	+13.3	+0.12	+ 1.9	−0.41	−5.4	+0.05	+ 5.9	−0.47	−12.0	−0.31
54	+13.6	−0.01	− 0.3	−0.35	−4.9	+0.08	+ 2.8	−0.55	−13.4	−0.17
60	+13.2	−0.13	− 2.3	−0.31	−4.5	+0.10	− 0.7	−0.58	−14.0	−0.02
66	+12.0	−0.25	− 4.0	−0.23	−3.7	+0.12	− 4.2	−0.61	−13.7	+0.13
72	+10.2	−0.34	− 5.1	−0.19	−3.1	+0.08	− 8.0	−0.58	−12.4	+0.29
78	+ 7.9	−0.39	− 6.3	−0.16	−2.7	+0.06	−11.2	−0.48	−10.2	+0.43
84	+ 5.5	−0.42	− 7.0	−0.11	−2.4	+0.05	−13.8	−0.36	− 7.2	+0.58
90	+ 2.8	−0.43	− 7.6	−0.08	−2.1	+0.06	−15.5	−0.18	− 3.2	+0.68
96	+ 0.3	−0.40	− 8.0	−0.08	−1.7	+0.06	−16.0	+0.02	+ 1.0	+0.75
102	− 2.0	−0.32	− 8.6	−0.08	−1.4	+0.07	−15.2	+0.25	+ 5.8	+0.76
108	− 3.6	−0.22	− 8.9	−0.01	−0.9	+0.10	−13.0	+0.49	+10.1	+0.63
114	− 4.7	−0.12	− 8.7	+0.03	−0.2	+0.12	− 9.3	+0.68	+13.4	+0.48
120	− 5.0	0.00	− 8.5	+0.05	+0.5	+0.11	− 4.8	+0.81	+15.8	+0.25
126	− 4.7	+0.10	− 8.1	+0.08	+1.1	+0.10	+ 0.4	+0.88	+16.4	−0.05
132	− 3.8	+0.18	− 7.5	+0.09	+1.7	+0.10	+ 5.7	+0.83	+15.2	−0.32
138	− 2.5	+0.24	− 7.0	+0.09	+2.3	+0.11	+10.4	+0.68	+12.5	−0.58
144	− 0.9	+0.28	− 6.4	+0.08	+3.0	+0.12	+13.8	+0.43	+ 8.2	−0.78
150	+ 0.8	+0.25	− 6.1	+0.08	+3.7	+0.11	+15.6	+0.14	+ 3.1	−0.88
156	+ 2.1	+0.21	− 5.4	+0.11	+4.3	+0.11	+15.5	−0.15	− 2.3	−0.87
162	+ 3.3	+0.15	− 4.8	+0.12	+5.0	+0.12	+13.8	−0.42	− 7.3	−0.76
168	+ 3.9	+0.06	− 3.9	+0.17	+5.8	+0.10	+10.4	−0.66	−11.4	−0.58
174	+ 4.0	−0.04	− 2.8	+0.21	+6.2	+0.06	+ 5.9	−0.79	−14.2	−0.32
180	+ 3.4	−0.15	− 1.4	+0.23	+6.5	+0.01	+ 0.9	−0.84	−15.2	−0.03
186	+ 2.2	−0.22	0.0	+0.25	+6.3	−0.06	− 4.2	−0.78	−14.6	+0.25
192	+ 0.8	−0.25	+ 1.6	+0.24	+5.8	−0.15	− 8.5	−0.65	−12.2	+0.48
198	− 0.8	−0.27	+ 2.9	+0.20	+4.5	−0.24	−12.0	−0.49	− 8.8	+0.65
204	− 2.4	−0.25	+ 4.0	+0.16	+2.9	−0.26	−14.4	−0.23	− 4.4	+0.77
210	− 3.8	−0.20	+ 4.8	+0.08	+1.4	−0.25	−14.8	+0.03	+ 0.4	+0.78
216	− 4.8	−0.12	+ 4.9	0.00	−0.1	−0.26	−14.0	+0.27	+ 5.0	+0.74
222	− 5.3	−0.02	+ 4.8	−0.04	−1.7	−0.24	−11.6	+0.51	+ 9.3	+0.64
228	− 5.1	+0.09	+ 4.4	−0.08	−3.0	−0.20	− 7.9	+0.68	+12.8	+0.45
234	− 4.2	+0.19	+ 3.9	−0.11	−4.1	−0.14	− 3.4	+0.78	+14.7	+0.20
240	− 2.8	+0.25	+ 3.1	−0.16	−4.7	−0.10	+ 1.5	+0.82	+15.2	−0.06
246	− 1.2	+0.30	+ 2.0	−0.17	−5.3	−0.07	+ 6.4	+0.76	+14.0	−0.33
252	+ 0.8	+0.32	+ 1.1	−0.16	−5.5	−0.01	+10.6	+0.62	+11.2	−0.57
258	+ 2.7	+0.29	+ 0.1	−0.18	−5.4	+0.06	+13.8	+0.40	+ 7.2	−0.75
264	+ 4.3	+0.24	− 1.1	−0.19	−4.8	+0.12	+15.4	+0.12	+ 2.2	−0.83
270	+ 5.6	+0.17	− 2.2	−0.14	−3.9	+0.16	+15.3	−0.18	− 2.8	−0.82
276	+ 6.3	+0.07	− 2.8	−0.08	−2.9	+0.19	+13.3	−0.42	− 7.6	−0.72
282	+ 6.4	−0.06	− 3.2	−0.06	−1.6	+0.22	+10.2	−0.64	−11.4	−0.52
288	+ 5.6	−0.18	− 3.5	+0.01	−0.3	+0.23	+ 5.6	−0.78	−13.8	−0.25
294	+ 4.3	−0.27	− 3.1	+0.10	+1.2	+0.21	+ 0.9	−0.78	−14.4	+0.02
300	+ 2.4	−0.33	− 2.3	+0.17	+2.2	+0.14	− 3.8	−0.71	−13.6	+0.27
306	+ 0.3	−0.37	− 1.1	+0.21	+2.9	+0.11	− 7.6	−0.56	−11.2	+0.50
312	− 2.0	−0.37	+ 0.2	+0.21	+3.5	+0.03	−10.5	−0.37	− 7.6	+0.62
318	− 4.1	−0.34	+ 1.4	+0.22	+3.3	−0.02	−12.0	−0.11	− 3.7	+0.67
324	− 6.1	−0.29	+ 2.8	+0.22	+3.2	−0.02	−11.8	+0.10	+ 0.4	+0.65
330	− 7.6	−0.20	+ 4.1	+0.18	+3.1	−0.01	−10.8	+0.27	+ 4.1	+0.57
336	− 8.5	−0.09	+ 5.0	+0.16	+3.1	−0.02	− 8.6	+0.44	+ 7.2	+0.43
342	− 8.7	+0.03	+ 6.0	+0.18	+2.8	−0.04	− 5.5	+0.53	+ 9.3	+0.27
348	− 8.1	+0.14	+ 7.2	+0.20	+2.6	−0.02	− 2.2	+0.57	+10.4	+0.09
354	− 7.0	+0.26	+ 8.4	+0.20	+2.5	−0.06	+ 1.3	+0.56	+10.4	−0.07
360	− 5.0	+0.35	+ 9.6	+0.17	+1.9	−0.12	+ 4.5	+0.52	+ 9.6	−0.20

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig+\Sigma_i\, b_i \cos ig+cT$.]

Tables of (105) Artemis—Continued.

TABLE IV.—u cos i—Continued.

PERIODIC TERMS.

Unit of a and b=0°.001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	+1.2	+0.02	+1.0	−0.10	+0.2	−0.01	+0.1	−0.02
6	+1.1	−0.04	+0.2	−0.11	+0.1	−0.01	0.0	−0.02
12	+0.7	−0.08	−0.3	−0.06	+0.1	−0.02	−0.1	+0.01
18	+0.2	−0.09	−0.5	+0.02	−0.1	−0.01	+0.1	+0.02
24	−0.4	−0.06	−0.1	+0.07	0.0	+0.02	+0.1	+0.01
30	−0.5	+0.01	+0.3	+0.07	+0.1	+0.02	+0.2	+0.01
36	−0.3	+0.08	+0.7	+0.08	+0.3	+0.02	+0.2	−0.01
42	+0.4	+0.12	+1.2	+0.04	+0.3	+0.02	+0.1	−0.02
48	+1.1	+0.12	+1.2	−0.04	+0.5	+0.01	−0.1	−0.03
54	+1.8	+0.09	+0.7	−0.12	+0.4	−0.02	−0.3	−0.03
60	+2.2	+0.02	−0.2	−0.15	+0.2	−0.04	−0.5	−0.02
66	+2.0	−0.06	−1.1	−0.15	−0.1	−0.04	−0.6	0.00
72	+1.5	−0.13	−2.0	−0.12	−0.3	−0.03	−0.5	+0.02
78	+0.4	−0.18	−2.6	−0.05	−0.5	−0.02	−0.3	+0.03
84	−0.6	−0.18	−2.6	+0.04	−0.6	0.00	−0.1	+0.04
90	−1.7	−0.13	−2.1	+0.12	−0.5	+0.02	+0.2	+0.04
96	−2.2	−0.08	−1.2	+0.17	−0.3	+0.03	+0.4	+0.02
102	−2.7	−0.02	−0.1	+0.17	−0.1	+0.03	+0.5	−0.01
108	−2.4	+0.08	+0.8	+0.14	+0.1	+0.02	+0.3	−0.02
114	−1.8	+0.12	+1.6	+0.11	+0.2	+0.01	+0.3	−0.02
120	−0.9	+0.14	+2.1	+0.04	+0.2	−0.01	+0.1	−0.02
126	−0.1	+0.12	+2.1	−0.02	+0.1	−0.01	0.0	−0.02
132	+0.6	+0.10	+1.9	−0.07	+0.1	−0.02	−0.1	+0.01
138	+1.1	+0.07	+1.3	−0.08	−0.1	−0.01	+0.1	+0.02
144	+1.4	+0.03	+1.0	−0.08	0.0	+0.02	+0.1	+0.01
150	+1.5	+0.01	+0.4	−0.10	+0.1	+0.02	+0.2	+0.01
156	+1.5	−0.01	−0.2	−0.08	+0.3	+0.02	+0.2	−0.01
162	+1.4	−0.02	−0.5	−0.06	+0.3	+0.02	+0.1	−0.02
168	+1.3	−0.05	−0.9	−0.08	+0.5	+0.01	−0.1	−0.03
174	+0.8	−0.08	−1.4	−0.06	+0.4	−0.02	−0.3	−0.03
180	+0.4	−0.09	−1.6	−0.02	+0.2	−0.04	−0.5	−0.02
186	−0.3	−0.11	−1.6	+0.01	−0.1	−0.04	−0.6	0.00
192	−0.9	−0.09	−1.5	+0.04	−0.3	−0.02	−0.5	+0.02
198	−1.4	−0.08	−1.1	+0.08	−0.5	−0.02	−0.3	+0.03
204	−1.8	−0.04	−0.5	+0.10	−0.6	0.00	−0.1	+0.04
210	−1.9	+0.01	+0.1	+0.12	−0.5	+0.02	+0.2	+0.04
216	−1.7	+0.06	+0.9	+0.11	−0.3	+0.03	+0.4	+0.02
222	−1.2	+0.09	+1.4	+0.07	−0.1	+0.03	+0.5	−0.01
228	−0.6	+0.10	+1.7	+0.02	+0.1	+0.02	+0.3	−0.02
234	0.0	+0.10	+1.7	−0.01	+0.2	+0.01	+0.3	−0.02
240	+0.6	+0.08	+1.6	−0.03	+0.2	−0.01	+0.1	−0.02
246	+1.0	+0.06	+1.3	−0.07	+0.1	−0.01	0.0	−0.02
252	+1.3	+0.02	+0.8	−0.08	+0.1	−0.02	−0.1	+0.01
258	+1.3	+0.01	+0.4	−0.05	−0.1	−0.01	+0.1	+0.02
264	+1.4	0.00	+0.2	−0.04	0.0	+0.02	+0.1	+0.01
270	+1.3	0.00	−0.1	−0.07	+0.1	+0.02	+0.2	+0.01
276	+1.4	0.00	−0.6	−0.07	+0.3	+0.02	+0.2	−0.01
282	+1.3	−0.02	−0.9	−0.05	+0.3	+0.02	+0.1	−0.02
288	+1.2	−0.04	−1.2	−0.08	+0.5	+0.01	−0.1	−0.03
294	+0.8	−0.09	−1.8	−0.08	+0.4	−0.02	−0.3	−0.03
300	+0.1	−0.12	−2.1	−0.02	+0.2	−0.04	−0.5	−0.02
306	−0.7	−0.12	−2.1	+0.03	−0.1	−0.04	−0.6	0.00
312	−1.4	−0.12	−1.7	+0.08	−0.3	−0.03	−0.5	+0.02
318	−2.1	−0.08	−1.1	+0.12	−0.5	−0.02	−0.3	+0.03
324	−2.4	−0.02	−0.2	+0.14	−0.6	0.00	−0.1	+0.04
330	−2.3	+0.06	+0.6	+0.15	−0.5	+0.02	+0.2	+0.04
336	−1.7	+0.11	+1.6	+0.12	−0.3	+0.03	+0.4	+0.02
342	−1.0	+0.15	+2.1	+0.02	−0.1	+0.03	+0.5	−0.01
348	+0.1	+0.15	+1.9	−0.06	+0.1	+0.02	+0.3	−0.02
354	+0.8	+0.09	+1.4	−0.08	+0.2	+0.01	+0.3	−0.02
360	+1.2	+0.02	+1.0	−0.10	+0.2	−0.01	+0.1	−0.02

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (105) Artemis—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY $T=(t-t_0)$ IN JULIAN YEARS.

g	$n\delta z$ Unit of $c=0°.001$		$\delta \log r$ Unit of $c=0.00001$		$u/\cos i$ Unit of $c=0°.001$	
	c	Diff. for 1°	c	Diff. for 1°	c	Diff. for 1°
°						
0	−2.18	+0.038	−0.86	−0.017	+1.56	−0.063
6	−1.95	+0.042	−0.96	−0.015	+1.16	−0.067
12	−1.68	+0.046	−1.04	−0.012	+0.76	−0.070
18	−1.40	+0.048	−1.11	−0.010	+0.32	−0.073
24	−1.10	+0.051	−1.16	−0.008	−0.12	−0.072
30	−0.79	+0.052	−1.20	−0.004	−0.54	−0.070
36	−0.47	+0.054	−1.21	−0.002	−0.96	−0.070
42	−0.14	+0.052	−1.22	0.000	−1.38	−0.068
48	+0.16	+0.052	−1.21	+0.003	−1.78	−0.062
54	+0.48	+0.052	−1.18	+0.006	−2.13	−0.057
60	+0.79	+0.049	−1.14	+0.008	−2.46	−0.054
66	+1.07	+0.048	−1.08	+0.010	−2.78	−0.048
72	+1.36	+0.044	−1.02	+0.010	−3.04	−0.040
78	+1.60	+0.040	−0.96	+0.013	−3.26	−0.035
84	+1.84	+0.037	−0.86	+0.016	−3.46	−0.030
90	+2.04	+0.032	−0.77	+0.014	−3.62	−0.022
96	+2.23	+0.030	−0.69	+0.015	−3.72	−0.015
102	+2.40	+0.026	−0.59	+0.017	−3.80	−0.011
108	+2.54	+0.020	−0.49	+0.018	−3.85	−0.006
114	+2.64	+0.015	−0.38	+0.017	−3.87	−0.001
120	+2.72	+0.012	−0.29	+0.018	−3.86	+0.006
126	+2.78	+0.006	−0.17	+0.018	−3.80	+0.011
132	+2.79	+0.001	−0.08	+0.016	−3.73	+0.014
138	+2.79	−0.004	+0.02	+0.017	−3.63	+0.019
144	+2.74	−0.008	+0.12	+0.016	−3.50	+0.024
150	+2.70	−0.011	+0.21	+0.017	−3.34	+0.028
156	+2.61	−0.017	+0.32	+0.016	−3.16	+0.032
162	+2.50	−0.021	+0.40	+0.014	−2.96	+0.035
168	+2.36	−0.025	+0.49	+0.013	−2.74	+0.039
174	+2.20	−0.028	+0.56	+0.012	−2.49	+0.042
180	+2.02	−0.032	+0.64	+0.012	−2.23	+0.044
186	+1.82	−0.035	+0.71	+0.011	−1.96	+0.046
192	+1.60	−0.038	+0.77	+0.009	−1.68	+0.050
198	+1.36	−0.040	+0.82	+0.008	−1.36	+0.052
204	+1.12	−0.042	+0.87	+0.008	−1.06	+0.052
210	+0.85	−0.046	+0.91	+0.006	−0.74	+0.053
216	+0.57	−0.046	+0.94	+0.004	−0.42	+0.053
222	+0.30	−0.046	+0.96	+0.003	−0.10	+0.053
228	+0.02	−0.047	+0.98	+0.002	+0.22	+0.053
234	−0.26	−0.048	+0.99	−0.001	+0.54	+0.053
240	−0.55	−0.048	+0.97	−0.002	+0.86	+0.052
246	−0.83	−0.048	+0.96	−0.002	+1.16	+0.050
252	−1.12	−0.046	+0.94	−0.004	+1.46	+0.048
258	−1.38	−0.043	+0.91	−0.008	+1.74	+0.047
264	−1.64	−0.042	+0.85	−0.010	+2.02	+0.045
270	−1.88	−0.039	+0.79	−0.009	+2.28	+0.042
276	−2.11	−0.037	+0.74	−0.012	+2.52	+0.037
282	−2.32	−0.032	+0.65	−0.015	+2.72	+0.031
288	−2.50	−0.028	+0.56	−0.016	+2.89	+0.027
294	−2.66	−0.023	+0.46	−0.017	+3.04	+0.021
300	−2.78	−0.018	+0.36	−0.019	+3.14	+0.013
306	−2.88	−0.014	+0.23	−0.020	+3.20	+0.006
312	−2.95	−0.008	+0.12	−0.019	+3.21	−0.002
318	−2.97	−0.001	0.00	−0.022	+3.18	−0.009
324	−2.96	+0.002	−0.14	−0.022	+3.10	−0.020
330	−2.94	+0.009	−0.27	−0.022	+2.94	−0.028
336	−2.85	+0.017	−0.41	−0.022	+2.76	−0.035
342	−2.74	+0.022	−0.54	−0.020	+2.52	−0.043
348	−2.58	+0.028	−0.65	−0.018	+2.24	−0.050
354	−2.41	+0.033	−0.76	−0.018	+1.92	−0.057
360	−2.18	+0.038	−0.86	−0.017	+1.56	−0.063

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (105) Artemis—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	A'	B'	C'	log sin a	log sin b	log sin c
	°	°	°			
1868. 0	331. 9602	241. 8561	294. 7577	9. 99948	9. 99970	8. 78814
9	. 9732	. 8689	. 8123	48	70	. 78868
1870	331. 9862	241. 8817	294. 8667	9. 99948	9. 99970	8. 78922
1	331. 9992	. 8945	. 9209	47	70	. 78976
2	332. 0122	. 9073	294. 9750	47	70	. 79030
3	. 0252	. 9201	295. 0291	47	70	. 79084
4	. 0382	. 9328	. 0831	47	70	. 79138
1875	332. 0513	241. 9456	295. 1371	9. 99947	9. 99970	8. 79192
6	. 0643	. 9584	. 1910	46	70	. 79246
7	. 0773	. 9712	. 2448	46	70	. 79300
8	. 0903	. 9840	. 2985	46	70	. 79354
9	. 1033	241. 9968	. 3519	46	70	. 79409
1880	332. 1163	242. 0096	295. 4053	9. 99946	9. 99970	8. 79463
1	. 1293	. 0224	. 4585	45	70	. 79517
2	. 1424	. 0352	. 5116	45	70	. 79571
3	. 1554	. 0480	. 5648	45	70	. 79625
4	. 1684	. 0608	. 6177	45	70	. 79679
1885	332. 1814	241. 0736	295. 6706	9. 99945	9. 99970	8. 79733
6	. 1944	. 0863	. 7234	44	70	. 79787
7	. 2074	. 0991	. 7759	44	70	. 79841
8	. 2204	. 1119	. 8284	44	70	. 79895
9	. 2334	. 1247	. 8807	44	70	. 79949
1890	332. 2465	242. 1375	295. 9329	9. 99944	9. 99970	8. 80003
1	. 2595	. 1503	295. 9851	44	70	. 80057
2	. 2725	. 1631	296. 0372	43	70	. 80111
3	. 2855	. 1759	. 0891	43	70	. 80166
4	. 2985	. 1887	. 1409	43	70	. 80220
1895	332. 3115	242. 2014	296. 1926	9. 99943	9. 99970	8. 80274
6	. 3245	. 2142	. 2441	43	70	. 80328
7	. 3376	. 2270	. 2955	42	70	. 80382
8	. 3506	. 2398	. 3468	42	70	. 80436
9	. 3636	. 2526	. 3979	42	70	. 80490
1900	332. 3766	242. 2654	296. 4489	9. 99942	9. 99970	8. 80544
1	. 3896	. 2782	. 4999	42	70	. 80597
2	. 4026	. 2910	. 5507	41	70	. 80650
3	. 4157	. 3038	. 6014	41	70	. 80703
4	. 4287	. 3165	. 6520	41	70	. 80755
1905	332. 4417	242. 3293	296. 7026	9. 99941	9. 99969	8. 80808
6	. 4547	. 3421	. 7530	41	69	. 80861
7	. 4677	. 3549	. 8034	40	69	. 80914
8	. 4807	. 3677	. 8536	40	69	. 80967
9	. 4938	. 3805	. 9037	40	69	. 81019
1910	332. 5068	242. 3933	296. 9537	9. 99940	9. 99969	8. 81072
1	. 5198	. 4061	297. 0036	40	69	. 81125
2	. 5328	. 4188	. 0533	39	69	. 81178
3	. 5458	. 4316	. 1030	39	69	. 81231
4	. 5588	. 4444	. 1526	39	69	. 81284
1915	332. 5719	242. 4572	297. 2022	9. 99939	9. 99969	8. 81336
6	. 5849	. 4700	. 2516	39	69	. 81389
7	. 5979	. 4828	. 3009	38	69	. 81442
8	. 6109	. 4956	. 3502	38	69	. 81495
9	. 6239	. 5084	. 3992	38	69	. 81548
1920	332. 6369	242. 5211	297. 4482	9. 9938	9. 99969	8. 81601
1	. 6500	. 5339	. 4971	38	69	. 81653
2	. 6630	. 5467	. 5457	37	69	. 81706
3	. 6760	. 5595	. 5945	37	69	. 81759
4	. 6890	. 5723	. 6431	37	69	. 81812
1925	332. 7020	242. 5851	297. 6916	9. 99937	9. 99969	8. 81865
6	. 7150	. 5979	. 7400	37	69	. 81917
7	. 7281	. 6107	. 7882	36	69	. 81970
8	. 7411	. 6234	. 8362	36	69	. 82023
9	. 7541	. 6362	. 8842	36	69	. 82076
1930	332. 7671	242. 6490	297. 9319	9. 99936	9. 99969	8. 82129

Year	log cos a	log cos b	log cos c
1868. 0	8. 690	8. 570 n	9. 999
1930. 0	8. 736	8. 570 n	9. 999

TABLES OF (115) THYRA.

MEAN ELEMENTS.

Epoch, 1890, Jan., 0.0372, M. T. Berlin=1890.000, M. T. Berlin.

$$
\begin{array}{rrrrl}
 & ^{\circ} & ' & '' & \\
g_0= & 299 & 32 & 18= & 299^{\circ}.5382 \\
\omega= & 94 & 15 & 37= & 94.2604 \\
\Omega= & 309 & 12 & 2= & 309.2006 \\
i= & 11 & 35 & 8= & 11.5856 \\
\varphi= & 11 & 6 & 59= & 11.1164 \\
n= & \multicolumn{3}{l}{966''.3084 \quad =} & 0.26841901
\end{array}
\left.\begin{array}{l} \\ \\ \\ \\ \end{array}\right\}\text{Mean equinox and ecliptic 1900.0}
$$

The elements are based on oppositions extending from 1871 to 1904 and on the perturbations of the first order by *Jupiter*, as given on page 247.

AUXILIARY QUANTITIES.

$\log a=0.37659$ $\log 57.2958e=1.04324$ $\log\sqrt{\frac{1-e}{1+e}}=9.91521$

$\log e=9.28511$ $\log p =0.36014$

TABLE I.—MEAN ANOMALY (g).

Jan., 0.0 of common years; Jan. 1.0 of leap years

Year	g	Year	g
	°		°
1871	236. 70020	1901	297. 76735
B 2	334. 94160	2	35. 74029
3	72. 91454	3	133. 71323
4	170. 88748	B 4	231. 95458
5	268. 86042	5	329. 92752
B 6	367. 10178	6	67. 90046
7	105. 07472	7	165. 87340
8	203. 04766	B 8	264. 11476
9	301. 02060	9	362. 08770
B 1880	39. 26195	1910	100. 06064
1	137. 23489	1	198. 03358
2	235. 20783	B 2	296. 27493
3	333. 18077	3	34. 24787
B 4	71. 42213	4	132. 22081
5	169. 39507	5	230. 19375
6	267. 36801	B 6	328. 43511
7	5. 34094	7	66. 40805
B 8	103. 58230	8	164. 38099
9	201. 55524	9	262. 35393
1890	299. 52818	B 1920	0. 59528
1	37. 50112	1	98. 56822
B 2	135. 74248	2	196. 54116
3	233. 71542	3	294. 51410
4	331. 68836	B 4	32. 75546
5	69. 66130	5	130. 72840
B 6	167. 90265	6	228. 70134
7	265. 87559	7	326. 67428
8	3. 84853	B 8	64. 91563
9	101. 82147	9	162. 88857
1900	199. 79441	1930	260. 86151

NOTE.—When g is used as an argument of the perturbations, add to the g of this table $\Delta\pi=\pi-\pi_0=+0^{\circ}.1367$. For explanation see page 203.

Table for beginning of month

Month	g
	°
Jan. 1.0 Jan. 0.0	0. 00000
Feb. 1.0 Feb. 0.0	8. 32099
Mar. 0.0	15. 83672
Apr. 0.0	24. 15771
May 0.0	32. 21028
June 0.0	40. 53127
July 0.0	48. 58384
Aug. 0.0	56. 90483
Sept. 0.0	65. 22582
Oct. 0.0	73. 27839
Nov. 0.0	81. 59938
Dec. 0.0	89. 65195

Change for n days[a]

n	g	n	g
	°		°
1	0. 26842	16	4. 29472
2	0. 53684	17	4. 56314
3	0. 80526	18	4. 83156
4	1. 07368	19	5. 09998
5	1. 34210	20	5. 36840
6	1. 61052	21	5. 63682
7	1. 87894	22	5. 90524
8	2. 14736	23	6. 17366
9	2. 41578	24	6. 44208
10	2. 68420	25	6. 71050
11	2. 95262	26	6. 97892
12	3. 22104	27	7. 24734
13	3. 48946	28	7. 51576
14	3. 75788	29	7. 78418
15	4. 02630	30	8. 05260

[a] For days during January and February of leap years subtract one day before entering this table.

Tables of (115) Thyra—Continued.

PERTURBATIONS.

Arg. $ig-i'g'$		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	0				−3		+3
0	0				+0.03nt		+0.15nt
+1	0				+3		
+1		−0.83nt	−4.84nt	−2.42nt	+0.42nt	−5.36nt	−0.52nt
+2					+1		
+2		−0.04nt	−0.23nt	−0.23nt	+0.04nt	−0.51nt	−0.05nt
+3	0		−0.02nt	−0.03nt		0.07nt	−0.01nt
−1	+1	+4	+1	−1	+2	+2	−2
0		−2	−9		+2	+5	−7
+1		−87	−55	−21	+32	−6	+8
+2	+1	−4	−3	−2	+4	−2	+3
−1	+2		−1	+1		−2	
0		−9	−14	+6	−4	−9	+4
+1		+115	+236	+65	−33	+10	−6
+2		+64	+121	+75	−40	+5	−1
+3		+5	+8	+9	−5	−1	
+4	+2	+1	−1	+1			
0	+3	−5	+5	−2	−2	+3	+4
+1		+488	+84	−7	−29	+8	−1
+2		+110	−217	−112	−58	−37	−1
+3		+5	+2	−1	−5	−3	
+4	+3	+1	+1		−1	−1	
+1	+4	−2	−3		−1		
+2		+17	+7	+2	−8	−1	−2
+3		+7	−4	−2	−5	−1	−1
+4	+4	−1	+1	+1			
+2	+5		−1				
+3		−2	−2	−1	+1		+1
+4	+5	+2			−1		
+2	+6		−1				
+3	+6	−1	−1				

Tables of (115) Thyra—Continued.

TABLE II.—$n\delta z$.

PERIODIC TERMS.

Unit of a and b=0°001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	−5.0	+0.18	+141.8	+3.15	+72.8	−7.77	+51.9	−1.89	−26.2	−2.48
6	−3.9	+0.18	+153.5	+0.73	+24.5	−8.22	+38.3	−2.50	−39.1	−1.68
12	−2.9	+0.17	+150.6	−1.68	−24.3	−7.90	+21.9	−2.80	−46.4	−0.72
18	−1.9	+0.16	+133.4	−3.86	−68.9	−6.78	+4.7	−2.78	−47.7	+0.27
24	−1.0	+0.13	+104.3	−5.60	−105.7	−5.20	−11.5	−2.44	−43.2	+1.15
30	−0.3	+0.12	+66.2	−6.75	−131.3	−3.18	−24.6	−1.81	−33.9	+1.86
36	+0.4	+0.10	+23.3	−7.38	−143.9	−1.01	−33.2	−1.01	−20.9	+2.34
42	+0.9	+0.07	−20.8	−7.20	−143.4	+1.21	−36.7	−0.11	−5.8	+2.51
48	+1.2	+0.07	−61.6	−6.23	−129.4	+3.25	−34.5	+0.82	+9.2	+2.32
54	+1.7	+0.06	−95.6	−4.84	−104.4	+4.86	−27.0	+1.59	+22.0	+1.84
60	+1.9	+0.03	−119.7	−3.05	−71.1	+5.92	−15.4	+2.18	+31.3	+1.15
66	+2.1	+0.04	−132.2	−1.08	−33.3	+6.41	−1.0	+2.48	+35.8	+0.28
72	+2.4	+0.04	−132.6	+0.98	+5.8	+6.26	+14.2	+2.44	+34.7	−0.66
78	+2.6	+0.03	−121.3	+2.71	+41.9	+5.51	+28.3	+2.11	+27.8	−1.58
84	+2.8	+0.04	−100.1	+4.15	+71.9	+4.22	+39.5	+1.49	+15.9	−2.29
90	+3.1	+0.04	−71.5	+5.11	+92.6	+2.59	+46.2	+0.62	+0.3	−2.76
96	+3.3	+0.02	−38.8	+5.46	+103.0	+0.83	+46.8	−0.43	−17.2	−2.92
102	+3.3	−0.01	−6.0	+5.19	+102.6	−0.96	+41.0	−1.48	−34.7	−2.73
108	+3.2	−0.01	+23.5	+4.39	+91.5	−2.54	+29.0	−2.39	−50.0	−2.16
114	+3.2	−0.02	+46.7	+3.15	+72.1	−3.72	+12.3	−3.08	−60.6	−1.29
120	+3.0	−0.05	+61.3	+1.60	+46.8	−4.42	−8.0	−3.48	−65.5	−0.24
126	+2.6	−0.08	+65.9	−0.80	+19.1	−4.54	−29.4	−3.50	−63.5	+0.92
132	+2.0	−0.10	+60.3	−1.70	−7.7	−4.08	−50.0	−3.14	−54.5	+2.06
138	+1.4	−0.12	+45.5	−3.06	−29.9	−3.12	−67.1	−2.42	−38.8	+3.04
144	+0.6	−0.13	+23.6	−4.01	−45.2	−1.76	−79.1	−1.42	−18.0	+3.73
150	−0.2	−0.12	−2.6	−4.44	−51.0	−0.08	−84.1	−0.21	+6.0	+4.07
156	−0.9	−0.12	−29.7	−4.28	−46.1	+1.63	−81.6	+1.02	+30.9	+4.06
162	−1.7	−0.11	−53.9	−3.52	−31.4	+3.22	−71.8	+2.22	+54.7	+3.65
168	−2.2	−0.08	−71.9	−2.25	−7.5	+4.49	−55.0	+3.25	+74.7	+2.88
174	−2.6	−0.05	−80.9	−0.59	+22.5	+5.29	−32.8	+3.99	+89.2	+1.82
180	−2.8	0.00	−79.0	+1.30	+56.0	+5.52	−7.1	+4.41	+96.6	+0.61
186	−2.6	+0.06	−65.3	+3.18	+88.7	+5.09	+20.1	+4.47	+96.5	−0.65
192	−2.1	+0.10	−40.8	+4.92	+117.1	+4.06	+46.5	+4.12	+88.8	−1.90
198	−1.4	+0.14	−6.2	+6.29	+137.4	+2.47	+69.5	+3.43	+73.7	−3.03
204	−0.4	+0.18	+34.7	+7.09	+146.7	+0.46	+87.7	+2.48	+52.4	−3.88
210	+0.7	+0.20	+78.9	+7.37	+142.9	−1.78	+99.2	+1.29	+27.1	−4.41
216	+2.0	+0.22	+121.7	+7.80	+125.3	−3.97	+103.2	+0.01	−0.5	−4.59
222	+3.3	+0.20	+159.2	+5.46	+95.3	−5.98	+99.3	−1.26	−28.0	−4.41
228	+4.4	+0.18	+187.2	+3.63	+53.6	−7.59	+88.1	−2.41	−53.4	−3.88
234	+5.5	+0.16	+202.8	+1.38	+4.2	−8.69	+70.4	−3.36	−74.6	−3.06
240	+6.3	+0.10	+203.8	−1.15	−49.4	−9.02	+47.8	−4.03	−90.1	−2.00
246	+6.7	+0.04	+189.0	−3.68	−102.5	−8.54	+22.0	−4.38	−98.5	−0.82
252	+6.8	−0.02	+159.6	−6.01	−150.4	−7.22	−4.8	−4.39	−99.9	+0.40
258	+6.4	−0.08	+116.9	−7.92	−189.1	−5.35	−30.7	−4.08	−93.8	+1.57
264	+5.8	−0.15	+64.5	−9.34	−214.7	−2.96	−53.7	−3.46	−81.1	+2.56
270	+4.6	−0.22	+6.3	−9.88	−224.6	−0.29	−72.2	−2.59	−63.1	+3.34
276	+3.2	−0.24	−52.6	−9.64	−218.2	+2.49	−84.8	−1.57	−41.0	+3.88
282	+1.7	−0.27	−107.8	−8.64	−195.9	+4.94	−91.0	−0.48	−16.5	+4.12
288	0.0	−0.29	−154.7	−6.76	−158.9	+7.22	−90.4	+0.66	+8.4	+4.02
294	−1.8	−0.28	−188.9	−4.45	−110.7	+8.80	−83.0	+1.76	+31.8	+3.62
300	−3.4	−0.27	−208.1	−1.83	−54.8	+9.66	−69.4	+2.67	+51.9	+2.96
306	−5.0	−0.23	−210.9	+0.91	+3.5	+9.66	−51.0	+3.33	+67.3	+2.07
312	−6.2	−0.18	−197.2	+3.55	+59.5	+8.89	−29.4	+3.71	+76.7	+1.01
318	−7.1	−0.13	−168.3	+5.84	+108.7	+7.28	−6.5	+3.77	+79.4	−0.11
324	−7.8	−0.08	−127.1	+7.70	+146.8	+5.21	+15.9	+3.52	+75.4	−1.18
330	−8.0	−0.01	−77.4	+8.77	+171.2	+2.76	+35.7	+2.94	+65.2	−2.12
336	−7.9	+0.04	−23.5	+9.00	+179.9	+0.14	+51.2	+2.09	+49.9	−2.86
342	−7.5	+0.09	+29.2	+8.39	+173.0	−2.43	+60.8	+1.08	+30.9	−3.28
348	−6.8	+0.12	+77.1	+7.21	+150.7	−4.72	+64.2	+0.02	+10.5	−3.34
354	−6.0	+0.15	+115.7	+5.39	+116.3	−6.49	+61.0	−1.02	−9.2	−3.06
360	−5.0	+0.18	+141.8	+3.15	+72.8	−7.77	+51.9	−1.89	−26.2	−2.48

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (115) Thyra—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS. Unit of a and b=0°001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	+3.9	−0.05	+0.7	−0.18	+0.9	+0.05	+0.9	−0.05
6	+3.5	−0.08	−0.2	−0.12	+1.1	+0.02	+0.5	−0.07
12	+3.0	−0.09	−0.8	−0.08	+1.1	−0.01	+0.1	−0.06
18	+2.4	−0.08	−1.1	−0.05	+1.0	−0.02	−0.2	−0.04
24	+2.1	−0.06	−1.4	−0.04	+0.8	−0.03	−0.4	−0.03
30	+1.7	−0.07	−1.6	−0.02	+0.6	−0.03	−0.6	−0.02
36	+1.3	−0.07	−1.6	−0.02	+0.4	−0.03	−0.7	0.00
42	+0.9	−0.06	−1.9	−0.03	+0.2	−0.02	−0.6	+0.02
48	+0.6	−0.07	−2.0	0.00	+0.1	−0.01	−0.5	0.00
54	+0.1	−0.08	−1.9	+0.02	+0.1	−0.01	−0.6	−0.01
60	−0.3	−0.05	−1.7	+0.04	0.0	−0.02	−0.6	0.00
66	−0.5	−0.02	−1.4	+0.05	−0.2	−0.02	−0.6	−0.01
72	−0.6	0.00	−1.1	+0.04	−0.3	−0.02	−0.7	0.00
78	−0.5	+0.02	−0.9	+0.02	−0.4	−0.03	−0.6	+0.02
84	−0.3	+0.02	−0.8	−0.02	−0.7	−0.04	−0.5	+0.02
90	−0.3	0.00	−1.1	−0.05	−0.9	−0.02	−0.3	+0.05
96	−0.3	−0.03	−1.4	−0.05	−0.9	−0.01	+0.1	+0.06
102	−0.7	−0.08	−1.7	−0.03	−1.0	+0.02	+0.4	+0.05
108	−1.3	−0.12	−1.8	+0.01	−0.7	+0.05	+0.7	+0.05
114	−2.1	−0.12	−1.6	+0.07	−0.4	+0.06	+1.0	+0.02
120	−2.7	−0.08	−1.0	+0.12	0.0	+0.07	+1.0	−0.01
126	−3.1	−0.04	−0.2	+0.15	+0.4	+0.06	+0.9	−0.02
132	−3.2	+0.02	+0.8	+0.18	+0.7	+0.03	+0.7	−0.06
138	−2.9	+0.09	+1.9	+0.16	+0.8	+0.02	+0.2	−0.08
144	−2.1	+0.15	+2.7	+0.12	+0.9	−0.02	−0.2	−0.07
150	−1.1	+0.17	+3.3	+0.06	+0.6	−0.06	−0.6	−0.05
156	−0.1	+0.17	+3.4	−0.02	+0.2	−0.07	−0.8	−0.02
162	+0.9	+0.16	+3.0	−0.08	−0.2	−0.08	−0.8	+0.02
168	+1.8	+0.10	+2.4	−0.12	−0.7	−0.06	−0.5	+0.04
174	+2.1	+0.04	+1.6	−0.14	−0.9	−0.02	−0.3	+0.07
180	+2.3	0.00	+0.7	−0.13	−0.9	+0.02	+0.3	+0.08
186	+2.1	−0.06	0.0	−0.09	−0.7	+0.05	+0.7	+0.05
192	+1.6	−0.09	−0.4	−0.06	−0.3	+0.08	+0.9	+0.04
198	+1.0	−0.09	−0.7	−0.02	+0.2	+0.08	+1.2	+0.01
204	+0.5	−0.08	−0.6	+0.02	+0.6	+0.07	+1.0	−0.05
210	+0.1	−0.05	−0.4	+0.07	+1.0	+0.05	+0.6	−0.08
216	−0.1	0.00	+0.2	+0.09	+1.2	0.00	+0.1	−0.09
222	+0.1	+0.06	+0.7	+0.07	+1.0	−0.02	−0.4	−0.08
228	+0.6	+0.10	+1.0	+0.05	+0.9	−0.04	−0.7	−0.06
234	+1.3	+0.12	+1.3	+0.01	+0.5	−0.08	−1.0	−0.02
240	+2.1	+0.13	+1.1	−0.08	0.0	−0.08	−1.0	+0.02
246	+2.9	+0.12	+0.4	−0.15	−0.4	−0.06	−0.8	+0.04
252	+3.6	+0.07	−0.7	−0.21	−0.7	−0.02	−0.5	+0.05
258	+3.7	−0.02	−2.1	−0.24	−0.6	+0.02	−0.2	+0.05
264	+3.3	−0.13	−3.6	−0.25	−0.5	+0.02	+0.1	+0.04
270	+2.1	−0.25	−5.1	−0.20	−0.3	+0.05	+0.3	+0.02
276	+0.3	−0.33	−6.0	−0.10	+0.1	+0.04	+0.3	−0.01
282	−1.9	−0.37	−6.3	+0.03	+0.2	+0.02	+0.2	−0.03
288	−4.1	−0.35	−5.6	+0.19	+0.3	0.00	−0.1	−0.05
294	−6.1	−0.25	−4.0	+0.32	+0.2	−0.02	−0.4	−0.04
300	−7.1	−0.10	−1.8	+0.40	0.0	−0.05	−0.6	−0.02
306	−7.3	+0.04	+0.8	+0.42	−0.4	−0.06	−0.7	+0.01
312	−6.6	+0.18	+3.2	+0.36	−0.7	−0.05	−0.5	+0.04
318	−5.1	+0.32	+5.1	+0.26	−1.0	−0.03	−0.2	+0.06
324	−2.8	+0.37	+6.3	+0.12	−1.1	0.00	+0.2	+0.07
330	−0.7	+0.34	+6.5	−0.02	−1.0	+0.02	+0.6	+0.07
336	+1.3	+0.30	+6.0	−0.14	−0.8	+0.05	+1.0	+0.05
342	+2.9	+0.21	+4.8	−0.22	−0.4	+0.08	+1.2	+0.02
348	+3.8	+0.10	+3.4	−0.23	+0.1	+0.08	+1.3	−0.01
354	+4.1	+0.01	+2.0	−0.22	+0.5	+0.07	+1.1	−0.03
360	+3.9	−0.05	+0.7	−0.18	+0.9	+0.05	+0.9	−0.05

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (115) Thyra—Continued.

TABLE III.—δ log r.

PERIODIC TERMS.

Unit of a and b=0.00001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	−1.4	−0.02	+ 7.7	−0.46	− 5.7	−0.32	− 7.7	−1.02	−21.2	+0.64
6	−1.5	−0.01	+ 4.7	−0.50	− 7.1	−0.16	−13.1	−0.72	−16.5	+0.90
12	−1.5	0.00	+ 1.7	−0.49	− 7.7	−0.04	−16.4	−0.38	−10.4	+1.05
18	−1.5	+0.01	− 1.2	−0.47	− 7.6	+0.10	−17.6	0.00	− 3.9	+1.04
24	−1.4	+0.02	− 3.9	−0.42	− 6.4	+0.23	−16.4	+0.37	+ 2.1	+0.93
30	−1.3	+0.02	− 6.2	−0.32	− 4.8	+0.30	−13.2	+0.64	+ 7.3	+0.73
36	−1.1	+0.02	− 7.7	−0.21	− 2.8	+0.36	− 8.6	+0.83	+10.9	+0.42
42	−1.1	+0.02	− 8.7	−0.10	− 0.5	+0.38	− 3.2	+0.89	+12.4	+0.07
48	−0.8	+0.03	− 8.8	+0.02	+ 1.8	+0.37	+ 2.1	+0.82	+11.7	−0.28
54	−0.7	+0.02	− 8.4	+0.10	+ 3.9	+0.34	+ 6.7	+0.68	+ 9.1	−0.57
60	−0.6	+0.02	− 7.7	+0.15	+ 5.9	+0.29	+10.2	+0.42	+ 4.9	−0.78
66	−0.5	+0.01	− 6.6	+0.20	+ 7.4	+0.22	+11.7	+0.06	− 0.3	−0.89
72	−0.5	+0.02	− 5.3	+0.22	+ 8.6	+0.18	+10.9	−0.30	− 5.8	−0.86
78	−0.3	+0.02	− 3.9	+0.24	+ 9.6	+0.12	+ 8.1	−0.62	−10.6	−0.70
84	−0.2	+0.01	− 2.3	+0.23	+10.0	+0.08	+ 3.5	−0.87	−14.2	−0.47
90	−0.2	0.00	− 1.1	+0.22	+10.5	+0.05	− 2.3	−1.03	−16.2	−0.14
96	−0.2	+0.02	+ 0.3	+0.22	+10.6	+0.02	− 8.9	−1.08	−15.9	+0.26
102	0.0	+0.02	+ 1.6	+0.20	+10.7	0.00	−15.2	−0.95	−13.1	+0.64
108	+0.1	+0.02	+ 2.7	+0.19	+10.6	−0.02	−20.3	−0.71	− 8.2	+0.98
114	+0.2	+0.01	+ 3.9	+0.21	+10.5	0.00	−23.7	−0.38	− 1.4	+1.21
120	+0.2	0.00	+ 5.2	+0.22	+10.6	−0.02	−24.9	+0.01	+ 6.3	+1.32
126	+0.2	+0.02	+ 6.5	+0.25	+10.3	−0.05	−23.6	+0.46	+14.5	+1.32
132	+0.4	+0.01	+ 8.2	+0.28	+10.0	−0.08	−19.4	+0.88	+22.2	+1.16
138	+0.3	−0.02	+ 9.9	+0.29	+ 9.3	−0.14	−13.0	+1.24	+28.4	+0.84
144	+0.2	−0.01	+11.7	+0.31	+ 8.3	−0.19	− 4.5	+1.50	+32.4	+0.47
150	+0.2	−0.02	+13.6	+0.32	+ 7.0	−0.28	+ 5.0	+1.62	+34.0	+0.02
156	−0.1	−0.05	+15.5	+0.29	+ 5.0	−0.38	+14.9	+1.60	+32.6	−0.49
162	−0.4	−0.06	+17.1	+0.22	+ 2.5	−0.45	+24.2	+1.41	+28.1	−0.96
168	−0.8	−0.06	+18.2	+0.16	− 0.4	−0.52	+31.8	+1.10	+21.1	−1.33
174	−1.1	−0.05	+19.0	+0.08	− 3.8	−0.58	+37.4	+0.70	+12.1	−1.63
180	−1.4	−0.06	+19.1	−0.04	− 7.5	−0.64	+40.2	+0.21	+ 1.5	−1.80
186	−1.8	−0.08	+18.5	−0.19	−11.5	−0.67	+39.9	−0.31	− 9.6	−1.81
192	−2.3	−0.07	+16.8	−0.32	−15.4	−0.63	+36.5	−0.81	−20.2	−1.68
198	−2.6	−0.04	+14.6	−0.48	−19.1	−0.58	+30.2	−1.25	−29.6	−1.38
204	−2.8	−0.03	+11.1	−0.63	−22.3	−0.48	+21.5	−1.59	−36.8	−1.01
210	−3.0	−0.02	+ 7.0	−0.72	−24.8	−0.35	+11.1	−1.82	−41.7	−0.55
216	−3.0	+0.01	+ 2.5	−0.79	−26.5	−0.18	− 0.3	−1.90	−43.4	−0.02
222	−2.9	+0.02	− 2.5	−0.85	−26.9	+0.01	−11.7	−1.83	−41.9	+0.50
228	−2.7	+0.05	− 7.7	−0.85	−26.4	+0.21	−22.3	−1.62	−37.4	+0.97
234	−2.3	+0.06	−12.7	−0.81	−24.4	+0.41	−31.2	−1.31	−30.3	+1.37
240	−2.0	+0.08	−17.4	−0.72	−21.5	+0.57	−38.0	−0.90	−21.0	+1.67
246	−1.4	+0.09	−21.3	−0.58	−17.6	+0.74	−42.0	−0.41	−10.3	+1.82
252	−0.9	+0.09	−24.3	−0.39	−12.6	+0.86	−42.9	+0.11	+ 0.9	+1.86
258	−0.3	+0.09	−26.0	−0.19	− 7.3	+0.93	−40.7	+0.59	+12.0	+1.74
264	+0.2	+0.08	−26.6	+0.02	− 1.5	+0.96	−35.8	+1.03	+21.8	+1.52
270	+0.7	+0.08	−25.8	+0.23	+ 4.2	+0.92	−28.3	+1.38	+30.2	+1.18
276	+1.1	+0.06	−23.8	+0.42	+ 9.6	+0.83	−19.2	+1.62	+35.9	+0.72
282	+1.4	+0.04	−20.7	+0.59	+14.2	+0.70	− 8.9	+1.74	+38.9	+0.26
288	+1.6	+0.02	−16.7	+0.73	+17.9	+0.52	+ 1.7	+1.71	+39.0	−0.22
294	+1.6	0.00	−12.0	+0.81	+20.5	+0.34	+11.6	+1.56	+36.2	−0.68
300	+1.6	−0.02	− 7.0	+0.83	+22.0	+0.12	+20.4	+1.29	+30.8	−1.07
306	+1.4	−0.04	− 2.0	+0.81	+22.0	−0.10	+27.1	+0.90	+23.4	−1.35
312	+1.1	−0.05	+ 2.7	+0.74	+20.8	−0.28	+31.2	+0.48	+14.6	−1.52
318	+0.8	−0.06	+ 6.9	+0.61	+18.6	−0.47	+32.8	+0.03	+ 5.2	−1.54
324	+0.4	−0.07	+10.0	+0.44	+15.2	−0.58	+31.6	−0.41	− 3.9	−1.44
330	0.0	−0.07	+12.3	+0.28	+11.6	−0.63	+27.9	−0.79	−12.1	−1.22
336	−0.4	−0.06	+13.3	+0.08	+ 7.6	−0.67	+22.1	−1.09	−18.6	−0.91
342	−0.7	−0.06	+13.3	−0.08	+ 3.6	−0.64	+14.8	−1.28	−23.0	−0.52
348	−1.1	−0.05	+12.3	−0.26	− 0.1	−0.57	+ 6.8	−1.30	−24.9	−0.10
354	−1.3	−0.02	+10.2	−0.38	− 3.2	−0.46	− 0.8	−1.21	−24.2	+0.31
360	−1.4	−0.02	+ 7.7	−0.46	− 5.7	−0.32	− 7.7	−1.02	−21.2	+0.64

[$n\delta z$, δ log r, and u cos i are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (115) Thyra—Continued.

TABLE III.—$\partial \log r$—Continued.

PERIODIC TERMS. Unit of a and b=0.00001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	+1.0	−0.15	−3.0	0.00	+0.5	−0.04	−0.5	−0.02
6	+0.2	−0.12	−2.8	+0.03	+0.2	−0.04	−0.6	0.00
12	−0.4	−0.10	−2.6	+0.06	0.0	−0.03	−0.5	+0.01
18	−1.0	−0.07	−2.1	+0.08	−0.2	−0.02	−0.5	+0.02
24	−1.2	−0.04	−1.7	+0.08	−0.3	−0.02	−0.3	+0.02
30	−1.4	−0.02	−1.1	+0.08	−0.4	0.00	−0.2	+0.02
36	−1.4	+0.01	−0.8	+0.06	−0.3	+0.02	−0.1	+0.02
42	−1.3	+0.02	−0.5	+0.04	−0.2	+0.01	+0.1	+0.02
48	−1.2	+0.02	−0.2	+0.02	−0.2	+0.01	+0.2	+0.01
54	−1.0	+0.03	−0.1	+0.02	−0.1	+0.01	+0.2	−0.01
60	−0.8	+0.02	0.0	+0.01	−0.1	+0.02	+0.1	−0.01
66	−0.8	0.00	0.0	−0.01	+0.1	+0.02	+0.1	−0.01
72	−0.8	0.00	−0.1	−0.01	+0.1	−0.02	0.0	−0.01
78	−0.8	−0.01	−0.1	+0.01	−0.1	−0.01	0.0	−0.01
84	−0.9	−0.02	0.0	+0.01	0.0	+0.01	−0.1	0.00
90	−1.1	−0.03	0.0	+0.02	0.0	0.00	0.0	+0.02
96	−1.3	−0.02	+0.2	+0.04	0.0	−0.01	+0.1	0.00
102	−1.4	−0.01	+0.5	+0.05	−0.1	+0.01	0.0	−0.01
108	−1.4	+0.01	+0.8	+0.07	+0.1	+0.02	0.0	−0.01
114	−1.3	+0.02	+1.3	+0.08	+0.1	−0.02	−0.1	−0.01
120	−1.1	+0.06	+1.7	+0.08	−0.1	−0.02	−0.1	−0.01
126	−0.6	+0.09	+2.2	+0.06	−0.1	−0.01	−0.2	−0.01
132	0.0	+0.10	+2.3	+0.02	−0.2	−0.01	−0.2	+0.01
138	+0.6	+0.11	+2.3	−0.02	−0.2	−0.01	−0.1	+0.02
144	+1.3	+0.11	+2.2	−0.04	−0.3	−0.02	+0.1	+0.02
150	+1.9	+0.08	+1.8	−0.08	−0.4	0.00	+0.2	+0.02
156	+2.3	+0.06	+1.2	−0.11	−0.3	+0.02	+0.3	+0.02
162	+2.6	+0.02	+0.5	−0.12	−0.2	+0.02	+0.5	+0.02
168	+2.6	−0.02	−0.2	−0.11	0.0	+0.03	+0.5	+0.01
174	+2.3	−0.06	−0.8	−0.08	+0.2	+0.04	+0.6	0.00
180	+1.9	−0.08	−1.3	−0.07	+0.5	+0.04	+0.5	−0.02
186	+1.4	−0.08	−1.6	−0.04	+0.7	+0.02	+0.3	−0.02
192	+1.0	−0.08	−1.7	−0.01	+0.8	−0.02	+0.1	−0.04
198	+0.5	−0.06	−1.7	+0.02	+0.6	−0.02	−0.2	−0.04
204	+0.3	−0.02	−1.5	+0.02	+0.6	−0.02	−0.5	−0.04
210	+0.2	−0.03	−1.4	+0.01	+0.4	−0.03	−0.7	−0.02
216	−0.1	−0.01	−1.4	0.00	+0.2	−0.05	−0.7	0.00
222	+0.1	−0.01	−1.4	−0.02	−0.2	−0.04	−0.7	+0.02
228	−0.2	−0.02	−1.6	−0.02	−0.3	−0.02	−0.5	+0.03
234	−0.2	−0.04	−1.7	−0.03	−0.4	−0.02	−0.3	+0.02
240	−0.7	−0.08	−2.0	−0.02	−0.5	0.00	−0.1	+0.03
246	−1.2	−0.09	−2.0	0.00	−0.4	+0.02	+0.1	+0.02
252	−1.8	−0.12	−2.0	+0.03	−0.2	+0.02	+0.2	+0.01
258	−2.6	−0.12	−1.6	+0.09	−0.1	+0.02	+0.2	−0.01
264	−3.2	−0.08	−0.9	+0.13	0.0	+0.01	+0.1	−0.02
270	−3.6	−0.04	0.0	+0.17	0.0	0.00	0.0	−0.02
276	−3.7	+0.01	+1.1	+0.18	0.0	−0.01	−0.1	−0.02
282	−3.5	+0.08	+2.2	+0.18	−0.1	−0.02	−0.2	−0.01
288	−2.7	+0.15	+3.3	+0.15	−0.2	−0.02	−0.2	+0.01
294	−1.7	+0.18	+4.0	+0.10	−0.4	−0.02	−0.1	+0.02
300	−0.5	+0.22	+4.5	+0.04	−0.5	0.00	+0.1	+0.03
306	+0.9	+0.22	+4.5	−0.04	−0.4	+0.02	+0.3	+0.02
312	+2.1	+0.19	+4.0	−0.11	−0.3	+0.02	+0.5	+0.03
318	+3.2	+0.15	+3.1	−0.18	−0.2	+0.04	+0.7	+0.02
324	+3.9	+0.08	+2.0	−0.20	+0.2	+0.05	+0.7	0.00
330	+4.2	0.00	+0.8	−0.20	+0.4	+0 03	+0.7	−0.02
336	+3.9	−0.05	−0.5	−0.18	+0.6	+0.02	+0.5	−0.04
342	+3.6	−0.08	−1.4	−0.16	+0.6	+0.02	+0.2	−0.04
348	+2.9	−0.13	−2.3	−0.12	+0.8	+0.01	−0.1	−0.04
354	+2.0	−0.16	−2.8	−0.06	+0.7	−0.02	−0.3	−0.02
360	+1.0	−0.15	−3.0	0.00	+0.5	−0.04	−0.5	−0.02

[$n\partial z$, $\partial \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig+\Sigma_i b_i \cos ig+cT$.]

Tables of (115) Thyra—Continued.

TABLE IV.—u/cos i.

PERIODIC TERMS. Unit of *a* and *b*=0°.001.

i	0		1				2				3			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°	a_3	Diff. for 1°	b_3	Diff. for 1°
°														
0	+1.1	+0.02	+3.4	−0.02	−0.4	−0.18	−9.8	−0.06	−0.3	+0.50	−1.4	+0.01	0.0	+0.08
6	+1.1	−0.01	+3.2	−0.08	−1.4	−0.16	−9.6	+0.13	+2.8	+0.51	−1.3	+0.03	+0.5	+0.07
12	+1.0	−0.02	+2.5	−0.13	−2.3	−0.10	−8.2	+0.28	+5.8	+0.45	−1.0	+0.04	+0.8	+0.04
18	+0.8	−0.04	+1.6	−0.17	−2.6	−0.06	−6.2	+0.40	+8.2	+0.33	−0.8	+0.05	+1.0	+0.02
24	+0.5	−0.04	+0.5	−0.18	−3.0	−0.04	−3.4	+0.50	+9.8	+0.19	−0.4	+0.06	+1.1	+0.02
30	+0.3	−0.05	−0.6	−0.18	−3.1	+0.02	−0.2	+0.53	+10.5	+0.02	−0.1	+0.05	+1.2	+0.01
36	−0.1	−0.05	−1.7	−0.18	−2.7	+0.08	+3.0	+0.52	+10.1	−0.16	+0.2	+0.05	+1.2	−0.02
42	−0.3	−0.05	−2.7	−0.16	−2.1	+0.12	+6.0	+0.44	+8.6	−0.30	+0.5	+0.03	+0.9	−0.03
48	−0.7	−0.04	−3.6	−0.11	−1.2	+0.17	+8.3	+0.32	+6.5	−0.43	+0.6	+0.04	+0.8	−0.02
54	−0.8	−0.02	−4.0	−0.05	−0.1	+0.18	+9.8	+0.18	+3.4	−0.53	+1.0	+0.04	+0.6	−0.03
60	−0.9	−0.02	−4.2	0.00	+1.0	+0.18	+10.4	+0.01	+0.1	−0.54	+1.1	+0.01	+0.4	−0.05
66	−1.0	0.00	−4.0	+0.06	+2.2	+0.18	+9.9	−0.19	−3.1	−0.51	+1.1	−0.01	0.0	−0.07
72	−0.9	0.00	−3.5	+0.10	+3.3	+0.15	+8.1	−0.34	−6.0	−0.43	+1.0	−0.01	−0.4	−0.05
78	−1.0	0.00	−2.8	+0.17	+4.0	+0.12	+5.8	−0.44	−8.3	−0.31	+1.0	−0.02	−0.6	−0.04
84	−0.9	+0.01	−1.5	+0.21	+4.8	+0.09	+2.8	−0.53	−9.7	−0.13	+0.7	−0.06	−0.9	−0.04
90	−0.9	+0.01	−0.3	+0.21	+5.1	+0.03	−0.6	−0.55	−9.9	+0.04	+0.3	−0.06	−1.1	−0.02
96	−0.8	0.00	+1.0	+0.22	+5.2	−0.01	−3.8	−0.52	−9.2	+0.21	0.0	−0.06	−1.2	+0.01
102	−0.9	0.00	+2.4	+0.22	+5.0	−0.08	−6.8	−0.41	−7.4	+0.36	−0.4	−0.07	−1.0	+0.03
108	−0.8	−0.01	+3.6	+0.18	+4.2	−0.12	−8.7	−0.26	−4.9	+0.48	−0.8	−0.06	−0.8	+0.05
114	−1.0	−0.02	+4.6	+0.18	+3.5	−0.13	−9.9	−0.12	−1.7	+0.54	−1.1	−0.02	−0.4	+0.06
120	−1.1	−0.01	+5.7	+0.13	+2.6	−0.16	−10.1	+0.06	+1.6	+0.55	−1.0	+0.02	−0.1	+0.06
126	−1.1	0.00	+6.2	+0.08	+1.6	−0.17	−9.2	+0.25	+4.9	+0.52	−0.9	+0.02	+0.3	+0.07
132	−1.1	+0.01	+6.6	+0.05	+0.6	−0.18	−7.1	+0.39	+7.8	+0.40	−0.7	+0.04	+0.7	+0.04
138	−1.0	+0.01	+6.8	0.00	−0.5	−0.18	−4.5	+0.48	+9.7	+0.26	−0.4	+0.07	+0.8	+0.02
144	−1.0	+0.03	+6.6	−0.04	−1.4	−0.13	−1.3	+0.55	+10.9	+0.11	+0.1	+0.07	+0.9	−0.01
150	−0.6	+0.06	+6.3	−0.08	−2.1	−0.10	+2.1	+0.56	+11.0	−0.08	+0.4	+0.04	+0.7	−0.03
156	−0.3	+0.08	+5.8	−0.09	−2.6	−0.08	+5.4	+0.52	+10.0	−0.25	+0.6	+0.03	+0.5	−0.06
162	+0.3	+0.11	+5.2	−0.10	−3.0	−0.04	+8.4	+0.42	+8.0	−0.39	+0.8	0.00	0.0	−0.06
168	+1.0	+0.13	+4.6	−0.10	−3.2	−0.02	+10.4	+0.28	+5.3	−0.50	+0.6	−0.02	−0.2	−0.05
174	+1.9	+0.14	+4.0	−0.10	−3.1	+0.02	+11.7	+0.13	+2.0	−0.55	+0.6	−0.03	−0.6	−0.03
180	+2.7	+0.15	+3.4	−0.10	−3.0	+0.02	+12.0	−0.04	−1.3	−0.57	+0.2	−0.06	−0.6	+0.01
186	+3.7	+0.16	+2.8	−0.09	−3.0	+0.02	+11.2	−0.22	−4.8	−0.54	−0.1	−0.05	−0.5	0.00
192	+4.6	+0.14	+2.3	−0.07	−2.7	+0.03	+9.4	−0.35	−7.8	−0.43	−0.4	−0.02	−0.6	+0.02
198	+5.4	+0.14	+2.0	−0.07	−2.6	+0.01	+7.0	−0.47	−10.0	−0.32	−0.4	−0.02	−0.2	+0.04
204	+6.3	+0.11	+1.5	−0.08	−2.6	+0.01	+3.8	−0.53	−11.6	−0.18	−0.6	−0.01	−0.1	+0.03
210	+6.7	+0.07	+1.0	−0.07	−2.5	+0.01	+0.6	−0.55	−12.1	−0.01	−0.5	+0.03	+0.2	+0.02
216	+7.1	+0.03	+0.7	−0.08	−2.5	−0.02	−2.8	−0.53	−11.7	+0.16	−0.2	+0.03	+0.2	+0.01
222	+7.1	−0.02	+0.1	−0.11	−2.7	−0.03	−5.8	−0.46	−10.2	+0.30	−0.1	+0.02	+0.3	0.00
228	+6.9	−0.06	−0.6	−0.12	−2.9	−0.03	−8.3	−0.37	−8.1	+0.42	0.0	+0.01	+0.2	−0.01
234	+6.4	−0.10	−1.4	−0.13	−3.1	−0.02	−10.2	−0.22	−5.2	+0.48	0.0	+0.01	+0.2	−0.02
240	+5.7	−0.13	−2.2	−0.15	−3.2	−0.02	−11.0	−0.06	−2.3	+0.52	+0.1	−0.01	0.0	−0.03
246	+4.8	−0.17	−3.2	−0.16	−3.4	+0.01	−10.9	+0.09	+1.1	+0.52	−0.1	−0.02	−0.2	0.00
252	+3.7	−0.18	−4.1	−0.13	−3.1	+0.05	−9.9	+0.22	+4.0	+0.45	−0.2	−0.02	0.0	+0.02
258	+2.6	−0.20	−4.8	−0.16	−2.8	+0.06	−8.2	+0.36	+6.5	+0.38	−0.4	−0.01	0.0	+0.02
264	+1.3	−0.19	−5.9	−0.14	−2.4	+0.09	−5.6	+0.45	+8.5	+0.25	−0.3	+0.01	+0.3	+0.04
270	+0.3	−0.18	−6.5	−0.09	−1.7	+0.13	−2.8	+0.48	+9.5	+0.09	−0.3	+0.01	+0.5	+0.04
276	−0.8	−0.15	−7.0	−0.06	−0.8	+0.14	+0.2	+0.50	+9.6	−0.08	−0.2	+0.04	+0.8	+0.02
282	−1.5	−0.12	−7.2	−0.02	0.0	+0.15	+3.2	+0.44	+8.6	−0.21	+0.2	+0.05	+0.8	0.00
288	−2.2	−0.09	−7.2	+0.05	+1.0	+0.18	+5.5	+0.36	+7.1	−0.32	+0.4	+0.06	+0.8	−0.02
294	−2.6	−0.04	−6.6	+0.09	+2.1	+0.17	+7.5	+0.25	+4.7	−0.42	+0.9	+0.07	+0.6	−0.04
300	−2.7	−0.01	−6.1	+0.12	+3.0	+0.12	+8.5	+0.09	+2.0	−0.47	+1.2	+0.03	+0.3	−0.06
306	−2.7	+0.02	−5.2	+0.18	+3.6	+0.10	+8.6	−0.07	−0.9	−0.48	+1.3	−0.01	−0.1	−0.08
312	−2.5	+0.06	−4.0	+0.22	+4.2	+0.08	+7.7	−0.21	−3.8	−0.43	+1.1	−0.02	−0.7	−0.08
318	−2.0	+0.09	−2.6	+0.23	+4.5	+0.03	+6.1	−0.33	−6.1	−0.34	+1.0	−0.05	−1.0	−0.05
324	−1.4	+0.08	−1.2	+0.22	+4.6	−0.02	+3.7	−0.43	−7.9	−0.22	+0.5	−0.08	−1.3	−0.03
330	−1.0	+0.09	+0.1	+0.22	+4.3	−0.07	+0.9	−0.48	−8.8	0.08	0.0	−0.08	−1.4	−0.02
336	−0.3	+0.09	+1.4	+0.19	+3.8	−0.12	−2.0	−0.49	−8.8	+0.10	−0.4	−0.07	−1.5	+0.02
342	+0.1	+0.08	+2.4	+0.13	+2.8	−0.15	−5.0	−0.43	−7.6	+0.24	−0.8	−0.07	−1.2	+0.06
348	+0.6	+0.07	+3.0	+0.08	+2.0	−0.17	−7.2	−0.32	−5.9	+0.37	−1.2	−0.05	−0.8	+0.07
354	+0.9	+0.04	+3.4	+0.03	+0.8	−0.20	−8.9	−0.22	−3.2	+0.47	−1.4	−0.02	−0.4	+0.07
360	+1.1	+0.02	+3.4	−0.02	−0.4	−0.18	−9.8	−0.06	−0.3	+0.50	−1.4	+0.01	0.0	+0.08

[$n\delta z$, $\partial \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (115) Thyra—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY $T=(t-t_0)$ IN JULIAN YEARS.

g	$n\delta z$ Unit of $c=0°.001$		$\delta \log r$ Unit of $c=0.00001$		$u \cos i$ Unit of $c=0°.001$	
	c	Diff. for 1°	c	Diff. for 1°	c	Diff. for 1°
°						
0	−2.42	−0.008	+0.17	−0.018	−0.20	−0.054
6	−2.44	−0.002	+0.07	−0.018	−0.52	−0.053
12	−2.45	+0.002	−0.05	−0.020	−0.84	−0.052
18	−2.42	+0.008	−0.17	−0.018	−1.14	−0.048
24	−2.35	+0.013	−0.27	−0.016	−1.41	−0.044
30	−2.26	+0.018	−0.36	−0.017	−1.67	−0.040
36	−2.14	+0.022	−0.47	−0.018	−1.89	−0.034
42	−1.99	+0.026	−0.57	−0.013	−2.08	−0.029
48	−1.83	+0.029	−0.63	−0.010	−2.24	−0.023
54	−1.64	+0.032	−0.69	−0.010	−2.36	−0.018
60	−1.44	+0.035	−0.75	−0.009	−2.46	−0.012
66	−1.22	+0.038	−0.80	−0.007	−2.51	−0.006
72	−0.99	+0.038	−0.83	−0.004	−2.53	−0.002
78	−0.76	+0.038	−0.85	−0.002	−2.53	+0.003
84	−0.53	+0.040	−0.86	−0.002	−2.49	+0.008
90	−0.28	+0.041	−0.87	−0.001	−2.43	+0.012
96	−0.04	+0.039	−0.87	+0.002	−2.34	+0.016
102	+0.19	+0.039	−0.85	+0.003	−2.24	+0.020
108	+0.43	+0.039	−0.83	+0.004	−2.10	+0.023
114	+0.66	+0.037	−0.80	+0.005	−1.96	+0.026
120	+0.87	+0.034	−0.77	+0.008	−1.79	+0.028
126	+1.07	+0.032	−0.71	+0.008	−1.63	+0.029
132	+1.26	+0.031	−0.67	+0.008	−1.44	+0.032
138	+1.44	+0.029	−0.61	+0.010	−1.24	+0.033
144	+1.61	+0.026	−0.55	+0.010	−1.04	+0.035
150	+1.75	+0.022	−0.49	+0.011	−0.82	+0.036
156	+1.88	+0.020	−0.42	+0.011	−0.61	+0.036
162	+1.99	+0.017	−0.36	+0.011	−0.38	+0.038
168	+2.08	+0.013	−0.29	+0.013	−0.15	+0.038
174	+2.15	+0.010	−0.20	+0.013	+0.07	+0.038
180	+2.20	+0.006	−0.13	+0.012	+0.30	+0.038
186	+2.22	+0.002	−0.05	+0.012	+0.52	+0.037
192	+2.23	0.000	+0.02	+0.013	+0.74	+0.037
198	+2.22	−0.005	+0.11	+0.013	+0.96	+0.036
204	+2.17	−0.008	+0.18	+0.012	+1.17	+0.034
210	+2.12	−0.011	+0.26	+0.012	+1.37	+0.033
216	+2.04	−0.016	+0.33	+0.012	+1.57	+0.031
222	+1.93	−0.019	+0.41	+0.012	+1.74	+0.028
228	+1.81	−0.021	+0.48	+0.011	+1.90	+0.028
234	+1.68	−0.024	+0.54	+0.011	+2.07	+0.025
240	+1.52	−0.028	+0.61	+0.011	+2.20	+0.022
246	+1.34	−0.031	+0.67	+0.010	+2.33	+0.019
252	+1.15	−0.033	+0.73	+0.008	+2.43	+0.015
258	+0.94	−0.035	+0.77	+0.008	+2.51	+0.012
264	+0.73	−0.038	+0.82	+0.008	+2.57	+0.008
270	+0.50	−0.039	+0.86	+0.006	+2.61	+0.004
276	+0.26	−0.039	+0.89	+0.004	+2.62	0.000
282	+0.03	−0.041	+0.91	+0.002	+2.61	−0.005
288	−0.23	−0.042	+0.92	+0.001	+2.56	−0.011
294	−0.48	−0.042	+0.92	−0.002	+2.48	−0.016
300	−0.73	−0.041	+0.90	−0.003	+2.37	−0.021
306	−0.97	−0.039	+0.88	−0.004	+2.23	−0.026
312	−1.20	−0.038	+0.85	−0.007	+2.06	−0.031
318	−1.42	−0.038	+0.80	−0.009	+1.86	−0.037
324	−1.65	−0.034	+0.74	−0.012	+1.62	−0.042
330	−1.83	−0.029	+0.66	−0.013	+1.36	−0.046
336	−2.00	−0.027	+0.58	−0.014	+1.07	−0.050
342	−2.15	−0.022	+0.49	−0.016	+0.76	−0.052
348	−2.26	−0.017	+0.39	−0.018	+0.45	−0.052
354	−2.35	−0.013	+0.28	−0.018	+0.13	−0.054
360	−2.42	−0.008	+0.17	−0.018	−0.20	−0.054

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (115) Thyra—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	A'	B'	C'	log sin a	log sin b	log sin c
	°	°	°			
1871.0	133.6335	38.3091	58.3609	9.99462	9.93598	9.72345
2	.6475	.3237	.3709	62	97	347
3	.6615	.3383	.3810	62	96	349
4	.6755	.3529	.3910	62	95	351
1875	133.6895	38.3674	58.4010	9.99462	9.93594	9.72353
6	.7035	.3820	.4111	62	93	355
7	.7175	.3966	.4211	63	92	357
8	.7315	.4112	.4312	63	91	359
9	.7455	.4257	.4412	63	90	361
1880	133.7595	38.4403	58.4512	9.99463	9.93589	9.72363
1	.7735	.4549	.4613	64	88	365
2	.7876	.4695	.4713	64	87	367
3	.8016	.4840	.4814	64	86	369
4	.8156	.4986	.4914	64	85	371
1885	133.8296	38.5132	58.5014	9.99464	9.93584	9.72373
6	.8436	.5278	.5115	64	83	375
7	.8576	.5424	.5215	65	82	377
8	.8716	.5569	.5316	65	81	379
9	.8856	.5715	.5416	65	80	381
1890	133.8996	38.5861	58.5516	9.99465	9.93579	9.72383
1	.9136	.6066	.5616	66	78	385
2	.9276	.6152	.5717	66	77	387
3	.9416	.6298	.5818	66	76	389
4	.9556	.6444	.5918	66	75	391
1895	133.9696	38.6590	58.6018	9.99466	9.93574	9.72393
6	.9836	.6735	.6119	66	73	395
7	133.9976	.6881	.6219	67	72	397
8	134.0117	.7027	.6320	67	71	399
9	.0257	.7172	.6420	67	70	401
1900	134.0397	38.7318	58.6520	9.99468	9.93568	9.72403
1	.0537	.7464	.6621	68	67	405
2	.0677	.7610	.6721	68	66	407
3	.0817	.7757	.6822	68	65	409
4	.0958	.7903	.6922	68	64	411
1905	134.1098	38.8049	58.7023	9.99468	9.93563	9.72413
6	.1238	.8195	.7123	69	62	415
7	.1378	.8342	.7224	69	61	417
8	.1518	.8488	.7324	69	60	419
9	.1659	.8634	.7425	69	59	421
1910	134.1799	38.8780	58.7526	9.99470	9.93558	9.72423
1	.1939	.8926	.7626	70	57	425
2	.2079	.9072	.7726	70	56	427
3	.2220	.9218	.7827	70	55	429
4	.2360	.9365	.7928	70	54	431
1915	134.2500	38.9511	58.8028	9.99470	9.93553	9.72433
6	.2640	.9657	.8129	71	52	435
7	.2780	.9803	.8229	71	51	437
8	.2921	38.9949	.8330	71	50	439
9	.3061	39.0096	.8430	71	49	441
1920	134.3201	39.0242	58.8531	9.99472	9.93548	9.72443
1	.3341	.0388	.8631	72	47	445
2	.3482	.0534	.8732	72	46	447
3	.3622	.0680	.8832	72	45	449
4	.3762	.0826	.8933	72	44	451
1925	134.3902	39.0972	58.9033	9.99472	9.93543	9.72453
6	.4042	.1119	.9134	73	42	455
7	.4183	.1265	.9234	73	41	457
8	.4323	.1411	.9335	73	40	459
9	.4463	.1557	.9435	73	39	461
1930	134.4603	39.1703	58.9536	9.99474	9.93537	9.72463

Year	log cos a	log cos b	log cos c
1871.0	9.1946n	9.7035n	9.9287
1930.0	9.1895n	9.7053n	9.9283

TABLES OF (128) NEMESIS.

MEAN ELEMENTS.

Epoch, 1896, July 3.0, M. T. Berlin=1896.504, M. T. Berlin

	°	′	″	°	
$g_0=$	101	41	9	$=101^\circ.6858$	
$\omega=$	299	56	32	$=299.9422$	Mean equinox and ecliptic 1900.0.
$\Omega=$	76	39	30	$=76.6584$	
$i=$	6	15	18	$=6.2551$	
$\varphi=$	7	16	50	$=7.2805$	
$n=$	$777.''8761$			$=0.21607669$	

The elements are based on oppositions extending from 1872 to 1899 and on the perturbations of the first order by *Jupiter*, as given on page 256.

AUXILIARY QUANTITIES.

$\log a=0.43940$ $\quad \log 57.2958e=0.86099$ $\quad \log\sqrt{\frac{1-e}{1+e}}=9.94466$

$\log e=9.10287$ $\quad \log p=0.43236$

TABLE I.—MEAN ANOMALY (g).

Jan. 0.0 of common years; Jan. 1.0 of leap years

Year	g	Year	g
	°		°
B 1872	327.7994	1902	175.13562
3	46.66739	3	254.00361
4	125.53538	B 4	333.08768
5	204.40338	5	51.95568
B 6	283.48744	6	130.82367
7	2.35544	7	209.69166
8	81.22343	B 8	288.77573
9	160.09142	9	7.64372
B 1880	239.17549	1910	86.51171
1	318.04348	1	165.37970
2	36.91147	B 2	244.46377
3	115.77947	3	323.33176
B 4	194.86354	4	42.19976
5	273.73153	5	121.06775
6	352.59952	B 6	200.15182
7	71.46751	7	279.01981
B 8	150.55158	8	357.88780
9	229.41957	9	76.75579
1890	308.28756	B 1920	155.83986
1	27.15556	1	234.70786
B 2	106.23962	2	313.57585
3	185.10762	3	32.44384
4	263.97561	B 4	111.52791
5	342.84360	5	190.39590
B 6	61.92767	6	269.26389
7	140.79566	7	348.13188
8	219.66365	B 8	67.21595
9	298.53165	9	146.08394
1900	17.39964	1930	224.95194
1	96.26763		

NOTE.—When g is used as an argument of the perturbations, add to the g of this table $\Delta\pi=\pi-\pi_0=0^\circ.3894$. For explanation see page 203.

Table for beginning of month

Month	g
	°
Jan. 1.0 0.0	0.00000
Feb. 1.0 0.0	6.69837
Mar. 0.0	12.74852
Apr. 0.0	19.44689
May 0.0	25.92919
June 0.0	32.62756
July 0.0	39.10986
Aug. 0.0	45.80823
Sept. 0.0	52.50660
Oct. 0.0	58.98890
Nov. 0.0	65.68727
Dec. 0.0	72.16964

Change for n days[a]

n	g	n	g
	°		°
1	0.21608	16	3.45723
2	0.43215	17	3.67330
3	0.64823	18	3.88938
4	0.86431	19	4.10546
5	1.08038	20	4.32153
6	1.29646	21	4.53761
7	1.51254	22	4.75369
8	1.72861	23	4.96976
9	1.94469	24	5.18584
10	2.16077	25	5.40192
11	2.37684	26	5.61799
12	2.59292	27	5.83407
13	2.80900	28	6.05015
14	3.02507	29	6.26622
15	3.24115	30	6.48230

[a] For days during January and February of leap years substract one day before entering this table.

Tables of (128) Nemesis—Continued.

PERTURBATIONS.

Arg. $ig-i'g'$		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	0				− 6		− 2
0	0						− 0.38nt
+1	0				+ 7		
+1		− 0.43nt	− 7.22nt	− 3.61nt	+ 0.21nt	+3.08nt	+ 2.03nt
+2			− 1				
+2		0.01nt	− 0.22nt	− 0.22nt	+ 0.01nt	+0.19nt	+ 0.13nt
+3	0		− 0.01nt	− 0.02nt		+0.02nt	+ 0.01nt
−1	+1	+ 1	− 1	+ 1		+1	+ 1
0		− 7	− 3		+ 2	+3	+ 4
+1		−226	− 19	− 5	+ 75	−1	− 4
+2	+1	− 9			+ 7	+2	− 2
0	+2	− 16			6	−2	− 6
+1		+581	+102	+18	−107	+2	+ 6
+2		+457	+ 71	+41	−263		+ 4
+3		+ 17	+ 3	+ 3	− 18	+1	− 1
+4	+2	+ 1			− 2		
0	+3		− 2	+ 1			− 1
+1		+ 30	− 19	+ 3	+ 1	−1	− 3
+2		+117	+ 44	+20	− 55	+6	+15
+3		+ 44	+ 10	+ 8	− 32	+1	+ 1
+4	+3	+ 2	+ 1	+ 1	− 3		
+2	+4	+ 1	− 3	− 1	− 1		
+3		− 14	− 7	− 3	+ 8	−1	− 3
+4		+ 8	+ 2	+ 2	− 7		
+5	+4	+ 1			− 1		
+2	+5	− 5	+ 10	+ 1			
+3		+ 6	+ 11	+ 6	− 3		+ 2
+4		− 2	1		+ 1		− 1
+5	+5	+ 2	+ 1	+ 1	−2		

Tables of (128) Nemesis—Continued.

TABLE II.—$n\delta z$.

PERIODIC TERMS.

Unit of a and b = 0°.001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	−1.0	+0.19	+108.5	+0.62	+ 17.9	−5.00	+156.4	+1.48	+ 33.3	−5.96
6	+0.1	+0.18	+108.6	−0.56	− 12.5	−4.96	+161.2	+0.03	− 3.7	−6.20
12	+1.2	+0.18	+101.8	−1.72	− 41.6	−4.67	+156.8	−1.47	− 41.1	−6.10
18	+2.3	+0.18	+ 88.0	−2.78	− 68.5	−4.14	+143.5	−2.94	− 76.9	−5.62
24	+3.3	+0.16	+ 68.5	−3.65	− 91.3	−3.37	+121.5	−4.24	−108.6	−4.73
30	+4.2	+0.12	+ 44.2	−4.38	−108.9	−2.42	+ 92.6	−5.26	−133.6	−3.56
36	+4.8	+0.09	+ 16.0	−4.83	−120.3	−1.36	+ 58.4	−5.92	−151.2	−2.12
42	+5.3	+0.07	− 13.8	−5.03	−125.2	−0.23	+ 21.5	−6.65	−159.2	−0.58
48	+5.6	+0.02	− 44.4	−4.98	−123.1	+0.92	− 16.3	−6.09	−158.2	+0.92
54	+5.6	−0.02	− 73.7	−4.71	−114.2	+2.00	− 51.6	−5.54	−148.1	+2.35
60	+5.4	−0.05	−100.9	−4.22	− 99.1	+3.02	− 82.8	−4.72	−130.0	+3.52
66	+5.0	−0.08	−124.3	−3.51	− 77.9	+3.91	−108.2	−3.63	−105.8	+4.40
72	+4.4	−0.12	−143.0	−2.63	− 52.2	+4.61	−126.4	−2.42	− 77.2	+4.94
78	+3.5	−0.14	−155.9	−1.63	− 22.6	+5.11	−137.2	−1.18	− 46.4	+5.18
84	+2.7	−0.15	−162.6	−0.57	+ 9.1	+5.39	−140.6	+0.02	− 15.0	+5.13
90	+1.7	−0.16	−162.7	+0.54	+ 42.1	+5.48	−136.9	+1.08	+ 15.2	+4.82
96	+0.8	−0.14	−156.1	+1.63	+ 74.8	+5.32	−127.6	+1.97	+ 42.8	+4.30
102	0.0	−0.14	−143.1	+2.68	+105.9	+4.95	−113.2	+2.72	+ 66.8	+3.66
108	−0.9	−0.14	−124.0	+3.62	+134.2	+4.41	− 94.9	+3.30	+ 86.8	+2.95
114	−1.7	−0.11	− 99.6	+4.43	+158.8	+3.68	− 73.5	+3.71	+102.2	+2.14
120	−2.2	−0.08	− 70.8	+5.12	+178.3	+2.78	− 50.2	+3.96	+112.5	+1.32
126	−2.6	−0.04	− 38.2	+5.62	+192.1	+1.80	− 26.0	+4.03	+118.0	+0.51
132	−2.7	−0.01	− 3.4	+5.91	+199.9	+0.74	− 1.8	+3.98	+118.6	−0.28
138	−2.7	+0.02	+ 32.7	+6.00	+201.0	−0.38	+ 21.7	+3.73	+114.6	−1.06
144	−2.4	+0.06	+ 68.6	+5.88	+195.4	−1.49	+ 43.0	+3.34	+105.9	−1.77
150	−2.0	+0.07	+103.3	+5.58	+183.1	−2.58	+ 61.8	+2.85	+ 93.4	−2.36
156	−1.6	+0.09	+135.5	+5.08	+164.3	−3.60	+ 77.2	+2.25	+ 77.6	−2.78
162	−0.9	+0.12	+164.2	+4.35	+139.9	−4.51	+ 88.8	+1.58	+ 60.0	−3.05
168	−0.1	+0.12	+187.7	+3.47	+110.2	−5.28	+ 96.2	+0.93	+ 41.0	−3.16
174	+0.6	+0.12	+205.8	+2.48	+ 76.5	−5.88	+100.0	+0.30	+ 22.1	−3.11
180	+1.4	+0.12	+217.5	+1.37	+ 39.7	−6.30	+ 99.8	−0.25	+ 3.7	−2.96
186	+2.1	+0.10	+222.2	+0.16	+ 0.9	−6.49	+ 97.0	−0.63	− 13.4	−2.72
192	+2.6	+0.08	+219.4	−1.07	− 38.2	−6.45	+ 92.2	−0.98	− 29.0	−2.48
198	+3.1	+0.08	+209.4	−2.26	− 76.5	−6.19	+ 85.2	−1.28	− 43.2	−2.28
204	+3.5	+0.04	+192.3	−3.38	−112.5	−5.68	+ 76.9	−1.47	− 56.4	−2.08
210	+3.6	+0.01	+168.8	−4.42	−144.7	−4.95	+ 67.6	−1.69	− 68.2	−1.93
216	+3.6	−0.01	+139.2	−5.32	−171.9	−4.02	+ 56.6	−1.98	− 79.6	−1.82
222	+3.5	−0.03	+105.0	−5.98	−193.0	−2.93	+ 43.8	−2.35	− 90.0	−1.63
228	+3.2	−0.08	+ 67.4	−6.44	−207.1	−1.71	+ 28.4	−2.75	− 99.2	−1.34
234	+2.6	−0.10	+ 27.7	−6.64	−213.5	−0.42	+ 10.8	−3.16	−106.1	−0.93
240	+2.0	−0.10	− 12.3	−6.57	−212.1	+0.90	− 9.5	−3.57	−110.4	−0.36
246	+1.4	−0.12	− 51.1	−6.24	−202.7	+2.18	− 32.0	−3.84	−110.4	+0.40
252	+0.6	−0.14	− 87.2	−5.62	−186.0	+3.35	− 55.5	−3.88	−105.6	+1.28
258	−0.3	−0.14	−118.5	−4.77	−162.4	+4.41	− 78.6	−3.72	− 95.0	+2.23
264	−1.1	−0.15	−144.4	−3.73	−133.1	+5.22	−100.2	−3.29	− 78.8	+3.17
270	−2.1	−0.16	−163.3	−2.52	− 99.7	+5.82	−118.1	−2.55	− 57.0	+4.03
276	−3.0	−0.14	−174.7	−1.23	− 63.2	+6.14	−130.8	−1.61	− 30.4	+4.66
282	−3.8	−0.12	−178.1	+0.09	− 26.0	+6.17	−137.4	−0.48	− 1.1	+5.04
288	−4.5	−0.11	−173.6	+1.41	+ 10.8	+5.92	−136.6	+0.74	+ 30.1	+5.16
294	−5.1	−0.09	−161.2	+2.62	+ 45.0	+5.38	−128.5	+1.93	+ 60.8	+4.92
300	−5.6	−0.06	−142.2	+3.68	+ 75.3	+4.59	−113.4	+3.04	+ 89.1	+4.38
306	−5.8	−0.04	−117.0	+4.53	+100.1	+3.58	− 92.0	+4.02	+113.4	+3.62
312	−6.1	−0.02	− 87.8	+5.11	+118.3	+2.42	− 65.1	+4.82	+132.5	+2.65
318	−6.1	+0.02	− 55.7	+5.43	+129.2	+1.18	− 34.2	+5.34	+145.2	+1.52
324	−5.8	+0.06	− 22.6	+5.47	+132.4	−0.09	− 1.0	+5.60	+150.7	+0.29
330	−5.4	+0.08	+ 9.9	+5.21	+128.1	−1.34	+ 33.0	+5.60	+148.7	−0.98
336	−4.8	+0.10	+ 39.9	+4.68	+116.3	−2.49	+ 66.2	+5.32	+139.0	−2.26
342	−4.1	+0.14	+ 66.0	+3.90	+ 98.2	−3.46	+ 96.8	+4.73	+121.6	−3.45
348	−3.1	+0.16	+ 86.7	+2.93	+ 74.8	−4.22	+123.0	+3.88	+ 97.6	−4.49
354	−2.2	+0.18	+101.2	+1.82	+ 47.5	−4.74	+143.4	+2.78	+ 67.9	−5.36
360	−1.0	+0.19	+108.5	+0.62	+ 17.9	−5.00	+156.4	+1.48	+ 33.3	−5.96

[$n\delta z$, $\partial \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (128) Nemesis—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS. Unit of a and b=0°.001.

i	3				4				5			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°	a_5	Diff. for 1°	b_5	Diff. for 1°
°												
0	+14.8	+0.30	+ 4.8	−0.68	+2.5	+0.04	+0.6	−0.15	+0.8	+0.02	+0.3	−0.06
6	+16.0	+0.08	+ 0.3	−0.78	+2.6	−0.02	−0.4	−0.15	+0.9	−0.01	−0.1	−0.07
12	+15.7	−0.18	− 4.5	−0.78	+2.3	−0.08	−1.2	−0.13	+0.7	−0.04	−0.5	−0.06
18	+13.8	−0.43	− 9.0	−0.68	+1.6	−0.12	−2.0	−0.09	+0.4	−0.06	−0.8	−0.03
24	+10.5	−0.63	−12.7	−0.51	+0.9	−0.12	−2.3	−0.04	0.0	−0.08	−0.9	0.00
30	+ 6.2	−0.75	−15.1	−0.28	+0.2	−0.14	−2.5	−0.01	−0.5	−0.06	−0.8	+0.03
36	+ 1.4	−0.79	−16.0	−0.01	−0.8	−0.15	−2.4	+0.05	−0.7	−0.03	−0.5	+0.06
42	− 3.3	−0.72	−15.2	+0.23	−1.6	−0.11	−1.9	+0.10	−0.9	−0.01	−0.1	+0.08
48	− 7.2	−0.58	−13.2	+0.42	−2.1	−0.06	−1.2	+0.13	−0.8	+0.03	+0.4	+0.07
54	−10.2	−0.40	−10.2	+0.55	−2.3	−0.02	−0.3	+0.14	−0.5	+0.05	+0.7	+0.04
60	−12.0	−0.22	− 6.6	+0.59	−2.2	+0.03	+0.4	+0.14	−0.2	+0.07	+0.9	+0.01
66	−12.8	−0.03	− 3.1	+0.58	−1.9	+0.10	+1.4	+0.12	+0.3	+0.07	+0.8	−0.02
72	−12.4	+0.12	+ 0.4	+0.52	−1.1	+0.13	+1.8	+0.07	+0.6	+0.04	+0.6	−0.05
78	−11.5	+0.20	+ 3.2	+0.44	−0.3	+0.14	+2.2	+0.02	+0.8	+0.02	+0.2	−0.07
84	−10.0	+0.28	+ 5.7	+0.38	+0.6	+0.13	+2.0	−0.05	+0.8	−0.02	−0.2	−0.06
90	− 8.2	+0.32	+ 7.8	+0.32	+1.3	+0.11	+1.6	−0.09	+0.6	−0.04	−0.5	−0.04
96	− 6.2	+0.38	+ 9.5	+0.24	+1.9	+0.06	+0.9	−0.14	+0.3	−0.06	−0.7	−0.02
102	− 3.7	+0.45	+10.7	+0.16	+2.0	−0.01	−0.1	−0.16	−0.1	−0.06	−0.7	+0.01
108	− 0.8	+0.51	+11.4	+0.08	+1.8	−0.08	−1.0	−0.13	−0.4	−0.04	−0.6	+0.03
114	+ 2.4	+0.55	+11.6	−0.06	+1.1	−0.13	−1.7	−0.08	−0.6	−0.02	−0.3	+0.05
120	+ 5.8	+0.56	+10.7	−0.25	+0.2	−0.15	−1.9	−0.02	−0.7	+0.01	0.0	+0.05
126	+ 9.1	+0.49	+ 8.6	−0.44	−0.7	−0.14	−1.9	+0.04	−0.5	+0.03	+0.3	+0.04
132	+11.7	+0.34	+ 5.4	−0.62	−1.5	−0.12	−1.4	+0.11	−0.3	+0.04	+0.5	+0.02
138	+13.2	+0.11	+ 1.2	−0.75	−2.0	−0.04	−0.6	+0.16	0.0	+0.05	+0.6	0.00
144	+13.0	−0.18	− 3.6	−0.78	−2.0	+0.02	+0.5	+0.17	+0.3	+0.03	+0.5	−0.02
150	+11.0	−0.48	− 8.2	−0.68	−1.8	+0.08	+1.4	+0.13	+0.4	+0.02	+0.3	−0.04
156	+ 7.2	−0.73	−11.9	−0.48	−1.0	+0.15	+2.1	+0.08	+0.5	0.00	0.0	−0.04
162	+ 2.2	−0.89	−14.0	−0.16	0.0	+0.17	+2.4	+0.01	+0.4	−0.02	−0.2	−0.03
168	− 3.5	−0.92	−13.8	+0.22	+1.0	+0.17	+2.2	−0.07	+0.2	−0.03	−0.4	−0.02
174	− 8.8	−0.79	−11.4	+0.57	+2.0	+0.13	+1.6	−0.13	0.0	−0.03	−0.4	+0.01
180	−13.0	−0.52	− 7.0	+0.86	+2.5	+0.05	+0.6	−0.18	−0.2	−0.02	−0.3	+0.02
186	−15.0	−0.11	− 1.1	+1.01	+2.6	−0.03	−0.6	−0.18	−0.3	−0.01	−0.1	+0.03
192	−14.3	+0.32	+ 5.1	+0.99	+2.1	−0.12	−1.6	−0.15	−0.3	+0.01	+0.1	+0.02
198	−11.2	+0.70	+10.8	+0.80	+1.2	−0.17	−2.4	−0.09	−0.2	+0.02	+0.2	+0.02
204	− 5.9	+0.97	+14.7	+0.46	+0.1	−0.18	−2.7	−0.01	0.0	+0.02	+0.3	0.00
210	+ 0.4	+1.08	+16.3	+0.04	−1.0	−0.18	−2.5	+0.08	+0.1	+0.02	+0.2	−0.02
216	+ 7.0	+1.01	+15.2	−0.41	−2.0	−0.13	−1.8	+0.15	+0.3	+0.02	+0.1	−0.02
222	+12.5	+0.77	+11.4	−0.78	−2.6	−0.04	−0.7	+0.18	+0.3	−0.01	−0.1	−0.02
228	+16.2	+0.41	+ 5.8	−1.02	−2.5	+0.04	+0.4	+0.18	+0.2	−0.02	−0.2	−0.02
234	+17.4	−0.02	− 0.8	−1.07	−2.1	+0.11	+1.5	+0.15	+0.1	−0.03	−0.3	−0.01
240	+16.0	−0.42	− 7.0	−0.96	−1.2	+0.17	+2.2	+0.09	−0.2	−0.03	−0.3	+0.01
246	+12.4	−0.73	−12.3	−0.72	−0.1	+0.19	+2.6	+0.01	−0.3	−0.02	−0.2	+0.02
252	+ 7.2	−0.92	−15.6	−0.38	+1.1	+0.17	+2.3	−0.08	−0.4	−0.02	0.0	+0.03
258	+ 1.3	−0.95	−16.8	−0.02	+1.9	+0.11	+1.6	−0.14	−0.4	+0.02	+0.2	+0.03
264	− 4.2	−0.84	−15.9	+0.30	+2.4	+0.05	+0.6	−0.17	−0.2	+0.03	+0.4	+0.02
270	− 8.8	−0.65	−13.2	+0.53	+2.5	−0.02	−0.4	−0.18	0.0	+0.04	+0.5	+0.01
276	−12.0	−0.41	− 9.5	+0.66	+2.1	−0.11	−1.5	−0.16	+0.3	+0.04	+0.5	−0.02
282	−13.7	−0.15	− 5.3	+0.69	+1.2	−0.16	−2.3	−0.09	+0.5	+0.02	+0.3	−0.04
288	−13.8	+0.06	− 1.2	+0.64	+0.2	−0.18	−2.6	−0.02	+0.6	+0.01	0.0	−0.05
294	−13.0	+0.18	+ 2.4	+0.54	−0.9	−0.16	−2.5	+0.06	+0.6	−0.02	−0.3	−0.05
300	−11.6	+0.28	+ 5.3	+0.42	−1.8	−0.13	−1.9	+0.12	+0.3	−0.04	−0.6	−0.03
306	− 9.7	+0.32	+ 7.4	+0.32	−2.5	−0.08	−1.1	+0.16	+0.1	−0.05	−0.7	−0.01
312	− 7.7	+0.36	+ 9.2	+0.27	−2.7	0.00	0.0	+0.18	−0.3	−0.06	−0.7	+0.02
318	− 5.4	+0.38	+10.6	+0.20	−2.5	+0.07	+1.0	+0.16	−0.6	−0.03	−0.4	+0.05
324	− 3.2	+0.40	+11.6	+0.17	−1.9	+0.11	+1.9	+0.12	−0.7	−0.02	−0.1	+0.06
330	− 0.6	+0.47	+12.6	+0.11	−1.2	+0.14	+2.4	+0.07	−0.8	+0.02	+0.3	+0.06
336	+ 2.4	+0.53	+12.9	−0.02	−0.2	+0.17	+2.7	+0.02	−0.5	+0.04	+0.6	+0.04
342	+ 5.8	+0.58	+12.4	−0.16	+0.8	+0.16	+2.6	−0.05	−0.2	+0.06	+0.8	+0.02
348	+ 9.3	+0.55	+11.0	−0.33	+1.7	+0.12	+2.0	−0.10	+0.2	+0.07	+0.8	−0.02
354	+12.4	+0.46	+ 8.4	−0.52	+2.2	+0.07	+1.4	−0.12	+0.6	+0.05	+0.6	−0.04
360	+14.8	+0.30	+ 4.8	−0.68	+2.5	+0.04	+0.6	−0.15	+0.8	+0.02	+0.3	−0.06

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig+\Sigma_i b_i \cos ig+cT$.]

Tables of (128) Nemesis—Continued.

TABLE III.—δ log r.

PERIODIC TERMS. Unit of a and b=0.00001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	−2.2	0.00	+3.2	−0.48	−5.0	−0.14	+13.0	−2.48	−65.3	−0.54
6	−2.2	+0.01	+0.1	−0.52	−5.5	−0.02	−2.3	−2.54	−66.8	+0.06
12	−2.1	+0.02	−3.0	−0.52	−5.2	+0.12	−17.5	−2.47	−64.6	+0.66
18	−2.0	+0.02	−6.1	−0.47	−4.1	+0.26	−31.9	−2.24	−58.8	+1.22
24	−1.8	+0.02	−8.6	−0.38	−2.1	+0.37	−44.4	−1.89	−49.9	+1.72
30	−1.7	+0.04	−10.6	−0.28	+0.3	+0.47	−54.6	−1.42	−38.2	+2.11
36	−1.4	+0.04	−12.0	−0.17	+3.4	+0.56	−61.6	−0.88	−24.6	+2.37
42	−1.2	+0.04	−12.6	−0.02	+7.0	+0.61	−65.1	−0.30	−9.8	+2.48
48	−0.9	+0.04	−12.3	+0.12	+10.7	+0.62	−65.2	+0.28	+5.3	+2.45
54	−0.7	+0.04	−11.1	+0.27	+14.4	+0.59	−61.7	+0.85	+19.6	+2.28
60	−0.5	+0.03	−9.1	+0.42	+17.8	+0.54	−55.0	+1.31	+32.7	+2.01
66	−0.3	+0.02	−6.1	+0.57	+20.9	+0.46	−45.8	+1.71	+43.7	+1.60
72	−0.2	+0.02	−2.3	+0.68	+23.3	+0.34	−34.5	+1.98	+51.9	+1.13
78	−0.1	+0.02	+2.0	+0.77	+25.0	+0.19	−22.0	+2.16	+57.3	+0.66
84	0.0	+0.01	+6.9	+0.82	+25.6	+0.04	−8.6	+2.18	+59.8	+0.16
90	0.0	−0.01	+11.8	+0.82	+25.5	−0.12	+4.2	+2.10	+59.3	−0.32
96	−0.1	−0.02	+16.8	+0.83	+24.1	−0.32	+16.6	+1.95	+55.9	−0.75
102	−0.3	−0.02	+21.8	+0.78	+21.7	−0.48	+27.6	+1.68	+50.3	−1.12
108	−0.4	−0.03	+26.1	+0.67	+18.3	−0.65	+36.8	+1.37	+42.5	−1.41
114	−0.7	−0.04	+29.7	+0.55	+13.9	−0.78	+44.0	+1.00	+33.4	−1.61
120	−0.9	−0.04	+32.7	+0.39	+8.9	−0.88	+48.8	+0.62	+23.2	−1.74
126	−1.2	−0.05	+34.4	+0.21	+3.4	−0.96	+51.5	+0.26	+12.4	−1.78
132	−1.5	−0.05	+35.2	+0.03	−2.6	−1.02	+51.9	−0.10	+1.9	−1.72
138	−1.8	−0.06	+34.8	−0.17	−8.7	−1.02	+50.3	−0.43	−8.2	−1.62
144	−2.2	−0.05	+33.2	−0.35	−14.8	−0.98	+46.7	−0.72	−17.6	−1.46
150	−2.4	−0.04	+30.6	−0.52	−20.6	−0.90	+41.7	−0.95	−25.7	−1.23
156	−2.7	−0.04	+26.9	−0.70	−25.6	−0.78	+35.3	−1.13	−32.4	−1.01
162	−2.9	−0.02	+22.2	−0.84	−30.0	−0.66	+28.1	−1.24	−37.8	−0.78
168	−3.0	−0.02	+16.8	−0.95	−33.5	−0.48	+20.4	−1.32	−41.7	−0.52
174	−3.1	−0.01	+10.8	−1.02	−35.8	−0.29	+12.3	−1.35	−44.1	−0.28
180	−3.1	0.00	+4.4	−1.07	−37.0	−0.12	+4.2	−1.34	−45.1	−0.06
186	−3.1	+0.02	−2.0	−1.08	−37.2	+0.08	−3.8	−1.32	−44.8	+0.14
192	−2.9	+0.02	−8.5	−1.03	−36.0	+0.27	−11.6	−1.27	−43.4	+0.35
198	−2.8	+0.02	−14.4	−0.94	−34.0	+0.45	−19.0	−1.19	−40.6	+0.55
204	−2.6	+0.04	−19.9	−0.84	−30.6	+0.62	−25.9	−1.11	−36.8	+0.72
210	−2.3	+0.05	−24.6	−0.72	−26.5	+0.74	−32.3	−1.01	−32.0	+0.89
216	−2.0	+0.05	−28.5	−0.57	−21.7	+0.86	−38.0	−0.88	−26.1	+1.08
222	−1.7	+0.05	−31.4	−0.40	−16.2	+0.91	−42.8	−0.70	−19.0	+1.27
228	−1.4	+0.06	−33.3	−0.22	−10.8	+0.95	−46.4	−0.50	−10.9	+1.42
234	−1.0	+0.05	−34.1	−0.02	−4.8	+1.06	−48.8	−0.24	−2.0	+1.53
240	−0.8	+0.04	−33.7	+0.14	+1.9	+0.95	−49.3	+0.08	+7.5	+1.62
246	−0.5	+0.06	−32.4	+0.28	+6.5	+0.80	−47.9	+0.42	+17.4	+1.64
252	−0.2	+0.02	−30.2	+0.43	+11.5	+0.80	−44.3	+0.76	+27.2	+1.59
258	−0.1	+0.02	−27.2	+0.55	+16.1	+0.68	−38.8	+1.09	+36.5	+1.45
264	+0.2	+0.02	−23.6	+0.66	+19.7	+0.52	−31.2	+1.42	+44.6	+1.22
270	+0.2	0.00	−19.3	+0.72	+22.4	+0.39	−21.7	+1.72	+51.1	+0.92
276	+0.2	0.00	−14.9	+0.76	+24.4	+0.24	−10.5	+1.93	+55.6	+0.55
282	+0.2	−0.01	−10.2	+0.77	+25.3	+0.09	+1.5	+2.05	+57.7	+0.11
288	+0.1	−0.02	−5.7	+0.75	+25.5	−0.06	+14.1	+2.08	+56.9	−0.36
294	−0.1	−0.04	−1.2	+0.68	+24.6	−0.21	+26.5	+1.99	+53.4	−0.82
300	−0.4	−0.02	+2.5	+0.61	+23.0	−0.33	+38.0	+1.80	+47.0	−1.28
306	−0.5	−0.04	+6.1	+0.52	+20.6	−0.45	+48.1	+1.50	+38.1	−1.68
312	−0.8	−0.06	+8.7	+0.39	+17.7	−0.52	+56.0	+1.10	+26.9	−2.02
318	−1.1	−0.04	+10.8	+0.28	+14.4	−0.57	+61.3	+0.65	+13.9	−2.25
324	−1.3	−0.03	+12.0	+0.12	+10.9	−0.58	+63.8	+0.11	−0.1	−2.37
330	−1.5	−0.03	+12.1	−0.03	+7.4	−0.58	+62.6	−0.47	−14.5	−2.37
336	−1.7	−0.04	+11.6	−0.14	+3.9	−0.54	+58.2	−0.99	−28.5	−2.23
342	−2.0	−0.02	+10.4	−0.27	+0.9	−0.48	+50.7	−1.49	−41.3	−1.97
348	−2.0	−0.02	+8.4	−0.38	−1.8	−0.39	+40.3	−1.92	−52.1	−1.58
354	−2.2	−0.02	+5.9	−0.43	−3.8	−0.27	+27.6	−2.28	−60.3	−1.10
360	−2.2	0.00	+3.2	−0.48	−5.0	−0.14	+13.0	−2.48	−65.3	−0.54

[$n\delta z$, δ log, r and u/cos i are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (128) Nemesis—Continued.

TABLE III.—δ log r—Continued.

PERIODIC TERMS. Unit of a and b=0.00001.

i	3				4				5			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°	a_5	Diff. for 1°	b_5	Diff. for 1°
°												
0	+2.9	−0.42	−9.5	−0.18	+0.7	−0.12	−2.3	−0.03	+0.2	−0.04	−0.6	−0.02
6	+0.2	−0.46	−10.2	−0.04	−0.2	−0.14	−2.4	+0.01	−0.1	−0.05	−0.7	+0.01
12	−2.6	−0.47	−10.0	+0.11	−1.0	−0.12	−2.2	+0.06	−0.4	−0.04	−0.5	+0.03
18	−5.4	−0.42	−8.9	+0.25	−1.7	−0.09	−1.7	+0.09	−0.6	−0.02	−0.3	+0.04
24	−7.7	−0.32	−7.0	+0.37	−2.1	−0.06	−1.1	+0.12	−0.7	0.00	0.0	+0.06
30	−9.2	−0.20	−4.5	+0.44	−2.4	−0.02	−0.3	+0.13	−0.6	+0.02	+0.4	+0.04
36	−10.1	−0.06	−1.7	+0.49	−2.3	+0.03	+0.5	+0.13	−0.4	+0.04	+0.5	+0.02
42	−9.9	+0.10	+1.4	+0.47	−2.0	+0.08	+1.3	+0.11	−0.1	+0.06	+0.7	+0.01
48	−8.9	+0.22	+3.9	+0.38	−1.3	+0.12	+1.8	+0.07	+0.3	+0.05	+0.6	−0.02
54	−7.2	+0.32	+6.0	+0.29	−0.5	+0.12	+2.1	+0.02	+0.5	+0.03	+0.4	−0.04
60	−5.2	+0.36	+7.4	+0.18	+0.2	+0.12	+2.1	−0.02	+0.7	+0.01	+0.2	−0.05
66	−2.9	+0.38	+8.2	+0.08	+1.0	+0.10	+1.8	−0.07	+0.6	−0.02	−0.2	−0.05
72	−0.6	+0.37	+8.3	−0.02	+1.4	+0.06	+1.2	−0.12	+0.5	−0.04	−0.5	−0.03
78	+1.5	+0.32	+8.0	−0.11	+1.7	+0.02	+0.5	−0.12	+0.2	−0.05	−0.6	−0.01
84	+3.3	+0.28	+7.0	−0.18	+1.7	−0.02	−0.2	−0.10	−0.2	−0.04	−0.6	+0.01
90	+4.8	+0.22	+5.8	−0.22	+1.4	−0.08	−0.8	−0.08	−0.4	−0.02	−0.5	+0.03
96	+6.0	+0.17	+4.4	−0.27	+0.8	−0.10	−1.2	−0.05	−0.5	−0.01	−0.2	+0.04
102	+6.8	+0.09	+2.6	−0.30	+0.2	−0.10	−1.4	+0.01	−0.5	0.00	+0.1	+0.04
108	+7.1	+0.02	+0.8	−0.32	−0.5	−0.10	−1.1	+0.05	−0.5	+0.02	+0.3	+0.02
114	+7.0	−0.06	−1.2	−0.33	−1.0	−0.06	−0.8	+0.08	−0.2	+0.04	+0.5	+0.02
120	+6.4	−0.16	−3.2	−0.30	−1.1	0.00	−0.2	+0.10	0.0	+0.03	+0.5	0.00
126	+5.1	−0.27	−4.9	−0.25	−1.0	+0.03	+0.4	+0.09	+0.2	+0.03	+0.4	−0.02
132	+3.2	−0.33	−6.2	−0.16	−0.7	+0.07	+0.9	+0.06	+0.4	+0.02	+0.2	−0.03
138	+1.1	−0.38	−6.8	−0.04	−0.2	+0.10	+1.1	+0.02	+0.5	0.00	0.0	−0.03
144	−1.4	−0.39	−6.7	+0.09	+0.5	+0.08	+1.1	−0.02	+0.4	−0.02	−0.2	−0.02
150	−3.6	−0.32	−5.7	+0.24	+0.9	+0.07	+0.8	−0.06	+0.2	−0.03	−0.3	−0.02
156	−5.3	−0.22	−3.8	+0.36	+1.3	+0.04	+0.5	−0.08	0.0	−0.02	−0.4	0.00
162	−6.2	−0.07	−1.4	+0.42	+1.4	−0.02	−0.2	−0.10	−0.2	−0.02	−0.3	+0.02
168	−6.1	+0.09	+1.2	+0.42	+1.2	−0.05	−0.8	−0.10	−0.3	−0.02	−0.2	+0.02
174	−5.1	+0.26	+3.6	+0.35	+0.8	−0.08	−1.4	−0.05	−0.3	+0.01	0.0	+0.02
180	−3.0	+0.39	+5.4	+0.22	+0.2	−0.10	−1.4	−0.01	−0.2	+0.02	+0.2	+0.02
186	−0.4	+0.45	+6.2	+0.04	−0.5	−0.10	−1.5	+0.02	−0.1	+0.02	+0.2	0.00
192	+2.4	+0.44	+5.9	−0.15	−1.0	−0.08	−1.1	+0.07	+0.1	+0.02	+0.2	0.00
198	+4.9	+0.34	+4.4	−0.32	−1.4	−0.04	−0.7	+0.09	+0.2	+0.02	+0.2	−0.02
204	+6.5	+0.18	+2.0	−0.44	−1.5	0.00	0.0	+0.11	+0.2	0.00	0.0	−0.02
210	+7.1	−0.01	−1.0	−0.49	−1.4	+0.03	+0.6	+0.08	+0.2	−0.01	−0.1	−0.02
216	+6.4	−0.22	−3.9	−0.45	−1.0	+0.09	+1.0	+0.06	+0.1	−0.02	−0.2	−0.01
222	+4.5	−0.38	−6.4	−0.34	−0.3	+0.10	+1.3	+0.03	−0.1	−0.02	−0.2	0.00
228	+2.0	−0.47	−8.0	−0.17	+0.2	+0.08	+1.4	−0.02	−0.2	−0.01	−0.2	+0.01
234	−1.1	−0.52	−8.4	+0.03	+0.7	+0.08	+1.1	−0.08	−0.2	0.00	−0.1	+0.02
240	−4.2	−0.47	−7.6	+0.21	+1.1	+0.05	+0.5	−0.09	−0.2	0.00	+0.2	+0.02
246	−6.7	−0.36	−5.9	+0.37	+1.3	−0.01	0.0	−0.08	−0.2	+0.02	+0.2	+0.02
252	−8.5	−0.18	−3.2	+0.47	+1.0	−0.05	−0.6	−0.09	0.0	+0.02	+0.3	+0.01
258	−8.9	−0.01	−0.3	+0.48	+0.7	−0.07	−1.1	−0.05	+0.2	+0.02	+0.3	−0.02
264	−8.6	+0.12	+2.5	+0.45	+0.2	−0.10	−1.2	−0.01	+0.3	+0.02	+0.2	−0.02
270	−7.4	+0.26	+5.0	+0.36	−0.5	−0.10	−1.2	+0.02	+0.4	+0.01	0.0	−0.02
276	−5.5	+0.34	+6.8	+0.24	−1.1	−0.08	−0.9	+0.06	+0.4	−0.02	−0.2	−0.03
282	−3.3	+0.38	+7.9	+0.12	−1.5	−0.03	−0.5	+0.08	+0.2	−0.03	−0.4	−0.02
288	−0.9	+0.38	+8.3	+0.02	−1.5	+0.01	+0.2	+0.10	0.0	−0.03	−0.5	0.00
294	+1.2	+0.34	+8.2	−0.08	−1.4	+0.03	+0.8	+0.10	−0.2	−0.04	−0.5	+0.02
300	+3.2	+0.28	+7.4	−0.14	−1.1	+0.08	+1.4	+0.08	−0.5	−0.02	−0.2	+0.02
306	+4.6	+0.24	+6.5	−0.18	−0.5	+0.11	+1.7	+0.05	−0.5	0.00	−0.1	+0.03
312	+6.1	+0.21	+5.2	−0.24	+0.2	+0.12	+2.0	0.00	−0.5	+0.02	+0.2	+0.04
318	+7.1	+0.15	+3.6	−0.26	+0.9	+0.11	+1.7	−0.05	−0.3	+0.03	+0.5	+0.02
324	+7.9	+0.11	+2.1	−0.29	+1.5	+0.09	+1.4	−0.08	−0.1	+0.01	+0.5	+0.02
330	+8.4	+0.05	+0.1	−0.32	+2.0	+0.06	+0.8	−0.10	+0.2	+0.06	+0.6	−0.01
336	+8.5	−0.03	−1.8	−0.35	+2.2	+0.02	+0.2	−0.12	+0.5	+0.03	+0.4	−0.04
342	+8.0	−0.12	−4.1	−0.37	+2.3	−0.04	−0.7	−0.12	+0.6	+0.01	+0.2	−0.04
348	+7.0	−0.23	−6.2	−0.32	+1.8	−0.08	−1.3	−0.11	+0.6	−0.02	−0.2	−0.05
354	+5.2	−0.34	−8.0	−0.28	+1.3	−0.09	−2.0	−0.08	+0.5	−0.03	−0.5	−0.03
360	+2.9	−0.42	−9.5	−0.18	+0.7	−0.12	−2.3	−0.03	+0.2	−0.04	−0.6	−0.02

[$n\delta z$, δ log r, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (128) Nemesis—Continued.

TABLE IV.—u cos i.

PERIODIC TERMS. Unit of *a* and *b*=0″.001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	−1.5	0.00	−0.4	0.00	+0.2	+0.02	+2.3	+0.24	+4.7	−0.09
6	−1.5	+0.02	−0.4	0.00	+0.4	0.00	+3.6	+0.19	+4.0	−0.17
12	−1.3	+0.03	−0.4	0.00	+0.2	−0.02	+4.6	+0.16	+2.7	−0.22
18	−1.1	+0.04	−0.4	+0.02	+0.2	0.00	+5.4	+0.08	+1.3	−0.25
24	−0.8	+0.04	−0.2	+0.02	+0.2	−0.01	+5.6	0.00	−0.3	−0.27
30	−0.6	+0.05	−0.2	0.00	+0.1	−0.02	+5.4	−0.08	−1.9	−0.26
36	−0.2	+0.06	−0.2	+0.01	0.0	−0.02	+4.6	−0.16	−3.4	−0.22
42	+0.2	+0.04	−0.1	+0.01	−0.2	−0.03	+3.5	−0.20	−4.5	−0.16
48	+0.3	+0.03	−0.1	+0.01	−0.4	−0.03	+2.2	−0.24	−5.3	−0.09
54	+0.6	+0.03	0.0	−0.01	−0.6	−0.05	+0.6	−0.26	−5.6	−0.02
60	+0.7	+0.02	−0.2	−0.02	−1.0	−0.05	−0.9	−0.25	−5.6	+0.07
66	+0.8	0.00	−0.3	−0.02	−1.2	−0.04	−2.4	−0.22	−4.8	+0.13
72	+0.7	−0.01	−0.4	−0.02	−1.5	−0.04	−3.6	−0.17	−4.0	+0.17
78	+0.7	−0.02	−0.6	−0.04	−1.7	−0.02	−4.4	−0.10	−2.8	+0.22
84	+0.4	−0.04	−0.9	−0.06	−1.8	−0.02	−4.8	−0.03	−1.4	+0.23
90	+0.2	−0.05	−1.3	−0.07	−1.9	−0.01	−1.8	+0.05	0.0	+0.22
96	−0.2	−0.06	−1.7	−0.06	−1.9	+0.01	−4.2	+0.10	+1.3	+0.20
102	−0.5	−0.06	−2.0	−0.06	−1.8	+0.02	−3.6	+0.15	+2.4	+0.15
108	−0.9	−0.08	−2.4	−0.07	−1.6	+0.05	−2.4	+0.20	+3.1	+0.09
114	−1.1	−0.07	−2.8	−0.05	−1.2	+0.07	−1.2	+0.19	+3.5	+0.02
120	−1.7	−0.07	−3.0	−0.02	−0.8	+0.08	−0.1	+0.18	+3.4	−0.04
126	−2.2	−0.07	−3.1	0.00	−0.2	+0.10	+1.0	+0.17	+3.0	−0.09
132	−2.5	−0.05	−3.0	+0.01	+0.4	+0.10	+1.9	+0.12	+2.3	−0.15
138	−2.8	−0.04	−3.0	+0.03	+1.0	+0.10	+2.5	+0.06	+1.2	−0.18
144	−3.0	−0.03	−2.6	+0.08	+1.6	+0.10	+2.6	−0.01	+0.1	−0.18
150	−3.2	−0.02	−2.0	+0.09	+2.2	+0.09	+2.4	−0.05	−0.9	−0.17
156	−3.2	0.00	−1.5	+0.10	+2.6	+0.06	+2.0	−0.12	−1.9	−0.13
162	−3.2	0.00	−0.8	+0.11	+2.8	+0.03	+1.0	−0.17	−2.5	−0.09
168	−3.2	+0.01	−0.2	+0.13	+3.0	+0.03	0.0	−0.18	−3.0	−0.03
174	−3.1	+0.02	+0.8	+0.13	+3.2	0.00	−1.1	−0.19	−2.9	+0.04
180	−2.9	+0.03	+1.4	+0.10	+3.0	−0.05	−2.3	−0.18	−2.5	+0.09
186	−2.7	+0.03	+2.0	+0.10	+2.6	−0.05	−3.2	−0.12	−1.8	+0.15
192	−2.5	+0.05	+2.6	+0.10	+2.4	−0.07	−3.8	−0.08	−0.7	+0.19
198	−2.1	+0.06	+3.2	+0.07	+1.8	−0.10	−4.2	−0.02	+0.5	+0.20
204	−1.8	+0.06	+3.4	+0.03	+1.2	−0.09	−4.0	+0.07	+1.7	+0.22
210	−1.4	+0.07	+3.6	+0.02	+0.7	−0.10	−3.4	+0.12	+3.1	+0.19
216	−1.0	+0.07	+3.6	−0.01	0.0	−0.11	−2.5	+0.18	+4.0	+0.13
222	−0.6	+0.08	+3.5	−0.02	−0.6	−0.08	−1.3	+0.21	+4.7	+0.09
228	−0.1	+0.07	+3.3	−0.06	−1.0	−0.07	0.0	+0.22	+5.1	+0.02
234	+0.2	+0.06	+2.8	−0.08	−1.4	−0.05	+1.4	+0.24	+5.0	−0.06
240	+0.6	+0.07	+2.4	−0.07	−1.6	−0.03	+2.9	+0.21	+4.4	−0.13
246	+1.0	+0.06	+2.0	−0.08	−1.8	−0.02	+4.0	+0.16	+3.4	−0.18
252	+1.3	+0.04	+1.4	−0.08	−1.7	+0.01	+4.8	+0.10	+2.2	−0.22
258	+1.5	+0.04	+1.0	−0.07	−1.7	+0.01	+5.2	+0.03	+0.8	−0.25
264	+1.8	+0.03	+0.6	−0.05	−1.6	+0.03	+5.2	−0.03	−0.8	−0.25
270	+1.9	+0.02	+0.4	−0.05	−1.3	+0.04	+4.8	−0.12	−2.2	−0.22
276	+2.0	0.00	0.0	−0.05	−1.1	+0.04	+3.8	−0.18	−3.5	−0.18
282	+1.9	−0.02	−0.2	−0.03	−0.8	+0.06	+2.6	−0.22	−4.4	−0.12
288	+1.7	−0.02	−0.4	−0.02	−0.4	+0.06	+1.2	−0.25	−4.9	−0.04
294	+1.6	−0.03	−0.4	0.00	−0.2	+0.03	−0.4	−0.26	−4.9	+0.02
300	+1.3	−0.05	−0.4	+0.01	0.0	+0.04	−1.9	−0.23	−4.6	+0.11
306	+1.0	−0.07	−0.3	+0.01	+0.3	+0.03	−3.2	−0.18	−3.6	+0.18
312	+0.5	−0.07	−0.3	+0.01	+0.4	+0.02	−4.1	−0.12	−2.5	+0.22
318	+0.2	−0.06	−0.2	+0.01	+0.4	0.00	−4.7	−0.06	−1.0	+0.25
324	−0.2	−0.07	−0.2	0.00	+0.4	0.00	−4.8	+0.02	+0.5	+0.26
330	−0.6	−0.07	−0.2	0.00	+0.4	0.00	−4.4	+0.10	+2.1	+0.23
336	−1.0	−0.05	−0.2	0.00	+0.4	0.00	−3.6	+0.17	+3.3	+0.18
342	−1.2	−0.03	−0.2	0.00	+0.4	−0.01	−2.4	+0.23	+4.3	+0.13
348	−1.4	−0.02	−0.2	−0.02	+0.3	−0.02	−0.8	+0.26	+5.0	+0.07
354	−1.5	−0.01	−0.4	−0.02	+0.2	−0.01	+0.7	+0.26	+5.1	−0.02
360	−1.5	0.00	−0.4	0.00	+0.2	+0.02	+2.3	+0.24	+4.7	−0.09

[$n\delta z$, $\partial \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (128) Nemesis—Continued.

TABLE IV.—$u/\cos i$—Continued.

PERIODIC TERMS.

Unit of a and b=0°.001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_3	Diff. for 1°	b_4	Diff. for 1°
°								
0	+0.3	−0.01	−0.5	−0.01	0.0	−0.03	−0.3	0.00
6	+0.2	−0.02	−0.5	−0.01	−0.2	−0.02	−0.3	+0.01
12	+0.1	−0.01	−0.6	−0.01	−0.3	−0.01	−0.2	+0.02
18	+0.1	−0.02	−0.6	+0.01	−0.3	0.00	0.0	+0.03
24	−0.1	−0.03	−0.5	+0.01	−0.3	+0.01	+0.2	+0.02
30	−0.3	−0.03	−0.5	+0.01	−0.2	+0.02	+0.3	+0.01
36	−0.5	−0.02	−0.4	+0.02	0.0	+0.03	+0.3	0.00
42	−0.6	−0.01	−0.2	+0.03	+0.2	+0.02	+0.3	−0.01
48	−0.6	+0.01	0.0	+0.02	+0.3	+0.01	+0.2	−0.02
54	−0.5	+0.02	+0.1	+0.02	+0.3	0.00	0.0	−0.03
60	−0.3	+0.03	+0.3	+0.02	+0.3	−0.01	−0.2	−0.02
66	−0.1	+0.02	+0.3	0.00	+0.2	−0.02	−0.3	−0.01
72	0.0	+0.01	+0.3	−0.02	0.0	−0.03	−0.3	0.00
78	0.0	+0.01	0.0	−0.04	−0.2	−0.02	−0.3	+0.01
84	+0.1	−0.01	−0.2	−0.02	−0.3	−0.01	−0.2	+0.02
90	−0.1	−0.03	−0.3	−0.02	−0.3	0.00	0.0	+0.03
96	−0.3	−0.03	−0.4	+0.02	−0.3	+0.01	+0.2	+0.02
102	−0.5	−0.04	−0.2	+0.04	−0.2	+0.02	+0.3	+0.01
108	−0.8	−0.03	+0.1	+0.06	0.0	+0.03	+0.3	0.00
114	−0.9	+0.02	+0.5	+0.07	+0.2	+0.02	+0.3	−0.01
120	−0.7	+0.04	+0.9	+0.07	+0.3	+0.01	+0.2	−0.02
126	−0.4	+0.08	+1.3	+0.04	+0.3	0.00	0.0	−0.03
132	+0.2	+0.10	+1.4	+0.01	+0.3	−0.01	−0.2	−0.02
138	+0.8	+0.09	+1.4	−0.02	+0.2	−0.02	−0.3	−0.01
144	+1.3	+0.08	+1.1	−0.08	0.0	−0.03	−0.3	0.00
150	+1.7	+0.04	+0.5	−0.11	−0.2	−0.02	−0.3	+0.01
156	+1.8	−0.01	−0.2	−0.12	−0.3	−0.01	−0.2	+0.02
162	+1.6	−0.05	−0.9	−0.11	−0.3	0.00	0.0	+0.03
168	+1.2	−0.09	−1.5	−0.08	−0.3	+0.01	+0.2	+0.02
174	+0.5	−0.12	−1.8	−0.03	−0.2	+0.02	+0.3	+0.01
180	−0.3	−0.12	−1.9	+0.02	0.0	+0.03	+0.3	0.00
186	−1.0	−0.10	−1.5	+0.08	+0.2	+0.02	+0.3	−0.01
192	−1.5	−0.06	−1.0	+0.11	+0.3	+0.01	+0.2	−0.02
198	−1.7	0.00	−0.2	+0.12	+0.3	0.00	0.0	−0.03
204	−1.5	+0.05	+0.5	+0.11	+0.3	−0.01	−0.2	−0.02
210	−1.1	+0.08	+1.1	+0.08	+0.2	−0.02	−0.3	−0.01
216	−0.5	+0.11	+1.4	+0.02	0.0	−0.03	−0.3	0.00
222	+0.2	+0.11	+1.4	−0.02	−0.2	−0.02	−0.3	+0.01
228	+0.8	+0.08	+1.2	−0.08	−0.3	−0.01	−0.2	+0.02
234	+1.1	+0.04	+0.5	−0.11	−0.3	0.00	0.0	+0.03
240	+1.3	0.00	−0.1	−0.10	−0.3	+0.01	+0.2	+0.02
246	+1.1	−0.06	−0.7	−0.08	−0.2	+0.02	+0.3	+0.01
252	+0.6	−0.09	−1.1	−0.06	0.0	+0.03	+0.3	0.00
258	0.0	−0.09	−1.4	−0.01	+0.2	+0.02	+0.3	−0.01
264	−0.5	−0.09	−1.2	+0.04	+0.3	+0.01	+0.2	−0.02
270	−1.1	−0.07	−0.9	+0.07	+0.3	0.00	0.0	−0.03
276	−1.3	−0.02	−0.4	+0.09	+0.3	0.00	−0.2	−0.02
282	−1.3	+0.01	+0.2	+0.09	+0.2	−0.02	−0.3	−0.01
288	−1.2	+0.05	+0.7	+0.08	0.0	−0.04	−0.3	0.00
294	−0.7	+0.08	+1.1	+0.05	−0.2	−0.02	−0.3	+0.01
300	−0.3	+0.08	+1.3	+0.02	−0.3	−0.01	−0.2	+0.02
306	+0.2	+0.07	+1.3	−0.02	−0.3	0.00	0.0	+0.03
312	+0.5	+0.04	+1.0	−0.04	−0.3	+0.01	+0.2	+0.02
318	+0.6	+0.02	+0.8	−0.06	−0.2	+0.02	+0.3	+0.01
324	+0.8	+0.02	+0.3	−0.06	0.0	+0.03	+0.3	0.00
330	+0.9	0.00	+0.1	−0.04	+0.2	+0.02	+0.3	−0.01
336	+0.8	−0.02	−0.2	−0.03	+0.3	+0.01	+0.2	−0.02
342	+0.6	−0.02	−0.3	−0.01	+0.3	0.00	0.0	−0.03
348	+0.5	−0.02	−0.3	−0.01	+0.3	−0.01	−0.2	−0.02
354	+0.3	−0.02	−0.4	−0.02	+0.2	−0.02	−0.3	−0.01
360	+0.3	−0.01	−0.5	−0.01	0.0	−0.03	−0.3	0.00

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (128) Nemesis—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY T=(t—t$_0$) IN JULIAN YEARS.

g	$n\delta z$ Unit of c=0°.001		δ log r Unit of c=0.00001		u/cos i Unit of c=0°.001	
	c	Diff. for 1°	c	Diff. for 1°	c	Diff. for 1°
°						
0	−2.85	0.00	+0.06	−0.02	+0.68	+0.02
6	−2.85	0.00	−0.05	−0.02	+0.81	+0.02
12	−2.81	0.00	−0.18	−0.02	+0.93	+0.02
18	−2.75	+0.01	−0.30	−0.02	+1.04	+0.02
24	−2.65	+0.02	−0.42	−0.02	+1.12	+0.01
30	−2.52	+0.02	−0.54	−0.02	+1.20	+0.01
36	−2.36	+0.02	−0.63	−0.02	+1.26	+0.01
42	−2.18	+0.03	−0.73	−0.02	+1.28	0.00
48	−1.97	+0.04	−0.81	−0.01	+1.30	0.00
54	−1.74	+0.04	−0.88	−0.01	+1.31	0.00
60	−1.49	+0.04	−0.93	−0.01	+1.28	0.00
66	−1.22	+0.04	−0.99	−0.01	+1.25	−0.01
72	−0.95	+0.05	−1.02	−0.00	+1.20	−0.01
78	−0.66	+0.05	−1.04	−0.00	+1.15	−0.01
84	−0.37	+0.05	−1.05	−0.00	+1.06	−0.02
90	−0.09	+0.05	−1.05	−0.00	+0.96	−0.02
96	+0.20	+0.05	−1.04	−0.00	+0.87	−0.02
102	+0.50	+0.05	−1.01	−0.00	+0.78	−0.02
108	+0.76	+0.04	−0.98	+0.01	+0.64	−0.02
114	+1.03	+0.04	−0.94	+0.01	+0.52	−0.02
120	+1.28	+0.04	−0.89	+0.01	+0.41	−0.02
126	+1.52	+0.04	−0.83	+0.01	+0.28	−0.02
132	+1.74	+0.04	−0.77	+0.01	+0.15	−0.02
138	+1.95	+0.03	−0.70	+0.01	+0.01	−0.02
144	+2.12	+0.03	−0.61	+0.01	−0.13	−0.02
150	+2.28	+0.02	−0.53	+0.01	−0.26	−0.02
156	+2.40	+0.02	−0.45	+0.02	−0.39	−0.02
162	+2.52	+0.02	−0.35	+0.02	−0.52	−0.02
168	+2.60	+0.01	−0.26	+0.02	−0.65	−0.02
174	+2.66	+0.01	−0.15	+0.02	−0.77	−0.02
180	+2.69	+0.01	−0.06	+0.02	−0.88	−0.02
186	+2.69	0.00	+0.04	+0.02	−0.99	−0.02
192	+2.67	0.00	+0.14	+0.02	−1.09	−0.02
198	+2.61	−0.01	+0.24	+0.02	−1.18	−0.01
204	+2.53	−0.01	+0.33	+0.02	−1.26	−0.01
210	+2.44	−0.02	+0.43	+0.02	−1.34	−0.01
216	+2.30	−0.02	+0.52	+0.02	−1.40	−0.01
222	+2.16	−0.03	+0.61	+0.01	−1.44	−0.01
228	+1.97	−0.03	+0.69	+0.01	−1.48	−0.01
234	+1.78	−0.03	+0.76	+0.01	−1.51	0.00
240	+1.56	−0.04	+0.83	+0.01	−1.52	0.00
246	+1.32	−0.04	+0.89	+0.01	−1.51	0.00
252	+1.07	−0.04	+0.94	+0.01	−1.50	0.00
258	+0.80	−0.04	+0.98	+0.01	−1.47	+0.01
264	+0.53	−0.05	+1.02	+0.01	−1.42	+0.01
270	+0.25	−0.05	+1.05	0.00	−1.36	+0.01
276	−0.04	−0.05	+1.05	0.00	−1.29	+0.01
282	−0.36	−0.05	+1.05	0.00	−1.22	+0.02
288	−0.62	−0.05	+1.04	0.00	−1.10	+0.02
294	−0.91	−0.05	+1.03	0.00	−0.98	+0.02
300	−1.20	−0.05	+1.00	−0.01	−0.87	+0.02
306	−1.46	−0.04	+0.94	−0.01	−0.74	+0.02
312	−1.72	−0.04	+0.89	−0.01	−0.59	+0.03
318	−1.95	−0.04	+0.82	−0.01	−0.43	+0.03
324	−2.16	−0.03	+0.74	−0.02	−0.27	+0.03
330	−2.35	−0.03	+0.64	−0.02	−0.12	+0.03
336	−2.50	−0.02	+0.54	−0.02	+0.05	+0.03
342	−2.64	−0.02	+0.42	−0.02	+0.22	+0.03
348	−2.74	−0.02	+0.32	−0.02	+0.37	+0.02
354	−2.82	−0.01	+0.18	−0.02	+0.52	+0.03
360	−2.85	0.00	+0.06	−0.02	+0.68	+0.02

[$n\delta z$, δ log r, and u/cos i are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (128) Nemesis—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	A'	B'	C'	log sin a	log sin b	log sin c
	°	°	°			
1872.0	106.1307	18.9491	3.3092	9.99755	9.95800	9.63598
3	.1447	.9631	.3217	55	01	596
4	.1587	.9771	.3342	55	01	594
1875	106.1728	18.9910	3.3467	9.99755	9.95802	9.63592
6	.1868	19.0050	.3592	55	02	589
7	.2008	.0190	.3717	55	03	587
8	.2149	.0330	.3842	55	03	585
9	.2289	.0470	.3967	55	04	583
1880	106.2429	19.0610	3.4092	9.99755	9.95804	9.63581
1	.2570	.0750	.4217	55	05	579
2	.2710	.0890	.4342	55	05	577
3	.2850	.1030	.4467	55	06	574
4	.2990	.1170	.4592	55	06	572
1885	106.3131	19.1310	3.4717	9.99755	9.95807	9.63570
6	.3271	.1450	.4842	55	07	568
7	.3411	.1590	.4967	55	08	565
8	.3552	.1730	.5092	55	09	563
9	.3692	.1870	.5217	55	09	561
1890	106.3832	19.2010	3.5342	9.99755	9.95810	9.63559
1	.3973	.2150	.5467	55	10	557
2	.4113	.2290	.5592	55	11	555
3	.4253	.2429	.5717	55	11	553
4	.4393	.2569	.5842	55	12	550
1895	106.4534	19.2709	3.5967	9.99755	9.95812	9.63548
6	.4674	.2849	.6092	55	13	546
7	.4814	.2989	.6217	55	13	544
8	.4955	.3129	.6342	55	14	542
9	.5095	.3269	.6468	55	14	540
1900	106.5235	19.3409	3.6593	9.99755	9.95815	9.63538
1	.5376	.3549	.6718	54	16	535
2	.5516	.3689	.6843	54	16	533
3	.5656	.3829	.6968	54	17	531
4	.5797	.3969	.7093	54	17	529
1905	106.5937	19.4109	3.7218	9.99754	9.95818	9.63527
6	.6078	.4249	.7343	54	18	525
7	.6218	.4389	.7468	54	19	522
8	.6358	.4529	.7594	54	19	520
9	.6499	.4669	.7719	54	20	518
1910	106.6639	19.4810	3.7844	9.99754	9.95820	9.63516
1	.6780	.4950	.7969	54	21	514
2	.6920	.5090	.8094	54	21	512
3	.7060	.5230	.8219	54	22	510
4	.7201	.5370	.8344	54	22	508
1915	106.7341	19.5510	3.8470	9.99754	9.95823	9.63505
6	.7482	.5650	.8595	54	23	503
7	.7622	.5790	.8720	54	24	501
8	.7762	.5930	.8845	54	24	499
9	.7903	.6070	.8970	54	25	497
1920	106.8043	19.6210	3.9096	9.99754	9.95825	9.63495
1	.8184	.6350	.9221	54	26	492
2	.8324	.6490	.9346	54	26	490
3	.8464	.6631	.9471	54	27	488
4	.8605	.6771	.9596	54	27	486
1925	106.8745	19.6911	3.9721	9.99754	9.95828	9.63484
6	.8886	.7051	.9847	54	29	482
7	.9026	.7191	3.9972	54	29	480
8	.9166	.7331	4.0097	54	30	477
9	.9307	.7471	.0222	54	30	475
1930	106.9447	19.7611	4.0347	9.99754	9.95831	9.63473

Year	log cos a	log cos b	log cos c
1872.0	9.025 n	9.623 n	9.955
1930.0	9.026 n	9.621 n	9.955

TABLES OF (133) CYRENE.

MEAN ELEMENTS.

Epoch, 1896, Dec. 10.0, M. T. Berlin=1896.942. M. T. Berlin.

$g_0=204^\circ\ 8'\ 9''=204^\circ.1357$
$\omega=285^\circ\ 19'\ 53''=285.3314$
$\Omega=321^\circ\ 10'\ 39''=321.1776$
$i=7^\circ\ 13'\ 53''=7.2315$
$\varphi=7^\circ\ 49'\ 26''=7.8239$
$n=661''.6605=0.18379457$

ω, Ω, i: Mean equinox and ecliptic 1900.0.

The elements are based on oppositions extending from 1873 to 1894 and on the perturbations of the first order by *Jupiter*, as given on page 266.

AUXILIARY QUANTITIES.

$\log a=0.48625$
$\log e=9.13395$
$\log 57.2957\ e=0.89207$
$\log p=0.47812$
$\log\sqrt{\frac{1-e}{1+e}}=9.94051$

TABLE I.—MEAN ANOMALY (g).

Jan. 0.0 of common years; Jan. 1.0 of leap years

Year	g	Year	g
	°		°
1873	36.85220	1902	183.42049
4	103.93722	3	250.50551
5	171.02224	B 4	317.77432
B 6	238.29105	5	24.85934
7	305.37607	6	91.94436
8	12.46108	7	159.02938
9	79.54610	B 8	226.29819
B 1880	146.81492	9	293.38321
1	213.89993	1910	0.46823
2	280.98495	1	67.55324
3	348.06997	B 2	134.82206
B 4	55.33878	3	201.90708
5	122.42380	4	268.99209
6	189.50882	5	336.07711
7	256.59384	B 6	43.34592
B 8	323.86265	7	110.43094
9	30.94767	8	177.51596
1890	98.03269	9	244.60098
1	165.11770	B 1920	311.86979
B 2	232.38652	1	18.95481
3	299.47154	2	86.03983
4	6.55655	3	153.12484
5	73.64157	B 4	220.39366
B 6	140.91038	5	287.47868
7	207.99540	6	354.56369
8	275.08042	7	61.64871
9	342.16544	B 8	128.91752
1900	49.25046	9	196.00254
1	116.33547	1930	263.08756

NOTE.—When g is used as an argument of the perturbations add to the g of this table $\Delta\pi=\pi-\pi_0=1^\circ.0139$. For explanation see page 203.

Table for beginning of month

Month	g
	°
Jan. 0.0 Jan. 1.0	0.00000
Feb. 0.0 Feb. 1.0	5.69763
Mar. 0.0	10.84388
Apr. 0.0	16.54151
May 0.0	22.05535
June 0.0	27.75298
July 0.0	33.26682
Aug. 0.0	38.96445
Sept. 0.0	44.66208
Oct. 0.0	50.17592
Nov. 0.0	55.87355
Dec. 0.0	61.38739

Change for n days[a]

n	g	n	g
	°		°
1	0.18379	16	2.94064
2	0.36758	17	3.12443
3	0.55137	18	3.30822
4	0.73516	19	3.49201
5	0.91895	20	3.67580
6	1.10274	21	3.85959
7	1.28653	22	4.04338
8	1.47032	23	4.22717
9	1.65411	24	4.41096
10	1.83790	25	4.59475
11	2.02169	26	4.77854
12	2.20548	27	4.96233
13	2.38927	28	5.14612
14	2.57306	29	5.32991
15	2.75685	30	5.51370

[a] For days during January and February of leap year subtract one day before entering this table.

Tables of (133) Cyrene—Continued.

PERTURBATIONS.

Arg. *ig*−*i′g′*		*nδz*		*ν*		*u*/cos *i*	
		sin	cos	sin	cos	sin	cos
i	*i′*	″	″	″	″		″
0	0				−10		−8
0	0				−0.06nt		−0.74nt
+1	0				+8		
+1		+1.80nt	−17.25nt	−8.62nt	−0.90nt	+11.34nt	+3.49nt
+2		−1			+1	−1	+2
+2		+0.06nt	−0.60nt	−0.60nt	−0.06nt	+0.79nt	+0.24nt
+3			−0.04nt	−0.06nt		+0.08nt	+0.03nt
+4	0			−0.01nt		+0.01nt	
−1	+1	−2	+1	−1	−1	+3	−6
0		+68	+54	−9	+13	+16	−20
+1		+240	+287	+86	−71	−17	+13
+2		+10	+7	−6	−7	−11	+5
+3	+1	+1	+1	+1	−1		
−1	+2	+1	−2	+2	+1	+5	−1
0		+18	−43	+22	+8	+65	−11
+1		−1110	+5920	+436	+87	−24	+8
+2		−484	+1900	+978	+250	−59	−20
+3		−21	+75	+75	+21	−1	
+4		−1	+5	+8	+2		
+5	+2			+1			
0	+3	−3	+3	−1	−1	−5	−3
+1		−78	+74	−23	−23	−13	−11
+2		+486	−405	−150	−182	−21	−24
+3		+97	−46	−32	−68	+3	+6
+4		+8	−3	−3	−9		−2
+5	+3	+1			−1		
+1	+4	−19	+5	−1	−9		−11
+2		+875	−68		−118	+1	+7
+3		+370	+84	+44	−198	−5	+29
+4		−1	−5	−3	−3	+1	
+5	+4	−1	−1	−1			
+1	+5	+3			+2		
+2		+72	+53	−12	+20	−6	+6
+3		−163	−193	−82	+68	+14	−14
+4		−22	−42	−29	+15	+5	−4
+5		−1	+2	+1	+1		
+6	+5		+1	+1			
+2	+6	+1	+10	−3			
+3		−14	−169	−34			
+4		+15	−85	−46	−8	+9	+2
+5		−4	+7	+4	+3		−1
+6	+6	+1			−1		
+3	+7	+36	−71	+6	+6	+1	+1
+4		−93	+81	+38	+44	−6	−6
+5		−17	+8	+6	+11		−1
+6	+7	+3			−2		

Tables of (133) Cyrene—Continued.

TABLE II.—$n\delta z$.

PERIODIC TERMS.

Unit of a and b=0?001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	+3.5	−0.45	−262.0	+58.78	+1715.0	+10.82	+264.8	+12.68	+411.1	−20.85
3			−83.7	+59.74	+1738.2	+4.58	+295.7	+8.07	+346.8	−21.53
6	+1.0	−0.40	+96.4	+60.04	+1742.5	−1.72	+313.2	+3.55	+281.9	−21.20
9			+276.5	+59.66	+1727.9	−7.98	+317.0	−0.65	+219.6	−19.98
12	−1.3	−0.35	+454.4	+58.59	+1694.6	−14.23	+309.3	−4.38	+162.0	−17.90
15			+628.0	+56.86	+1642.5	−20.35	+290.7	−7.48	+112.2	−15.15
18	−3.2	−0.28	+795.5	+54.52	+1572.5	−26.23	+264.4	−9.72	+71.1	−11.85
21			+955.1	+51.56	+1185.1	−31.82	+232.4	−11.15	+41.1	−8.20
24	−4.7	−0.23	+1104.8	+47.94	+1381.6	−37.08	+197.5	−11.63	+21.9	−4.42
27			+1242.7	+43.80	+1262.6	−41.97	+162.6	−11.25	+14.6	−0.72
30	−6.0	−0.19	+1367.6	+39.22	+1129.8	−46.37	+130.0	−9.95	+17.6	+2.67
33			+1478.0	+34.20	+984.4	−50.26	+102.9	−7.83	+30.6	+5.60
36	−7.0	−0.12	+1572.8	+28.74	+828.2	−53.60	+83.0	−5.03	+51.2	+7.93
39			+1650.4	+22.92	+662.8	−56.34	+72.7	−1.76	+78.2	+9.53
42	−7.4	−0.07	+1710.4	+16.92	+490.2	−58.42	+72.4	+1.80	+108.4	+10.18
45			+1752.0	+10.72	+312.3	−59.85	+83.5	+5.48	+139.3	+9.93
48	−7.8	−0.04	+1774.7	+4.33	+131.1	−60.66	+105.3	+9.07	+168.0	+8.73
51			+1778.0	−2.02	−51.6	−60.75	+137.9	+12.32	+191.7	+6.70
54	−7.9	0.00	+1762.6	−8.33	−233.4	−60.14	+179.2	+15.00	+208.2	+3.78
57			+1728.0	−14.60	−412.4	−58.88	+227.9	+17.00	+214.4	+0.20
60	−7.8	+0.02	+1675.0	−20.65	−586.7	−56.97	+281.2	+18.18	+209.4	−3.82
63			+1604.1	−26.45	−754.2	−54.42	+337.0	+18.50	+191.5	−8.10
66	−7.7	+0.02	+1516.3	−32.00	−913.2	−51.28	+392.2	+17.80	+160.8	−12.48
69			+1412.1	−37.15	−1061.9	−47.62	+443.8	+16.13	+116.6	−16.73
72	−7.4	+0.03	+1293.4	−41.80	−1198.9	−43.40	+489.0	+13.50	+60.4	−20.68
75			+1161.3	−46.00	−1322.3	−38.68	+524.8	+10.08	−7.5	−24.12
78	−7.3	+0.01	+1017.4	−49.70	−1431.0	−33.62	+549.5	+5.87	−84.4	−26.82
81			+863.1	−52.84	−1524.0	−28.23	+560.0	+1.08	−168.4	−28.67
84	−7.3	−0.01	+700.4	−55.36	−1600.4	−22.53	+556.0	−4.03	−256.4	−29.55
87			+531.0	−57.24	−1659.2	−16.60	+535.8	−9.33	−345.7	−29.47
90	−7.4	−0.05	+357.0	−58.46	−1700.0	−10.52	+500.0	−14.63	−433.2	−28.30
93			+180.3	−59.06	−1722.3	−4.37	+448.0	−19.70	−515.5	−26.17
96	−7.9	−0.10	+2.6	−59.10	−1726.2	+1.80	+381.8	−24.28	−590.2	−23.10
99			−174.3	−58.46	−1711.5	+7.90	+302.3	−28.30	−654.1	−19.20
102	−8.6	−0.14	−348.1	−57.10	−1678.8	+13.82	+212.0	−31.58	−705.4	−14.58
105			−516.9	−55.16	−1628.4	+19.60	+112.8	−34.00	−741.6	−9.48
108	−9.6	−0.21	−679.0	−52.64	−1561.2	+25.14	+8.0	−35.43	−762.3	−3.98
111			−832.8	−49.63	−1477.6	+30.37	−99.8	−35.90	−765.5	+1.70
114	−11.1	−0.27	−976.8	−46.07	−1379.0	+35.22	−207.4	−35.32	−752.1	+7.32
117			−1109.2	−42.03	−1266.3	+39.67	−311.7	−33.84	−721.6	+12.76
120	−12.8	−0.28	−1229.0	−37.58	−1141.0	+43.67	−410.4	−31.46	−675.5	+17.83
123			−1334.7	−32.77	−1004.3	+47.17	−500.5	−28.30	−614.6	+22.37
126	−14.5	−0.32	−1425.6	−27.65	−858.0	+50.12	−580.2	−24.45	−541.3	+26.25
129			−1500.6	−22.26	−703.6	+52.56	−647.2	−20.06	−457.1	+29.42
132	−16.7	−0.37	−1559.2	−16.63	−542.7	+54.40	−700.6	−15.28	−364.7	+31.78
135			−1600.4	−10.86	−377.2	+55.66	−738.9	−10.30	−266.4	+33.28
138	−18.9	−0.38	−1624.4	−5.05	−208.8	+56.32	−762.4	−5.25	−165.0	+33.87
141			−1630.7	+0.78	−39.3	+56.40	−770.4	−0.25	−63.2	+33.67
144	−21.2	−0.38	−1619.7	+6.62	+129.6	+55.87	−763.9	+4.53	+37.0	+32.78
147			−1591.0	+12.35	+295.9	+54.74	−743.2	+8.95	+133.5	+31.24
150	−23.5	−0.36	−1545.6	+17.86	+458.0	+53.02	−710.2	+12.90	+224.4	+28.95
153			−1483.8	+23.22	+614.0	+50.77	−665.8	+16.36	+307.2	+26.12
156	−25.5	−0.29	−1406.3	+28.38	+762.6	+48.00	−612.0	+19.26	+381.1	+22.97
159			−1313.5	+33.15	+902.0	+44.70	−550.2	+21.57	+445.0	+19.55
162	−27.0	−0.21	−1207.4	+37.50	+1030.8	+40.92	−482.6	+23.18	+498.4	+15.95
165			−1088.5	+41.47	+1147.5	+36.74	−411.1	+24.20	+540.7	+12.33
168	−28.0	−0.12	−958.6	+44.98	+1251.2	+32.18	−337.4	+24.62	+572.4	+8.78
171			−818.6	+48.08	+1340.6	+27.27	−263.4	+24.53	+593.4	+5.40
174	−28.4	−0.01	−670.1	+50.62	+1414.8	+22.03	−190.2	+23.97	+604.8	+2.27
177			−514.9	+52.56	+1472.8	+16.60	−119.6	+23.00	+607.0	−0.57
180	−28.1	+0.12	−354.8	+53.90	+1514.4	+11.03	−52.2	+21.70	+601.4	−3.05

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in tbe form $\Sigma_i a_i \sin ig+\Sigma_i b_i \cos ig+cT$.]

Tables of (133) Cyrene—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit of a and b=0°001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
180	−28.1	+0.12	−354.8	+53.90	+1514.4	+11.03	−52.2	+21.70	+601.4	−3.05
183			−191.5	+54.66	+1539.0	+5.32	+10.5	+20.17	+588.7	−5.18
186	−27.0	+0.25	−26.8	+54.88	+1546.3	−0.48	+68.8	+18.53	+570.3	−6.88
189			+137.8	+54.50	+1536.1	−6.22	+121.8	+16.86	+547.4	−8.25
192	−25.1	+0.38	+300.2	+53.46	+1509.0	−11.87	+170.0	+15.20	+520.8	−9.28
195			+458.6	+51.86	+1464.9	−17.42	+213.0	+13.57	+491.7	−9.98
198	−22.4	+0.52	+611.4	+49.67	+1404.5	−22.76	+251.4	+12.10	+460.9	−10.36
201			+756.6	+46.93	+1328.3	−27.87	+285.6	+10.80	+429.5	−10.55
204	−18.9	+0.65	+893.0	+43.72	+1237.3	−32.65	+316.2	+9.72	+397.6	−10.66
207			+1018.9	+40.00	+1132.4	−37.02	+343.9	+8.83	+365.5	−10.72
210	−14.6	+0.74	+1133.0	+35.82	+1015.2	−40.96	+369.2	+8.15	+333.2	−10.76
213			+1233.8	+31.28	+886.6	−44.50	+392.8	+7.63	+300.9	−10.83
216	−10.0	+0.82	+1320.7	+26.42	+748.2	−47.53	+415.0	+7.28	+268.2	−11.02
219			+1392.3	+21.25	+601.4	−50.04	+436.5	+7.00	+234.8	−11.36
222	−4.8	+0.88	+1448.2	+15.82	+448.0	−51.94	+457.0	+6.72	+200.0	−11.90
225			+1487.2	+10.20	+289.8	−53.23	+476.8	+6.38	+163.4	−12.60
228	+0.6	+0.91	+1509.4	+4.52	+128.3	−54.04	+495.3	+5.97	+124.4	−13.45
231			+1514.3	−1.20	−34.4	−54.18	+512.6	+5.40	+82.7	−14.43
234	+6.1	+0.92	+1502.2	−6.92	−196.8	−53.76	+527.7	+4.58	+37.8	−15.65
237			+1472.8	−12.57	−357.0	−52.73	+540.1	+3.52	−11.2	−16.95
240	+11.6	+0.90	+1426.8	−18.03	−513.2	−51.09	+548.8	+2.12	−63.9	−18.15
243			+1364.6	−23.30	−663.5	−48.90	+552.8	+0.40	−179.2	−19.22
246	+16.9	+0.83	+1287.0	−28.33	−806.6	−46.22	+551.2	−1.63	−157.2	−20.22
249			+1194.6	−33.06	−940.8	−43.03	+543.0	−4.02	−241.4	−21.00
252	+21.6	+0.73	+1088.6	−37.42	−1064.8	−39.36	+527.1	−6.73	−305.2	−21.43
255			+970.1	−41.36	−1177.0	−35.20	+502.6	−9.63	−370.0	−21.48
258	+25.7	+0.64	+840.4	−44.88	−1276.0	−30.68	+469.3	−12.68	−434.0	−21.00
261			+700.8	−47.90	−1361.1	−25.90	+426.5	−15.82	−496.0	−20.07
264	+29.3	+0.52	+553.0	−50.40	−1431.4	−20.75	+374.4	−19.03	−554.4	−18.63
267			+398.4	−52.36	−1485.6	−15.36	+312.3	−22.12	−607.8	−16.63
270	+32.0	+0.38	+238.8	−53.76	−1523.6	−9.83	+241.7	−24.90	−654.2	−13.98
273			+75.8	−54.60	−1544.6	−4.17	+162.9	−27.38	−691.7	−10.80
276	+33.9	+0.25	−88.8	−54.85	−1548.6	+1.55	+77.4	−29.43	−719.0	−7.17
279			−253.3	−54.55	−1535.3	+7.27	−13.7	−30.96	−734.7	−3.15
282	+35.0	+0.11	−416.1	−53.65	−1505.0	+12.95	−108.4	−31.88	−737.9	+1.27
285			−575.2	−52.08	−1457.6	+18.53	−205.0	−32.10	−727.1	+5.90
288	+35.2	−0.02	−728.6	−49.95	−1393.8	+23.90	−301.0	−31.50	−702.5	+10.62
291			−874.9	−47.35	−1314.2	+29.03	−394.0	−30.15	−663.4	+15.32
294	+34.7	−0.15	−1012.7	−44.22	−1219.6	+33.92	−481.9	−28.03	−610.6	+19.85
297			−1140.2	−40.55	−1110.7	+38.46	−562.2	−25.15	−544.3	+24.07
300	+33.4	−0.27	−1256.0	−36.42	−988.8	+42.62	−632.8	−21.53	−466.2	+27.80
303			−1358.7	−31.87	−855.0	+46.35	−691.4	−17.30	−377.5	+30.95
306	+31.5	−0.38	−1447.2	−26.93	−710.7	+49.56	−736.6	−12.52	−280.5	+33.42
309			−1520.3	−21.70	−557.6	+52.25	−766.5	−7.37	−177.0	+35.06
312	+28.9	−0.45	−1577.4	−16.18	−397.2	+54.44	−780.8	−1.93	−70.1	+35.80
315			−1617.4	−10.43	−231.0	+56.04	−778.1	+3.60	+37.8	+35.65
318	+26.1	−0.49	−1640.0	−4.55	−61.0	+57.02	−759.2	+9.03	+143.8	+34.50
321			−1644.7	+1.42	+111.1	+57.38	−723.9	+14.20	+244.8	+32.47
324	+23.0	−0.53	−1631.5	+7.43	+283.3	+57.12	−674.0	+18.95	+338.6	+29.64
327			−1600.1	+13.42	+453.8	+56.22	−610.2	+23.16	+422.6	+26.04
330	+19.7	−0.56	−1551.0	+19.28	+620.6	+54.66	−535.0	+26.65	+494.8	+21.65
333			−1484.4	+25.02	+781.8	+52.50	−450.3	+29.30	+552.5	+16.75
336	+16.3	−0.58	−1400.9	+30.52	+935.6	+49.75	−359.2	+30.98	+595.3	+11.52
339			−1301.3	+35.66	+1080.3	+46.46	−264.4	+31.70	+621.6	+6.13
342	+12.8	−0.56	−1186.9	+40.45	+1214.4	+42.64	−169.0	+31.38	+632.1	+0.78
345			−1058.6	+44.82	+1336.1	+38.30	−76.1	+30.13	+626.3	−4.38
348	+9.6	−0.53	−918.0	+48.73	+1444.2	+33.48	+11.8	+27.96	+605.8	−9.10
351			−766.2	+52.15	+1537.0	+28.26	+91.7	+24.83	+571.7	−13.23
354	+6.4	−0.51	−605.1	+54.96	+1613.8	+22.72	+161.8	+21.15	+526.4	−16.63
357			−436.4	+57.18	+1673.3	+16.86	+219.6	+17.16	+471.9	−19.22
360	+3.5	−0.45	−262.0	+58.78	+1715.0	+10.82	+264.8	+12.68	+411.1	−20.85

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (133) Cyrene—Continued.

TABLE II. *nδz*—Continued.

PERIODIC TERMS.

Unit of *a* and *b*=0°0001.

i	3				i	3			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	g'	a_3	Diff. for 1°	b_3	Diff. for 1°
°					°				
0	+82.6	−10.17	−89.2	−5.02	180	+100.6	+5.35	+85.0	−7.82
3	+50.7	−10.60	−98.8	−1.66	183	+114.0	+3.53	+59.7	−8.82
6	+19.0	−9.93	−99.2	+1.47	186	+121.8	+1.50	+32.1	−9.33
9	−8.9	−8.40	−90.0	+4.20	189	+123.0	−0.67	+3.7	−9.37
12	−31.4	−6.13	−74.0	+6.18	192	+117.8	−2.82	−24.1	−8.97
15	−45.7	−3.47	−52.9	+7.33	195	+106.1	−4.83	−50.1	−8.08
18	−52.2	−0.65	−30.0	+7.40	198	+88.8	−6.62	−72.6	−6.62
21	−49.6	+1.93	−8.5	+6.63	201	+66.4	−8.00	−89.8	−4.77
24	−40.6	+3.87	+9.8	+5.05	204	+40.8	−8.85	−101.2	−2.65
27	−26.4	+5.17	+21.8	+2.93	207	+13.3	−9.17	−105.7	−0.40
30	−9.6	+5.63	+27.4	+0.52	210	−14.2	−8.90	−103.6	+1.87
33	+7.4	+5.28	+24.9	−1.85	213	−40.1	−8.10	−94.5	+4.02
36	+22.1	+3.97	+16.3	−3.85	216	−62.8	−6.75	−79.5	+5.88
39	+31.2	+2.02	+1.8	−5.28	219	−80.6	−5.03	−59.2	+7.38
42	+34.2	−0.35	−15.4	−5.83	222	−93.0	−3.03	−35.2	+8.33
45	+29.1	−2.78	−33.2	−5.58	225	−98.8	−0.87	−9.2	+8.75
48	+17.5	−4.98	−48.9	−4.38	228	−98.2	+1.33	+17.3	+8.60
51	−0.8	−6.68	−59.5	−2.52	231	−90.8	+3.40	+42.4	+7.95
54	−22.6	−7.65	−64.0	−0.03	234	−77.8	+5.17	+65.0	+6.83
57	−46.7	−7.83	−59.7	+2.75	237	−59.8	+6.60	+83.4	+5.42
60	−69.6	−6.88	−47.5	+5.47	240	−38.2	+7.62	+97.5	+3.68
63	−88.0	−5.15	−26.9	+7.85	243	−14.1	+8.23	+105.5	+1.78
66	−100.5	−2.63	−0.4	+9.60	246	+11.2	+8.42	+108.2	−0.07
69	−103.8	+0.40	+30.7	+10.53	249	+36.4	+8.18	+105.1	−1.90
72	−98.1	+3.63	+62.8	+10.38	252	+60.3	+7.58	+96.8	−3.63
75	−82.0	+6.78	+93.0	+9.30	255	+81.9	+6.72	+83.3	−5.20
78	−57.4	+9.58	+118.6	+7.23	258	+100.6	+5.55	+65.6	−6.48
81	−24.6	+11.70	+136.4	+4.47	261	+115.2	+4.17	+44.4	−7.53
84	+12.8	+12.82	+145.4	+1.05	264	+125.6	+2.63	+20.4	−8.33
87	+52.3	+12.97	+142.7	−2.58	267	+131.0	+0.95	−5.6	−8.88
90	+90.6	+12.03	+129.9	−6.07	270	+131.3	−0.83	−32.9	−9.17
93	+124.5	+10.22	+106.3	−9.25	273	+126.0	−2.68	−60.6	−9.08
96	+151.9	+7.52	+74.4	−11.80	276	+115.2	−4.60	−87.1	−8.63
99	+169.6	+4.22	+35.5	−13.53	279	+98.4	−6.47	−112.4	−7.80
102	+177.2	+0.57	−6.8	−14.18	282	+76.4	−8.17	−134.2	−6.55
105	+173.0	−3.10	−49.6	−13.90	285	+49.4	−9.67	−151.7	−4.93
108	+158.6	−6.45	−90.2	−12.66	288	+18.4	−10.95	−163.8	−2.90
111	+134.3	−9.33	−125.6	−10.66	291	−16.3	−11.83	−169.1	−0.53
114	+102.6	−11.56	−154.2	−8.00	294	−52.6	−12.10	−167.0	+2.15
117	+64.9	−13.05	−173.6	−4.93	297	−88.9	−11.75	−156.2	+4.97
120	+24.3	−13.58	−183.8	−1.67	300	−123.1	−10.67	−137.2	+7.73
123	−16.6	−13.38	−183.6	+1.57	303	−152.9	−8.92	−109.8	+10.27
126	−56.0	−12.42	−174.4	+4.50	306	−176.6	−6.43	−75.6	+12.40
129	−91.1	−10.83	−156.6	+7.03	309	−191.5	−3.40	−35.4	+13.93
132	−121.0	−8.78	−132.2	+9.02	312	−197.0	+0.02	+8.0	+14.62
135	−143.8	−6.40	−102.5	+10.47	315	−191.4	+3.57	+52.3	+14.43
138	−159.4	−3.88	−69.4	+11.28	318	−175.6	+7.07	+94.6	+13.28
141	−167.1	−1.36	−34.8	+11.55	321	−149.0	+10.23	+132.0	+11.28
144	−167.6	+1.02	−0.1	+11.26	324	−114.2	+12.78	+162.3	+8.38
147	−161.0	+3.23	+32.8	+10.53	327	−72.3	+14.53	+182.3	+4.90
150	−148.2	+5.17	+63.1	+8.57	330	−27.0	+15.20	+191.7	+1.02
153	−130.0	+6.77	+84.2	+7.98	333	+18.9	+14.86	+188.4	−2.90
156	−107.6	+8.02	+111.0	+7.18	336	+62.2	+13.42	+174.3	−6.55
159	−81.9	+8.93	+127.3	+4.53	339	+99.4	+11.06	+149.1	−9.68
162	−54.0	+9.52	+138.2	+2.68	342	+128.6	+7.88	+116.2	−11.97
165	−24.8	+9.77	+143.4	+0.77	345	+146.7	+4.27	+77.3	−13.33
168	+4.6	+9.62	+142.8	−1.20	348	+154.2	+0.48	+36.2	−13.53
171	+32.9	+9.07	+136.2	−3.15	351	+149.6	−3.17	−3.9	−12.72
174	+59.0	+8.17	+123.9	−4.93	354	+135.2	−6.32	−40.1	−10.80
177	+81.9	+6.93	+106.6	−6.48	357	+111.7	−8.77	−68.7	−8.18
180	+100.6	+5.35	+85.0	−7.82	360	+82.6	−10.17	−89.2	−5.02

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (133) Cyrene—Continued.

TABLE 11.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit of a and b=0°001.

i	4				5				6			
g'	a_4	Diff. for 1°	b_4	Diff. for 1°	a_5	Diff. for 1°	b_5	Diff. for 1°	a_6	Diff. for 1°	b_6	Diff. for 1°
°												
0	−27.0	−0.80	−13.2	+3.22	−6.3	+0.47	+4.5	+0.68	+1.1	0.00	0.0	−0.12
6	−25.0	+1.27	+5.0	+2.58	−2.0	+0.81	+7.6	+0.19	+0.8	−0.08	−0.7	−0.09
12	−13.8	+2.17	+16.0	+0.95	+3.4	+0.74	+6.8	−0.36	+0.2	−0.12	−1.1	−0.02
18	−1.4	+1.76	+16.4	−0.62	+6.9	+0.32	+3.3	−0.73	−0.6	−0.10	−0.9	+0.06
24	+6.0	+0.63	+10.2	−1.25	+7.3	−0.22	−2.0	−0.79	−1.0	−0.03	−0.4	+0.11
30	+6.2	−0.44	+3.3	−0.78	+4.3	−0.66	−6.2	−0.45	−1.0	+0.05	+0.4	+0.12
36	+2.2	−0.65	+0.8	+0.02	−0.6	−0.81	−7.4	+0.10	−0.4	+0.10	+1.0	+0.05
42	0.0	+0.07	+3.5	+0.71	−5.4	−0.57	−5.0	+0.58	+0.2	+0.10	+1.0	−0.03
48	+3.0	+0.88	+7.8	+0.51	−7.4	−0.03	−0.5	+0.78	+0.8	+0.07	+0.6	−0.08
54	+10.5	+1.39	+8.0	−0.60	−5.8	+0.49	+4.4	+0.62	+1.0	−0.01	0.0	−0.11
60	+17.8	+0.80	+0.6	−1.83	−1.5	+0.76	+7.0	+0.15	+0.7	−0.08	−0.7	−0.08
66	+18.4	−0.77	−12.6	−2.37	+3.3	+0.68	+6.2	−0.38	0.0	−0.10	−1.0	−0.01
72	+8.6	−2.48	−25.2	−1.54	+6.6	+0.27	+2.4	−0.70	−0.5	−0.08	−0.8	+0.07
78	−9.6	−3.33	−28.9	+0.52	+6.5	−0.26	−2.2	−0.68	−0.9	−0.02	−0.2	+0.10
84	−28.3	−2.56	−19.0	+2.75	+3.5	−0.63	−5.8	−0.36	−0.7	+0.05	+0.4	+0.08
90	−37.5	−0.18	+2.4	+4.13	−1.1	−0.70	−6.5	+0.14	−0.3	+0.08	+0.8	+0.03
96	−30.4	+2.61	+27.2	+3.70	−4.9	−0.42	−4.1	+0.55	+0.3	+0.08	+0.8	−0.03
102	−7.7	+4.66	+43.2	+1.31	−6.2	+0.02	+0.1	+0.66	+0.7	+0.03	+0.4	−0.08
108	+21.8	+4.74	+41.2	−1.92	−4.6	+0.44	+3.8	+0.46	+0.7	−0.02	−0.2	−0.08
114	+45.0	+2.56	+20.2	−4.76	−0.9	+0.62	+5.6	+0.07	+0.4	−0.07	−0.6	−0.04
120	+50.0	−0.95	−12.2	−5.54	+2.9	+0.48	+4.6	−0.34	−0.1	−0.08	−0.7	+0.02
126	+33.6	−4.36	−41.6	−3.80	+4.9	+0.12	+1.5	−0.57	−0.6	−0.04	−0.4	+0.06
132	+1.0	−6.00	−54.6	−0.22	+4.4	−0.27	−2.2	−0.48	−0.6	+0.02	0.0	+0.07
138	−33.2	−4.86	−44.2	+3.58	+1.7	−0.50	−4.2	−0.15	−0.4	+0.05	+0.4	+0.05
144	−53.2	−1.53	−14.5	+5.89	−1.6	−0.45	−4.0	+0.22	0.0	+0.07	+0.6	0.00
150	−50.3	+2.51	+21.6	+5.53	−3.7	−0.17	−1.6	+0.44	+0.4	+0.05	+0.4	−0.05
156	−25.2	+5.41	+47.2	+2.61	−3.6	+0.18	+1.3	+0.42	+0.6	0.00	0.0	−0.06
162	+10.1	+5.80	+50.8	−1.44	−1.6	+0.41	+3.4	+0.18	+0.4	−0.05	−0.3	−0.04
168	+39.4	+3.46	+31.2	−4.80	+1.3	+0.42	+3.4	−0.16	0.0	−0.07	−0.5	0.00
174	+48.6	−0.47	−2.5	−5.82	+3.4	+0.18	+1.5	−0.39	−0.4	−0.04	−0.3	+0.04
180	+33.8	−4.15	−33.4	−4.01	+3.5	−0.15	−1.3	−0.41	−0.5	0.00	0.0	+0.05
186	+2.6	−5.71	−47.0	−0.26	+1.6	−0.38	−3.4	−0.21	−0.4	+0.04	+0.3	+0.04
192	−29.6	−4.47	−36.5	+3.58	−1.0	−0.41	−3.8	+0.12	0.0	+0.07	+0.5	0.00
198	−47.0	−0.93	−7.4	+5.62	−3.3	−0.24	−1.9	+0.38	+0.4	+0.05	+0.3	−0.04
204	−40.8	+2.96	+25.8	+4.89	−3.9	+0.08	+0.8	+0.42	+0.6	0.00	0.0	−0.06
210	−14.2	+5.46	+46.9	+1.79	−2.3	+0.36	+3.2	+0.25	+0.4	−0.05	−0.4	−0.05
216	+19.8	+5.28	+45.6	−2.25	+0.4	+0.42	+3.8	−0.05	0.0	−0.07	−0.6	0.00
222	+44.4	+2.52	+22.0	−5.17	+2.7	+0.27	+2.6	−0.32	−0.4	−0.05	−0.4	+0.05
228	+47.8	−1.47	−11.8	−5.54	+3.6	−0.01	−0.1	−0.42	−0.6	−0.02	0.0	+0.07
234	+28.1	−4.74	−39.4	−3.19	+2.6	−0.29	−2.4	−0.28	−0.6	+0.04	+0.4	+0.06
240	−4.6	−5.60	−47.2	+0.67	+0.1	−0.41	−3.4	0.00	−0.1	+0.08	+0.7	+0.02
246	−34.0	−3.71	−31.4	+4.25	−2.3	−0.26	−2.4	+0.27	+0.4	+0.07	+0.6	−0.04
252	−45.8	0.00	−0.2	+5.64	−3.0	+0.02	−0.2	+0.40	+0.7	+0.02	+0.2	−0.08
258	−34.0	+3.80	+31.1	+4.23	−2.1	+0.28	+2.4	+0.28	+0.7	−0.03	−0.4	−0.08
264	−3.7	+5.74	+46.6	+0.62	+0.3	+0.40	+3.2	−0.02	+0.3	−0.08	−0.8	−0.03
270	+29.5	+4.80	+38.6	−3.28	+2.7	+0.28	+2.1	−0.01	−0.3	−0.08	−0.8	+0.03
276	+49.6	+1.54	+10.0	−5.75	+3.7	−0.02	−0.5	−0.44	−0.7	−0.05	−0.4	+0.08
282	+46.4	−2.55	−25.4	−5.48	+2.4	−0.36	−3.2	−0.32	−0.9	+0.02	+0.2	+0.10
288	+21.0	−5.53	−51.0	−2.62	−0.6	−0.51	−4.4	0.00	−0.5	+0.08	+0.8	+0.07
294	−15.4	−6.04	−54.6	+1.38	−3.7	−0.39	−3.2	+0.37	0.0	+0.10	+1.0	−0.01
300	−46.4	−3.81	−34.4	+4.92	−5.3	−0.05	0.0	+0.58	+0.7	+0.08	+0.7	−0.08
306	−58.0	+0.08	+0.4	+6.17	−4.3	+0.38	+3.7	+0.49	+1.0	+0.01	0.0	−0.11
312	−45.4	+3.86	+34.6	+4.72	−0.8	+0.63	+5.9	+0.16	+0.8	−0.07	−0.6	−0.08
318	−15.2	+5.71	+53.4	+1.28	+3.3	+0.60	+5.6	−0.29	+0.2	−0.10	−1.0	−0.03
324	+18.6	+5.11	+49.9	−2.40	+6.4	+0.28	+2.4	−0.67	−0.4	−0.10	−1.0	+0.05
330	+42.3	+2.44	+27.0	−4.81	+6.7	−0.22	−2.4	−0.72	−1.0	−0.05	−0.4	+0.12
336	+46.4	−1.00	−3.6	−4.93	+3.8	−0.64	−6.3	−0.42	−1.0	+0.03	+0.4	+0.11
342	+31.9	−3.53	−28.3	−3.00	−1.0	−0.79	−7.4	+0.09	−0.6	+0.10	+0.9	+0.06
348	+7.4	−4.24	−37.8	−0.20	−5.7	−0.55	−5.2	+0.58	+0.2	+0.12	+1.1	−0.02
354	−15.4	−3.04	−30.7	+2.27	−7.6	−0.05	−0.5	+0.81	+0.8	+0.08	+0.7	−0.09
360	−27.0	−0.80	−13.2	+3.22	−6.3	+0.47	+4.5	+0.68	+1.1	0.00	0.0	−0.12

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (133) Cyrene—Continued.

TABLE III.—δ log r.

PERIODIC TERMS.

Unit of a and b=0.00001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	+2.0	−0.12	+106.7	+0.04	−1.0	−3.32	+163.7	−1.66	−10.9	−4.94
6	+1.3	−0.12	+105.1	−0.58	−20.8	−3.24	+151.6	−2.26	−38.1	−4.13
12	+0.5	−0.12	+99.7	−1.17	−39.9	−3.08	+136.6	−2.62	−60.5	−3.37
18	−0.2	−0.12	+91.1	−1.70	−57.7	−2.79	+120.2	−2.75	−78.5	−2.72
24	−1.0	−0.12	+79.3	−2.18	−73.4	−2.42	+103.6	−2.77	−93.2	−2.24
30	−1.7	−0.11	+65.0	−2.56	−86.7	−2.00	+87.0	−2.78	−105.4	−1.88
36	−2.3	−0.10	+48.7	−2.88	−97.4	−1.51	+70.2	−2.82	−115.7	−1.62
42	−2.9	−0.08	+30.5	−3.10	−104.8	−0.98	+53.1	−2.92	−124.8	−1.48
48	−3.3	−0.05	+11.5	−3.23	−109.2	−0.41	+35.2	−3.16	−133.4	−1.33
54	−3.5	−0.02	−8.3	−3.28	−109.7	+0.20	+15.2	−3.54	−140.8	−1.10
60	−3.6	−0.01	−27.9	−3.21	−106.7	+0.79	−7.3	−3.98	−146.6	−0.73
66	−3.6	+0.02	−46.8	−3.05	−100.2	+1.38	−32.6	−4.47	−149.6	−0.18
72	−3.4	+0.04	−64.5	−2.79	−90.1	+1.93	−60.9	−4.95	−148.8	+0.60
78	−3.1	+0.07	−80.3	−2.40	−77.0	+2.46	−92.0	−5.26	−142.4	+1.68
84	−2.6	+0.08	−93.3	−1.91	−60.6	+2.92	−124.0	−5.27	−128.7	+2.98
90	−2.1	+0.09	−103.2	−1.33	−41.9	+3.26	−155.3	−4.93	−106.6	+4.44
96	−1.5	+0.11	−109.3	−0.68	−21.5	+3.51	−183.2	−4.11	−75.4	+5.92
102	−0.8	+0.12	−111.3	+0.01	+0.2	+3.62	−204.6	−2.76	−35.5	+7.26
108	−0.1	+0.10	−109.2	+0.75	+22.0	+3.56	−216.3	−0.94	+11.7	+8.22
114	+0.4	+0.10	−102.3	+1.49	+42.9	+3.33	−215.9	+1.21	+63.1	+8.62
120	+1.1	+0.08	−91.3	+2.16	+62.0	+2.95	−201.8	+3.54	+115.1	+8.37
126	+1.4	+0.06	−76.4	+2.72	+78.3	+2.43	−173.4	+5.78	+163.6	+7.44
132	+1.8	+0.04	−58.6	+3.16	+91.2	+1.79	−132.4	+7.70	+204.4	+5.81
138	+1.9	0.00	−38.5	+3.46	+99.8	+1.04	−81.0	+9.10	+233.3	+3.63
144	+1.8	−0.04	−17.1	+3.58	+103.7	+0.25	−23.2	+9.80	+248.0	+1.17
150	+1.4	−0.08	+4.4	+3.51	+102.8	−0.55	+36.6	+9.75	+247.3	−1.41
156	+0.9	−0.10	+25.0	+3.28	+97.1	−1.30	+93.8	+8.99	+231.1	−3.81
162	+0.2	−0.14	+43.7	+2.87	+87.2	−1.96	+144.5	+7.62	+201.6	−5.84
168	−0.8	−0.16	+59.4	+2.32	+73.6	−2.52	+185.2	+5.81	+161.0	−7.37
174	−1.7	−0.18	+71.6	+1.70	+57.0	−2.93	+214.2	+3.78	+113.2	−8.26
180	−3.0	−0.21	+79.8	+0.99	+38.4	−3.18	+230.6	+1.72	+61.9	−8.62
186	−4.2	−0.20	+83.5	+0.27	+18.9	−3.29	+234.8	−0.22	+9.7	−8.52
192	−5.4	−0.21	+83.0	−0.44	−1.1	−3.22	+228.0	−1.96	−40.3	−7.98
198	−6.7	−0.20	+78.2	−1.13	−19.8	−3.00	+211.3	−3.43	−86.1	−7.19
204	−7.8	−0.17	+69.4	−1.72	−37.1	−2.67	+186.8	−4.62	−126.6	−6.23
210	−8.7	−0.15	+57.5	−2.25	−51.8	−2.18	+155.8	−5.62	−160.9	−5.17
216	−9.6	−0.12	+42.4	−2.68	−63.3	−1.64	+119.3	−6.44	−188.6	−4.02
222	−10.2	−0.07	+25.3	−2.94	−71.5	−1.00	+78.5	−7.08	−209.1	−2.78
228	−10.4	−0.02	+7.1	−3.08	−75.4	−0.29	+34.3	−7.58	−222.0	−1.41
234	−10.5	+0.02	−11.6	−3.09	−75.0	+0.41	−12.4	−7.89	−226.0	+0.11
240	−10.2	+0.08	−30.0	−2.93	−70.5	+1.09	−60.4	−7.93	−220.7	+1.72
246	−9.6	+0.11	−46.8	−2.61	−61.9	+1.76	−107.6	−7.62	−205.4	+3.44
252	−8.9	+0.15	−61.3	−2.16	−49.4	+2.33	−151.8	−6.89	−179.4	+5.20
258	−7.8	+0.18	−72.7	−1.59	−33.9	+2.78	−190.4	−5.72	−143.0	+6.84
264	−6.7	+0.19	−80.4	−0.95	−16.0	+3.12	−220.4	−4.04	−97.3	+8.19
270	−5.5	+0.22	−84.1	−0.21	+3.6	+3.28	−238.9	−2.00	−44.7	+9.12
276	−4.1	+0.22	−82.9	+0.56	+23.4	+3.28	−244.4	+0.32	+12.1	+9.50
282	−2.8	+0.22	−77.4	+1.28	+42.9	+3.10	−235.1	+2.73	+69.3	+9.21
288	−1.4	+0.22	−67.6	+1.97	+60.6	+2.73	−211.6	+5.00	+122.6	+8.25
294	−0.2	+0.19	−53.8	+2.52	+75.7	+2.27	−175.1	+6.92	+168.3	+6.68
300	+0.9	+0.18	−37.3	+2.96	+87.8	+1.68	−128.6	+8.29	+202.7	+4.60
306	+1.9	+0.15	−18.3	+3.25	+95.8	+0.97	−75.6	+9.01	+223.5	+2.25
312	+2.7	+0.12	+1.7	+3.38	+99.4	+0.24	−20.5	+9.02	+229.7	−0.12
318	+3.3	+0.08	+22.3	+3.37	+98.7	−0.50	+32.7	+8.38	+222.0	−2.34
324	+3.6	+0.05	+42.1	+3.17	+93.4	−1.20	+80.0	+7.17	+201.6	−4.20
330	+3.9	+0.02	+60.3	+2.83	+84.3	−1.82	+118.7	+5.58	+171.6	−5.51
336	+3.8	−0.02	+76.1	+2.41	+71.6	−2.37	+147.0	+3.82	+135.5	−6.28
342	+3.6	−0.05	+89.2	+1.89	+55.9	−2.79	+164.6	+2.12	+96.3	−6.50
348	+3.2	−0.08	+98.8	+1.28	+38.1	−3.08	+172.3	+0.58	+57.5	−6.26
354	+2.7	−0.10	+104.6	+0.66	+19.0	−3.26	+171.5	−0.72	+21.2	−5.70
360	+2.0	−0.12	+106.7	+0.04	−1.0	−3.32	+163.7	−1.66	−10.9	−4.94

[$n\delta z$, δ log r, and u cos i are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (133) Cyrene—Continued.

TABLE III.—δ log r—Continued.

PERIODIC TERMS.

Unit of a and b=0.00001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	−6.7	−1.92	−34.1	+1.28	−6.1	+1.10	+9.5	+0.44
6	−15.4	−1.02	−24.6	+1.62	+0.9	+0.98	+9.7	−0.28
12	−19.0	−0.27	−14.7	+1.53	+5.6	+0.45	+6.1	−0.69
18	−18.6	+0.22	−6.2	+1.21	+6.3	−0.08	+1.4	−0.65
24	−16.3	+0.42	−0.2	+0.82	+4.7	−0.32	−1.7	−0.29
30	−13.6	+0.43	+3.6	+0.55	+2.5	−0.25	−2.1	+0.02
36	−11.1	+0.40	+6.4	+0.47	+1.7	−0.02	−1.5	+0.08
42	−8.8	+0.43	+9.2	+0.50	+2.3	+0.13	−1.2	−0.09
48	−5.9	+0.63	+12.4	+0.55	+3.3	+0.02	−2.6	−0.35
54	−1.2	+0.97	+15.8	+0.44	+2.6	−0.34	−5.4	−0.44
60	+5.7	+1.34	+17.7	+0.07	−0.8	−0.73	−7.9	−0.17
66	+14.9	+1.55	+16.6	−0.58	−6.2	−0.82	−7.4	+0.41
72	+24.3	+1.38	+10.8	−1.40	−10.7	−0.44	−3.0	+0.98
78	+31.5	+0.78	−0.2	−2.18	−11.5	+0.30	+4.4	+1.21
84	+33.7	−0.25	−15.3	−2.65	−7.1	+1.11	+11.5	+0.88
90	+28.5	−1.58	−32.0	−2.70	+1.8	+1.55	+14.9	−0.01
96	+14.8	−2.88	−46.4	−1.86	+11.5	+1.29	+11.4	−1.09
102	−6.0	−3.87	−54.3	−0.48	+17.3	+0.37	+1.8	−1.79
108	−30.2	−4.03	−52.2	+1.30	+15.9	−0.88	−10.1	−1.74
114	−52.6	−3.30	−38.7	+3.08	+6.8	−1.87	−19.1	−0.89
120	−68.1	−1.61	−15.3	+4.52	−6.5	−2.12	−20.8	+0.48
126	−71.9	+0.47	+13.9	+5.00	−18.6	−1.45	−13.4	+1.75
132	−62.5	+2.61	+42.8	+4.44	−23.9	−0.09	+0.2	+2.32
138	−40.6	+4.41	+65.3	+2.78	−19.7	+1.38	+14.4	+1.90
144	−11.4	+5.19	+76.1	+0.66	−7.4	+2.26	+23.0	+0.68
150	+19.6	+4.95	+73.2	−1.57	+7.4	+2.17	+22.6	−0.86
156	+45.9	+3.63	+57.3	−3.52	+18.6	+1.14	+12.7	−1.98
162	+61.9	+1.62	+32.7	−4.53	+21.1	−0.35	−1.2	−2.16
168	+65.3	−0.41	+4.9	−4.56	+14.4	−1.59	−13.2	−1.38
174	+57.0	−2.13	−20.2	−3.56	+2.0	−2.05	−17.7	+0.01
180	+39.7	−3.34	−37.8	−2.11	−10.2	−1.49	−13.1	+1.31
186	+18.5	−3.62	−45.5	−0.42	−15.9	−0.20	−2.0	+1.92
192	−2.2	−3.07	−42.9	+1.10	−12.6	+1.14	+9.9	+1.54
198	−18.3	−2.08	−32.3	+2.15	−2.2	+1.88	+16.5	+0.36
204	−27.1	−0.78	−17.1	+2.62	+9.9	+1.67	+14.2	−0.98
210	−27.7	+0.49	−0.8	+2.53	+17.8	+0.62	+4.8	−1.84
216	−21.2	+1.56	+13.3	+1.93	+17.3	−0.78	−7.9	−1.82
222	−9.0	+2.26	+22.4	+0.95	+8.5	−1.76	−17.0	−0.87
228	+5.9	+2.51	+24.7	−0.23	−3.8	−1.88	−18.3	+0.49
234	+21.1	+2.21	+19.6	−1.45	−14.0	−1.08	−11.1	+1.59
240	+32.4	+1.35	+7.3	−2.48	−16.7	+0.26	+0.8	+1.86
246	+37.3	+0.08	−10.1	−3.07	−10.9	+1.43	+11.2	+1.18
252	+33.4	−1.40	−29.5	−3.16	+0.5	+1.87	+15.0	−0.10
258	+20.5	−2.88	−46.5	−2.38	+11.5	+1.32	+10.0	−1.38
264	−1.1	−4.04	−56.7	−0.84	+16.2	+0.04	−1.5	−1.97
270	−26.4	−4.28	−56.6	+1.01	+12.0	−1.33	−13.6	−1.57
276	−50.8	−3.63	−44.6	+2.90	+0.2	−2.16	−20.3	−0.32
282	−68.3	−2.00	−21.8	+4.48	−13.9	−1.96	−17.5	+1.18
288	−74.8	+0.07	+7.6	+5.16	−23.4	−0.84	−6.2	+2.22
294	−67.5	+2.29	+37.9	+4.72	−24.0	+0.72	+9.1	+2.33
300	−47.3	+4.22	+62.2	+3.13	−14.7	+2.02	+21.8	+1.45
306	−18.7	+5.14	+75.5	+1.08	+0.2	+2.47	+26.5	−0.05
312	+12.3	+5.00	+75.2	−1.13	+14.9	+1.92	+21.2	−1.50
318	+39.4	+3.88	+61.9	−3.11	+23.3	+0.64	+8.5	−2.28
324	+57.5	+2.02	+39.3	−4.28	+22.6	−0.81	−6.1	−2.08
330	+63.7	+0.05	+12.6	−4.42	+13.6	−1.78	−16.4	−1.10
336	+58.1	−1.65	−12.0	−3.56	+1.2	−1.92	−19.3	+0.18
342	+43.9	−2.84	−30.1	−2.29	−9.4	−1.28	−14.2	+1.19
348	+25.6	−3.02	−39.5	−0.82	−14.1	−0.24	−5.0	+1.55
354	+7.7	−2.69	−40.0	+0.45	−12.3	+0.67	+4.4	+1.21
360	−6.7	−1.92	−34.1	+1.28	−6.1	+1.10	+9.5	+0.44

[$n\delta z$, δ log r, and u/cos i are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (133) Cyrene—Continued.

TABLE III.—δ log r—Continued.

PERIODIC TERMS. Unit of a and b=0.00001.

i	5				6			
g'	a_5	Diff. for 1°	b_5	Diff. for 1°	a_6	Diff. for 1°	b_6	Diff. for 1°
°								
0	+2.3	+0.34	+3.2	−0.25	+0.2	−0.07	−0.5	−0.02
6	+3.9	+0.12	+0.9	−0.41	−0.2	−0.05	−0.5	+0.02
12	+3.7	−0.18	−1.7	−0.38	−0.4	−0.02	−0.3	+0.05
18	+1.8	−0.38	−3.6	−0.18	−0.5	+0.02	+0.1	+0.05
24	−0.8	−0.39	−3.8	+0.11	−0.2	+0.05	+0.3	+0.02
30	−2.9	−0.23	−2.3	+0.33	+0.1	+0.04	+0.3	−0.01
36	−3.6	+0.02	+0.2	+0.40	+0.3	+0.01	+0.2	−0.03
42	−2.6	+0.28	+2.5	+0.27	+0.2	−0.02	−0.1	−0.03
48	−0.2	+0.39	+3.4	+0.02	+0.1	−0.03	−0.2	−0.02
54	+2.1	+0.31	+2.7	−0.24	−0.2	−0.03	−0.3	+0.01
60	+3.5	+0.08	+0.5	−0.38	−0.3	−0.01	−0.1	+0.04
66	+3.0	−0.19	−1.8	−0.32	−0.3	+0.02	+0.2	+0.05
72	+1.2	−0.35	−3.4	−0.12	−0.1	+0.05	+0.5	+0.02
78	−1.2	−0.36	−3.3	+0.13	+0.3	+0.05	+0.4	−0.02
84	−3.1	−0.18	−1.8	+0.32	+0.5	+0.02	+0.2	−0.05
90	−3.4	+0.07	+0.5	+0.35	+0.5	−0.02	−0.2	−0.07
96	−2.3	+0.26	+2.4	+0.21	+0.2	−0.06	−0.6	−0.04
102	−0.3	+0.32	+3.0	−0.01	−0.2	−0.06	−0.7	+0.01
108	+1.6	+0.22	+2.3	−0.21	−0.5	−0.05	−0.5	+0.07
114	+2.4	+0.02	+0.5	−0.28	−0.8	−0.01	+0.1	+0.09
120	+1.9	−0.17	−1.1	−0.21	−0.6	+0.05	+0.5	+0.06
126	+0.4	−0.25	−2.0	−0.04	−0.2	+0.08	+0.8	+0.02
132	−1.1	−0.20	−1.6	+0.14	+0.4	+0.08	+0.7	−0.03
138	−2.0	−0.05	−0.3	+0.24	+0.7	+0.03	+0.4	−0.08
144	−1.7	+0.14	+1.3	+0.20	+0.8	−0.02	−0.2	−0.08
150	−0.3	+0.23	+2.1	+0.04	+0.5	−0.06	−0.6	−0.05
156	+1.1	+0.19	+1.8	−0.12	+0.1	−0.08	−0.8	+0.01
162	+2.0	+0.08	+0.6	−0.22	−0.5	−0.07	−0.5	+0.05
168	+2.0	−0.10	−0.9	−0.21	−0.7	−0.01	−0.2	+0.06
174	+0.8	−0.22	−1.9	−0.09	−0.6	+0.04	+0.2	+0.06
180	−0.7	−0.21	−2.0	+0.08	−0.2	+0.07	+0.5	+0.02
186	−1.7	−0.08	−0.9	+0.22	+0.2	+0.05	+0.5	−0.02
192	−1.7	+0.07	+0.6	+0.22	+0.4	+0.02	+0.3	−0.05
198	−0.9	+0.18	+1.7	+0.12	+0.5	−0.02	−0.1	−0.05
204	+0.5	+0.22	+2.0	−0.05	+0.2	−0.05	−0.3	−0.02
210	+1.8	+0.12	+1.1	−0.20	−0.1	−0.04	−0.3	+0.01
216	+2.0	−0.05	−0.4	−0.22	−0.3	−0.01	−0.2	+0.03
222	+1.2	−0.18	−1.6	−0.13	−0.2	+0.02	+0.1	+0.03
228	−0.1	−0.22	−2.0	+0.02	−0.1	+0.03	+0.2	+0.02
234	−1.4	−0.14	−1.4	+0.15	+0.2	+0.03	+0.3	−0.01
240	−1.8	+0.02	−0.2	+0.21	+0.3	+0.01	+0.1	−0.04
246	−1.2	+0.17	+1.1	+0.13	+0.3	−0.02	−0.2	−0.05
252	+0.2	+0.20	+1.4	−0.02	+0.1	−0.05	−0.5	−0.02
258	+1.2	+0.11	+0.9	−0.17	−0.3	−0.05	−0.4	+0.02
264	+1.5	−0.03	−0.5	−0.22	−0.5	−0.02	−0.2	+0.05
270	+0.8	−0.19	−1.7	−0.12	−0.5	+0.02	+0.2	+0.07
276	−0.8	−0.26	−2.0	+0.03	−0.2	+0.06	+0.6	+0.04
282	−2.3	−0.17	−1.3	+0.21	+0.2	+0.06	+0.7	−0.01
288	−2.8	+0.02	+0.5	+0.29	+0.5	+0.05	+0.5	−0.07
294	−2.1	+0.22	+2.2	+0.23	+0.8	+0.01	−0.1	−0.08
300	−0.2	+0.33	+3.3	+0.04	+0.6	−0.05	−0.5	−0.06
306	+1.9	+0.29	+2.7	−0.19	+0.2	−0.08	−0.8	−0.02
312	+3.3	+0.11	+1.0	−0.34	−0.4	−0.08	−0.7	+0.03
318	+3.2	−0.15	−1.4	−0.34	−0.7	−0.03	−0.4	+0.08
324	+1.5	−0.33	−3.1	−0.17	−0.8	+0.02	+0.2	+0.08
330	−0.8	−0.38	−3.3	+0.09	−0.5	+0.06	+0.6	+0.05
336	−3.0	−0.24	−2.0	+0.32	−0.1	+0.08	+0.8	−0.01
342	−3.7	+0.03	+0.5	+0.39	+0.5	+0.07	+0.5	−0.05
348	−2.6	+0.30	+2.7	+0.28	+0.7	+0.01	+0.2	−0.06
354	−0.2	+0.41	+3.9	+0.04	+0.6	−0.04	−0.2	−0.06
360	+2.3	+0.34	+3.2	−0.25	+0.2	−0.07	−0.5	−0.02

[$n\delta z$, δ log r, and u/cos i are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (133) Cyrene—Continued.

TABLE IV.—u/cos i.

PERIODIC TERMS.

Unit of *a* and *b*=0°001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	−11.7	−0.64	−17.0	−0.19	−2.5	+0.42	−15.8	+0.47	+6.8	+0.44
6	−15.4	−0.58	−17.8	−0.05	+0.3	+0.54	−12.7	+0.52	+8.8	+0.25
12	−18.7	−0.51	−17.6	+0.14	+4.0	+0.61	−9.6	+0.48	+9.8	+0.07
18	−21.5	−0.41	−16.1	+0.35	+7.6	+0.61	−7.0	+0.34	+9.6	−0.12
24	−23.6	−0.31	−13.4	+0.53	+11.3	+0.56	−5.5	+0.18	+8.4	−0.19
30	−25.2	−0.21	−9.7	+0.69	+14.3	+0.42	−4.8	+0.02	+7.3	−0.15
36	−26.1	−0.09	−5.1	+0.82	+16.3	+0.24	−5.2	−0.12	+6.6	−0.06
42	−26.3	+0.02	+0.2	+0.88	+17.2	+0.06	−6.2	−0.16	+6.6	+0.10
48	−25.8	+0.14	+5.4	+0.85	+17.0	−0.17	−7.1	−0.13	+7.8	+0.29
54	−24.6	+0.27	+10.4	+0.75	+15.2	−0.38	−7.8	−0.01	+10.1	+0.45
60	−22.6	+0.38	+14.4	+0.58	+12.5	−0.52	−7.2	+0.22	+13.2	+0.51
66	−20.1	+0.47	+17.4	+0.38	+9.0	−0.61	−5.2	+0.45	+16.2	+0.48
72	−17.0	+0.56	+19.0	+0.17	+5.2	−0.63	−1.8	+0.66	+19.0	+0.35
78	−13.4	+0.62	+19.4	−0.05	+1.4	−0.62	+2.7	+0.81	+20.4	+0.12
84	−9.6	+0.66	+18.4	−0.26	−2.2	−0.52	+7.9	+0.88	+20.4	−0.12
90	−5.5	+0.69	+16.3	−0.40	−4.8	−0.37	+13.3	+0.84	+18.9	−0.42
96	−1.3	+0.68	+13.6	−0.48	−6.6	−0.20	+18.0	+0.68	+15.3	−0.69
102	+2.7	+0.66	+10.6	−0.50	−7.2	−0.04	+21.4	+0.46	+10.6	−0.86
108	+6.6	+0.62	+7.6	−0.48	−7.1	+0.08	+23.5	+0.18	+5.0	−0.93
114	+10.1	+0.53	+4.9	−0.40	−6.2	+0.21	+23.6	−0.08	−0.6	−0.93
120	+13.0	+0.43	+2.8	−0.29	−4.6	+0.28	+22.6	−0.31	−6.2	−0.88
126	+15.3	+0.31	+1.4	−0.18	−2.8	+0.30	+19.9	−0.52	−11.2	−0.72
132	+16.7	+0.17	+0.6	−0.08	−1.0	+0.26	+16.4	−0.62	−14.8	−0.56
138	+17.3	+0.04	+0.5	0.00	+0.3	+0.21	+12.4	−0.70	−17.9	−0.40
144	+17.2	−0.10	+0.6	+0.06	+1.5	+0.14	+8.0	−0.72	−19.6	−0.24
150	+16.1	−0.24	+1.2	+0.07	+2.0	+0.03	+3.8	−0.73	−20.8	−0.10
156	+14.3	−0.37	+1.4	+0.05	+1.9	−0.03	−0.8	−0.75	−20.8	+0.04
162	+11.7	−0.48	+1.8	+0.02	+1.6	−0.08	−5.2	−0.75	−20.3	+0.16
168	+8.5	−0.56	+1.7	−0.02	+1.0	−0.09	−9.8	−0.74	−18.9	+0.32
174	+5.0	−0.60	+1.5	−0.04	+0.5	−0.09	−14.1	−0.67	−16.4	+0.49
180	+1.3	−0.63	+1.2	−0.06	−0.1	−0.07	−17.8	−0.57	−13.0	+0.67
186	−2.6	−0.62	+0.8	−0.07	−0.3	−0.02	−20.9	−0.41	−8.4	+0.83
192	−6.1	−0.56	+0.4	−0.04	−0.4	+0.01	−22.8	−0.20	−3.0	+0.94
198	−9.3	−0.49	+0.3	−0.02	−0.2	+0.02	−23.4	+0.06	+2.9	+1.02
204	−12.0	−0.39	+0.2	+0.02	−0.1	+0.04	−22.1	+0.37	+9.2	+0.99
210	−14.0	−0.26	+0.5	+0.08	+0.3	+0.04	−19.0	+0.62	+14.8	+0.85
216	−15.1	−0.11	+1.1	+0.11	+0.3	−0.02	−14.6	+0.87	+19.4	+0.65
222	−15.3	+0.04	+1.8	+0.12	0.0	−0.06	−8.6	+1.02	+22.6	+0.38
228	−14.6	+0.19	+2.6	+0.12	−0.4	−0.08	−2.3	+1.07	+24.0	+0.08
234	−13.0	+0.32	+3.2	+0.07	−1.0	−0.14	+4.2	+1.03	+23.5	−0.25
240	−10.8	+0.42	+3.4	+0.01	−2.1	−0.17	+10.1	+0.88	+21.0	−0.51
246	−7.9	+0.52	+3.3	−0.06	−3.0	−0.14	+14.8	+0.69	+17.4	−0.70
252	−4.6	+0.58	+2.7	−0.11	−3.8	−0.13	+18.4	+0.46	+12.6	−0.83
258	−1.0	+0.62	+2.0	−0.16	−4.6	−0.12	+20.3	+0.21	+7.4	−0.87
264	+2.8	+0.61	+0.8	−0.21	−5.2	−0.07	+20.9	0.00	+2.2	−0.84
270	+6.3	+0.58	−0.5	−0.22	−5.4	+0.02	+20.3	−0.18	−2.7	−0.76
276	+9.7	+0.52	−1.8	−0.21	−5.0	+0.05	+18.8	−0.31	−6.9	−0.69
282	+12.5	+0.41	−3.0	−0.17	−4.8	+0.06	+16.6	−0.42	−11.0	−0.61
288	+14.6	+0.28	−3.8	−0.12	−4.3	+0.08	+13.7	−0.52	−14.2	−0.48
294	+15.9	+0.17	−4.5	−0.08	−3.8	+0.06	+10.4	−0.61	−16.8	−0.38
300	+16.6	+0.03	−4.8	−0.04	−3.6	+0.03	+6.4	−0.68	−18.8	−0.27
306	+16.3	−0.11	−5.0	−0.05	−3.4	−0.02	+2.3	−0.74	−20.0	−0.13
312	+15.3	−0.23	−5.4	−0.06	−3.8	−0.09	−2.4	−0.78	−20.4	+0.04
318	+13.5	−0.38	−5.7	−0.10	−4.5	−0.12	−7.0	−0.75	−19.5	+0.23
324	+10.8	−0.48	−6.6	−0.18	−5.3	−0.12	−11.4	−0.68	−17.6	+0.42
330	+7.7	−0.56	−7.8	−0.23	−6.0	−0.12	−15.2	−0.55	−14.4	+0.60
336	+4.1	−0.62	−9.4	−0.32	−6.8	−0.08	−18.0	−0.37	−10.4	+0.72
342	+0.3	−0.65	−11.6	−0.34	−6.9	+0.03	−19.6	−0.13	−5.7	+0.79
348	−3.7	−0.68	−13.5	−0.32	−6.4	+0.18	−19.6	+0.11	−0.9	+0.76
354	−7.8	−0.67	−15.5	−0.29	−4.7	+0.32	−18.3	+0.32	+3.4	+0.64
360	−11.7	−0.64	−17.0	−0.19	−2.5	+0.42	−15.8	+0.47	+6.8	+0.45

[*nδz*, *δ* log *r*, and *u* cos *i* are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (133) Cyrene—Continued.

TABLE IV.—$u \cos i$—Continued.

PERIODIC TERMS.

Unit of a and b=0°.001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	+3.5	+0.31	+5.8	−0.28	+2.6	−0.26	−2.8	−0.20
6	+4.8	+0.15	+4.0	−0.32	+0.8	−0.29	−3.5	−0.03
12	+5.3	+0.03	+2.0	−0.32	−0.9	−0.23	−3.2	+0.10
18	+5.2	−0.04	+0.1	−0.27	−2.0	−0.14	−2.3	+0.18
24	+4.8	−0.10	−1.2	−0.21	−2.6	−0.06	−1.1	+0.19
30	+4.0	−0.12	−2.4	−0.17	−2.7	+0.01	0.0	+0.18
36	+3.3	−0.12	−3.2	−0.13	−2.5	+0.08	+1.0	+0.16
42	+2.5	−0.17	−4.0	−0.13	−1.8	+0.12	+1.9	+0.13
48	+1.3	−0.22	−4.8	−0.12	−1.1	+0.16	+2.6	+0.08
54	−0.1	−0.28	−5.4	−0.06	+0.1	+0.22	+2.9	−0.01
60	−2.0	−0.32	−5.5	+0.03	+1.6	+0.23	+2.5	−0.11
66	−4.0	−0.32	−5.0	+0.16	+2.9	+0.16	+1.6	−0.21
72	−5.9	−0.29	−3.6	+0.32	+3.5	−0.01	0.0	−0.30
78	−7.5	−0.17	−1.1	+0.46	+2.8	−0.18	−2.0	−0.28
84	−7.9	+0.05	+1.9	+0.52	+1.3	−0.31	−3.3	−0.12
90	−6.9	+0.28	+5.2	+0.51	−0.9	−0.36	−3.4	+0.10
96	−4.6	+0.48	+8.0	+0.37	−3.0	−0.23	−2.1	+0.28
102	−1.1	+0.64	+9.6	+0.13	−3.7	+0.02	0.0	+0.38
108	+3.1	+0.69	+9.6	−0.15	−2.8	+0.26	+2.5	+0.32
114	+7.2	+0.58	+7.8	−0.46	−0.6	+0.41	+3.9	+0.09
120	+10.1	+0.33	+4.1	−0.69	+2.1	+0.40	+3.6	−0.20
126	+11.2	0.00	−0.5	−0.79	+4.2	+0.20	+1.5	−0.42
132	+10.1	−0.36	−5.4	−0.74	+4.5	−0.12	−1.4	−0.48
138	+6.9	−0.66	−9.4	−0.52	+2.8	−0.39	−4.3	−0.32
144	+2.2	−0.85	−11.7	−0.18	−0.2	−0.52	−5.2	0.00
150	−3.3	−0.85	−11.6	+0.22	−3.4	−0.44	−4.3	+0.32
156	−8.0	−0.66	−9.0	+0.59	−5.5	−0.16	−1.4	+0.52
162	−11.2	−0.34	−4.5	+0.84	−5.3	+0.19	+2.0	+0.52
168	−12.1	+0.08	+1.1	+0.90	−3.2	+0.45	+4.8	+0.29
174	−10.3	+0.48	+6.3	+0.78	+0.1	+0.53	+5.5	−0.07
180	−6.3	+0.79	+10.4	+0.48	+3.2	+0.39	+4.0	−0.35
186	−0.8	+0.92	+12.0	+0.05	+4.8	+0.09	+1.3	−0.47
192	+4.7	+0.83	+11.0	−0.38	+4.3	−0.23	−1.6	−0.40
198	+9.2	+0.58	+7.5	−0.72	+2.0	−0.41	−3.5	−0.16
204	+11.6	+0.18	+2.4	−0.89	−0.6	−0.38	−3.5	+0.14
210	+11.4	−0.26	−3.2	−0.88	−2.5	−0.18	−1.8	+0.34
216	+8.5	−0.64	−8.2	−0.67	−2.7	+0.09	+0.6	+0.32
222	+3.7	−0.87	−11.2	−0.28	−1.4	+0.30	+2.1	+0.15
228	−1.9	−0.90	−11.6	+0.15	+0.9	+0.32	+2.4	−0.08
234	−7.1	−0.72	−9.4	+0.54	+2.5	+0.16	+1.1	−0.29
240	−10.6	−0.39	−5.1	+0.82	+2.8	−0.08	−1.1	−0.34
246	−11.8	+0.02	+0.4	+0.91	+1.5	−0.31	−3.0	−0.21
252	−10.3	+0.44	+5.8	+0.79	−0.9	−0.39	−3.6	+0.05
258	−6.5	+0.75	+9.9	+0.49	−3.2	−0.27	−2.4	+0.31
264	−1.3	+0.88	+11.7	+0.09	−4.1	−0.01	+0.1	+0.43
270	+4.1	+0.82	+11.0	−0.31	−3.3	+0.26	+2.8	+0.35
276	+8.6	+0.58	+8.0	−0.63	−1.0	+0.44	+4.3	+0.10
282	+11.1	+0.22	+3.4	−0.83	+2.0	+0.42	+4.0	−0.18
288	+11.3	−0.16	−2.0	−0.83	+4.0	+0.18	+2.1	−0.41
294	+9.2	−0.50	−6.6	−0.64	+4.2	−0.11	−0.9	−0.46
300	+5.3	−0.72	−9.7	−0.36	+2.7	−0.33	−3.4	−0.29
306	+0.6	−0.77	−10.9	−0.01	+0.2	−0.43	−4.4	0.00
312	−3.9	−0.68	−9.8	+0.32	−2.5	−0.37	−3.4	+0.28
318	−7.5	−0.46	−7.0	+0.56	−4.2	−0.12	−1.1	+0.42
324	−9.4	−0.15	−3.1	+0.67	−4.0	+0.17	+1.6	+0.40
330	−9.3	+0.13	+1.0	+0.62	−2.2	+0.36	+3.7	+0.23
336	−7.8	+0.36	+4.4	+0.48	+0.3	+0.41	+4.4	−0.04
342	−5.0	+0.49	+6.7	+0.28	+2.7	+0.31	+3.2	−0.27
348	−1.9	+0.51	+7.7	+0.05	+4.0	+0.10	+1.2	−0.36
354	+1.1	+0.45	+7.3	−0.16	+3.9	−0.12	−1.1	−0.33
360	+3.5	+0.31	+5.8	−0.28	+2.6	−0.26	−2.8	−0.20

[$n\delta z$, $\delta \log r$, and $u \cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig+\Sigma_i\, b_i \cos ig +cT$.]

Tables of (133) Cyrene—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY $T=(t-t_0)$ IN JULIAN YEARS.

g	$n\delta z$ Unit of $c=0°.001$		$\delta \log r$ Unit of $c=0.0001$		$u/\cos i$ Unit of $c=0°.001$	
	c	Diff. for 1°	c	Diff. for 1°	c	Diff. for 1°
°						
0	−5. 82	+0. 011	−0. 25	−0. 043	+0. 98	+0. 075
6	−5. 72	+0. 023	−0. 51	−0. 042	+1. 42	+0. 072
12	−5. 54	+0. 034	−0. 76	−0. 040	+1. 84	+0. 068
18	−5. 31	+0. 044	−0. 99	−0. 038	+2. 23	+0. 061
24	−5. 01	+0. 056	−1. 22	−0. 036	+2. 57	+0. 054
30	−4. 64	+0. 065	−1. 42	−0. 032	+2. 88	+0. 048
36	−4. 23	+0. 072	−1. 61	−0. 029	+3. 14	+0. 040
42	−3. 77	+0. 080	−1. 77	−0. 024	+3. 36	+0. 032
48	−3. 27	+0. 087	−1. 90	−0. 020	+3. 52	+0. 022
54	−2. 73	+0. 092	−2. 01	−0. 016	+3. 63	+0. 015
60	−2. 17	+0. 095	−2. 09	−0. 011	+3. 70	+0. 007
66	−1. 59	+0. 098	−2. 14	−0. 008	+3. 71	−0. 002
72	−1. 00	+0. 100	−2. 18	−0. 002	+3. 68	−0. 009
78	−0. 39	+0. 100	−2. 17	+0. 002	+3. 60	−0. 015
84	+0. 20	+0. 098	−2. 15	+0. 005	+3. 50	−0. 022
90	+0. 79	+0. 097	−2. 11	+0. 008	+3. 34	−0. 028
96	+1. 36	+0. 092	−2. 05	+0. 012	+3. 16	−0. 035
102	+1. 90	+0. 089	−1. 96	+0. 016	+2. 92	−0. 039
108	+2. 43	+0. 086	−1. 86	+0. 018	+2. 69	−0. 041
114	+2. 93	+0. 079	−1. 74	+0. 021	+2. 43	−0. 046
120	+3. 38	+0. 072	−1. 61	+0. 022	+2. 14	−0. 049
126	+3. 80	+0. 067	−1. 47	+0. 026	+1. 84	−0. 053
132	+4. 18	+0. 059	−1. 30	+0. 028	+1. 50	−0. 056
138	+4. 51	+0. 052	−1. 14	+0. 028	+1. 17	−0. 058
144	+4. 80	+0. 043	−0. 96	+0. 030	+0. 82	−0. 058
150	+5. 03	+0. 034	−0. 78	+0. 031	+0. 47	−0. 060
156	+5. 21	+0. 028	−0. 59	+0. 031	+0. 10	−0. 059
162	+5. 36	+0. 018	−0. 41	+0. 032	−0. 24	−0. 058
168	+5. 43	+0. 008	−0. 20	+0. 033	−0. 60	−0. 060
174	+5. 45	−0. 001	−0. 01	+0. 032	−0. 96	−0. 058
180	+5. 42	−0. 009	+0. 19	+0. 033	−1. 30	−0. 057
186	+5. 34	−0. 018	+0. 39	+0. 032	−1. 64	−0. 055
192	+5. 20	−0. 028	+0. 58	+0. 032	−1. 96	−0. 052
198	+5. 01	−0. 036	+0. 77	+0. 031	−2. 27	−0. 051
204	+4. 77	−0. 044	+0. 95	+0. 029	−2. 57	−0. 048
210	+4. 48	−0. 052	+1. 12	+0. 027	−2. 84	−0. 042
216	+4. 15	−0. 059	+1. 27	+0. 026	−3. 08	−0. 038
222	+3. 77	−0. 067	+1. 43	+0. 025	−3. 30	−0. 035
228	+3. 35	−0. 073	+1. 57	+0. 023	−3. 50	−0. 031
234	+2. 89	−0. 078	+1. 71	+0. 021	−3. 67	−0. 026
240	+2. 41	−0. 084	+1. 82	+0. 017	−3. 82	−0. 020
246	+1. 89	−0. 089	+1. 91	+0. 014	−3. 91	−0. 013
252	+1. 34	−0. 093	+1. 99	+0. 012	−3. 98	−0. 009
258	+0. 77	−0. 095	+2. 05	+0. 008	−4. 02	−0. 003
264	+0. 20	−0. 097	+2. 09	+0. 005	−4. 02	+0. 003
270	−0. 39	−0. 098	+2. 11	+0. 002	−3. 98	+0. 010
276	−0. 98	−0. 098	+2. 11	−0. 002	−3. 90	+0. 018
282	−1. 56	−0. 096	+2. 08	−0. 007	−3. 76	+0. 024
288	−2. 13	−0. 094	+2. 03	−0. 010	−3. 61	+0. 031
294	−2. 69	−0. 091	+1. 96	−0. 015	−3. 39	+0. 039
300	−3. 22	−0. 086	+1. 85	−0. 019	−3. 14	+0. 044
306	−3. 72	−0. 080	+1. 73	−0. 022	−2. 86	+0. 052
312	−4. 18	−0. 072	+1. 58	−0. 027	−2. 52	+0. 059
318	−4. 59	−0. 065	+1. 41	−0. 031	−2. 15	+0. 065
324	−4. 96	−0. 057	+1. 21	−0. 035	−1. 74	+0. 070
330	−5. 27	−0. 046	+0. 99	−0. 037	−1. 31	+0. 073
336	−5. 51	−0. 036	+0. 77	−0. 038	−0. 86	+0. 074
342	−5. 70	−0. 025	+0. 53	−0. 042	−0. 41	+0. 077
348	−5. 81	−0. 012	+0. 27	−0. 043	+0. 06	+0. 078
354	−5. 85	−0. 001	+0. 01	−0. 043	+0. 52	+0. 077
360	−5. 82	+0. 011	−0. 25	−0. 043	+0. 98	+0. 075

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (133) Cyrene—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	A′	B′	C′	log sin *a*	log sin *b*	log sin *c*
	°	°	°			
1873. 0	336. 3562	243. 8244	254. 5000	9. 99861	9. 94195	9. 69090
4	. 3701	. 8390	. 5112	61	94	091
1875	336. 3841	243. 8536	254. 5224	9. 99862	9. 94194	9. 69092
6	. 3980	. 8682	. 5336	62	93	093
7	. 4120	. 8827	. 5448	62	93	095
8	. 4259	. 8973	. 5560	62	92	096
9	. 4398	. 9119	. 5672	62	92	097
1880	336. 4538	243. 9265	254. 5784	9. 99862	9. 94192	9. 69098
1	. 4677	. 9411	. 5896	62	91	100
2	. 4816	. 9556	. 6008	62	91	101
3	. 4956	. 9702	. 6120	62	91	102
4	. 5095	. 9848	. 6232	62	90	103
1885	336. 5235	243. 9994	254. 6344	9. 99862	9. 94190	9. 69104
6	. 5374	244. 0139	. 6456	63	89	106
7	. 5513	. 0285	. 6569	63	88	107
8	. 5653	. 0431	. 6681	63	88	108
9	. 5792	. 0577	. 6793	63	87	109
1890	336. 5931	244. 0722	254. 6905	9. 99863	9. 94187	9. 69110
1	. 6071	. 0868	. 7017	63	86	112
2	. 6210	. 1014	. 7129	63	86	113
3	. 6350	. 1160	. 7241	63	85	114
4	. 6489	. 1306	. 7353	63	85	116
1895	336. 6628	244. 1451	254. 7465	9. 99864	9. 94184	9. 69117
6	. 6768	. 1597	. 7577	64	84	118
7	. 6907	. 1743	. 7689	64	83	119
8	. 7046	. 1889	. 7801	64	83	120
9	. 7186	. 2034	. 7913	64	82	122
1900	336. 7325	244. 2180	254. 8025	9. 99864	9. 94182	9. 69123
1	. 7464	. 2325	. 8137	64	82	124
2	. 7604	. 2471	. 8249	64	81	125
3	. 7743	. 2616	. 8360	64	81	127
4	. 7882	. 2762	. 8472	64	80	128
1905	336. 8022	244. 2907	254. 8584	9. 99864	9. 94180	9. 69129
6	. 8161	. 3053	. 8696	65	79	130
7	. 8300	. 3198	. 8808	65	79	132
8	. 8439	. 3344	. 8919	65	78	133
9	. 8579	. 3489	. 9031	65	78	134
1910	336. 8718	244. 3635	254. 9143	9. 99865	9. 94177	9. 69135
1	. 8857	. 3780	. 9255	65	77	137
2	. 8997	. 3926	. 9367	65	76	138
3	. 9136	. 4071	. 9478	65	76	139
4	. 9275	. 4217	. 9590	65	75	140
1915	336. 9414	244. 4362	254. 9702	9. 99866	9. 94175	9. 69141
6	. 9554	. 4508	. 9814	66	75	143
7	. 9693	. 4653	254. 9926	66	74	144
8	. 9832	. 4798	255. 0037	66	74	145
9	336. 9972	. 4944	. 0149	66	73	146
1920	337. 0111	244. 5089	255. 0261	9. 99866	9. 94173	9. 69148
1	. 0250	. 5235	. 0373	66	72	149
2	. 0390	. 5380	. 0485	66	72	150
3	. 0529	. 5526	. 0596	66	71	151
4	. 0668	. 5671	. 0708	66	71	152
1925	337. 0808	244. 5817	255. 0820	9. 99866	9. 94170	9. 69154
6	. 0947	. 5962	. 0932	67	70	155
7	. 1086	. 6108	. 1044	67	69	156
8	. 1225	. 6253	. 1155	67	69	157
9	. 1365	. 6399	. 1267	67	68	159
1930	337. 1504	244. 6544	255. 1379	9. 99867	9. 94168	9. 69160

Year	log cos *a*	log cos *b*	log cos *c*
1873. 0	8. 902 *n*	9. 685 *n*	9. 940
1930. 0	8. 893 *n*	9. 686 *n*	9. 940

TABLES OF (139) JUEWA.

MEAN ELEMENTS.

Epoch, 1897, Jan. 29.0, M. T. Berlin=1897.079, M. T. Berlin.

$$\begin{array}{rrrl} & ^{\circ} & ' & '' \\ g_0=155 & 29 & 57= & 155^{\circ}\!.4991 \end{array}$$

$$\left.\begin{array}{rrrl} \omega=162 & 12 & 34= & 162.2094 \\ \Omega=\ \ 2 & 27 & 38= & 2.4604 \\ i=\ 10 & 55 & 12= & 10.9200 \end{array}\right\}\text{Mean equinox and ecliptic 1900.0.}$$

$$\begin{array}{rrrl} \varphi=\ 10 & 2 & 40= & 10.0443 \\ n=764''.1684 & & = & 0.21226900 \end{array}$$

The elements are based on oppositions extending from 1874 to 1898 and on the perturbations of the first order by *Jupiter*, as given on page 279.

AUXILIARY QUANTITIES.

$\log a=0.44454$ $\qquad \log 57.2958\ e=0.99970$ $\qquad \log\sqrt{\dfrac{1-e}{1+e}}=9.92347$

$\log e=9.24158$ $\qquad \log p=0.43113$

TABLE I.—MEAN ANOMALY (g).

Jan. 0.0 of common years; Jan. 1.0 of leap years

Year	g	Year	g
	°		°
1874	166.07140	1902	176.73419
5	243.54958	3	254.21238
B 6	321.24004	B 4	331.90283
7	38.71822	5	49.38102
8	116.19641	6	126.85920
9	193.67459	7	204.33739
B 1880	271.36505	B 8	282.02784
1	348.84323	9	359.50603
2	66.32142	1910	76.98421
3	143.79960	1	154.46240
B 4	221.49006	B 2	232.15285
5	298.96824	3	309.63104
6	16.44643	4	27.10922
7	93.92461	5	104.58741
B 8	171.61507	B 6	182.27786
9	249.09325	7	259.75604
1890	326.57144	8	337.23423
1	44.04962	9	54.71242
B 2	121.74008	B 1920	132.40287
3	199.21826	1	209.88105
4	276.69644	2	287.35924
5	354.17463	3	4.83742
B 6	71.86508	B 4	82.52788
7	149.34327	5	160.00606
8	226.82145	6	237.48425
9	304.29964	7	314.96243
1900	21.77782	B 8	32.65289
1	99.25601	9	110.13107
		1930	187.60926

NOTE.—When g is used as an argument of the perturbations add to the g of this table $\Delta\pi=\pi-\pi_0=+0^{\circ}\!.2733$. For explanation see page 203.

Table for beginning of month

Month	g
	°
Jan. 0.0 Jan. 1.0	0.00000
Feb. 0.0 Feb. 1.0	6.58034
Mar. 0.0	12.52387
Apr. 0.0	19.10421
May 0.0	25.47228
June 0.0	32.05262
July 0.0	38.42069
Aug. 0.0	45.00103
Sept. 0.0	51.58137
Oct. 0.0	57.94944
Nov. 0.0	64.52978
Dec. 0.0	70.89785

Change for n days [a]

n	g	n	g
	°		°
1	0.21227	16	3.39632
2	0.42454	17	3.60859
3	0.63681	18	3.82086
4	0.84908	19	4.03313
5	1.06135	20	4.24540
6	1.27362	21	4.45767
7	1.48589	22	4.66994
8	1.69816	23	4.88221
9	1.91043	24	5.09448
10	2.12270	25	5.30675
11	2.33497	26	5.51902
12	2.54724	27	5.73129
13	2.75951	28	5.94356
14	2.97178	29	6.15583
15	3.18405	30	6.36810

[a] For days during January and February of leap years subtract one day before entering this table.

Tables of (139) Juewa—Continued.

PERTURBATIONS.

Arg. $ig-i'g'$		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	0				− 6		+ 1
0	0				+ 0.08nt		+ 2.04nt
+1	0				+ 9		
+1		− 2.01nt	− 17.75nt	− 8.87nt	+ 1.00nt	− 2.44nt	− 7.76nt
+2		+ 1	− 1		− 1	+ 2	− 1
+2		− 0.08nt	− 0.76nt	− 0.76nt	+ 0.08nt	− 0.21nt	− 0.67nt
+3		− 0.01nt	− 0.07nt	− 0.10nt	+ 0.01nt	− 0.03nt	− 0.09nt
+4	0		0.01nt	− 0.01nt			− 0.01nt
−2	+1	+ 1			+ 1	+ 1	
−1		+ 14	+ 1		+ 9	+ 7	− 1
0		+ 56	− 28	+ 3	+ 8	+ 9	− 3
+1		+ 215	− 100	− 33	− 71	− 1	
+2	+1	+ 12	− 7	− 5	− 9	+ 6	− 4
−1	+2	+ 2	− 1	+ 1	+ 2	+ 5	− 2
0		+ 23	+ 3	− 3	+ 8	+21	−16
+1		+ 703	− 942	−161	−111	−16	+13
+2		+ 284	− 410	−235	−163	+ 1	− 6
+3		+ 14	− 22	− 23	− 15	− 1	+ 1
+4	+2	+ 1	− 2	− 3	− 2		
−1	+3		− 1			− 1	+ 1
0		− 4	− 2		− 3	− 7	+10
+1		+ 173	− 424	+ 69	+ 23	− 4	+11
+2		− 177	+ 645	+283	+ 76	+10	−26
+3		− 11	+ 62	+ 50	+ 9	+ 1	− 2
+4		− 1	+ 5	+ 7	+ 1		− 1
+5	+3		+ 1	+ 1			
0	+4	+ 1	− 2	+ 1			+ 2
+1		+ 2	− 18	+ 7			+ 9
+2		+ 16	+ 267	+ 74	− 5		− 9
+3		+ 20	+ 90	+ 55	− 11		− 5
+4	+4	− 2	− 2		+ 1		− 1
0	+5						+ 2
+1		− 13	− 16	+ 8	− 7	+ 6	+26
+2		+2034	+5210	+189	− 78	+ 3	+ 2
+3		+ 395	+ 645	+343	−210	−21	−49
+4		+ 8	+ 18	+ 22	− 12	− 2	− 3
+5		+ 2	+ 3	+ 4	− 3		
+6	+5	+ 1	+ 1	+ 1	− 1		
+1	+6	− 2	− 4	+ 2	− 1		
+2		+ 17	+ 26	− 6	+ 6	− 2	− 4
+3		− 72	− 62	− 23	+ 28	+ 4	+ 4
+4		− 17	− 12	− 7	+ 12	+ 2	+ 1
+5	+6	+ 2			− 2		
+2	+7	0	− 5	+ 2	+ 1		
+3		− 86	− 42	− 4	+ 19		
+4		− 40	− 8	− 5	+ 21		
+5		+ 3			− 1		
+6	+7	− 1			+ 1		
+3	+8	− 80			− 13		
+4		+ 71	− 17	− 9	− 32		
+5		+ 9	− 3	− 2	− 7	− 1	
+6	+8	− 1	+ 1	+ 1	+ 1		

Tables of (139) Juewa—Continued.

TABLE II.—$n\delta z$.

PERIODIC TERMS.

Unit of a and b=0°001.

i	0		1				2, 3	4			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°		a_4	Diff. for 1°	b_4	Diff. for 1°
°											
0	−8.3	−0.45	+294.8	−16.55	−417.2	−10.05	For i=2 and 3. g' is given for every 3 degrees on pages 281 and 282.	+5.6	−0.72	−4.8	−1.06
6	−10.9	−0.41	+190.2	−18.08	−464.4	−5.63		−1.6	−1.40	−8.1	+0.12
12	−13.2	−0.37	+80.3	−18.35	−484.8	−1.16		−9.2	−0.85	−3.4	+1.35
18	−15.3	−0.32	−27.7	−17.47	−478.3	+3.12		−10.2	+0.59	+6.6	+1.73
24	−17.0	−0.26	−127.6	−15.68	−447.3	+6.99		−2.1	+1.98	+15.0	+0.76
30	−18.4	−0.22	−214.3	−13.02	−395.8	+10.07		+11.4	+2.17	+14.2	−1.06
36	−19.6	−0.18	−283.8	−9.99	−328.0	+12.35		+20.9	+0.74	+2.3	−2.62
42	−20.5	−0.14	−334.2	−6.68	−249.2	+13.82		+18.8	−1.39	−14.5	−2.61
48	−21.3	−0.11	−364.0	−3.23	−163.8	+14.43		+4.2	−3.15	−25.9	−0.86
54	−21.8	−0.07	−373.0	+0.12	−77.6	+14.23		−15.8	−3.06	−23.4	+1.72
60	−22.1	−0.02	−362.6	+3.21	+5.5	+13.32		−29.0	−1.05	−6.6	+3.58
66	−22.1	+0.03	−334.5	+5.94	+80.8	+11.62		−26.8	+1.83	+16.0	+3.44
72	−21.7	+0.10	−291.3	+8.26	+144.9	+9.51		−8.6	+3.85	+30.8	+1.18
78	−20.9	+0.16	−236.7	+9.80	+194.9	+7.00		+15.4	+3.68	+28.6	−1.89
84	−19.8	+0.22	−175.0	+10.63	+228.9	+4.28		+31.6	+1.33	+9.8	−4.02
90	−18.2	+0.30	−110.6	+10.75	+246.2	+1.58		+29.8	−1.89	−15.4	−3.82
96	−16.2	+0.38	−47.4	+10.06	+247.8	−0.92		+10.8	−4.04	−32.0	−1.40
102	−13.7	+0.44	+10.2	+8.85	+235.1	−3.03		−14.4	−3.85	−30.7	+1.85
108	−10.9	+0.48	+58.8	+7.29	+211.4	−4.62		−31.4	−1.47	−12.0	+3.96
114	−7.9	+0.49	+97.7	+5.55	+179.6	−5.65		−30.6	+1.69	+12.5	+3.74
120	−5.0	+0.49	+125.4	+3.79	+143.6	−6.08		−13.1	+3.74	+29.0	+1.29
126	−2.0	+0.48	+143.2	+2.22	+106.7	−6.02		+10.0	+3.41	+28.0	−1.63
132	+0.7	+0.42	+152.0	+0.88	+71.3	−5.67		+24.4	+1.04	+11.7	−3.39
138	+3.1	+0.36	+153.8	−0.09	+38.7	−5.11		+22.5	−1.62	−8.6	−2.89
144	+5.0	+0.29	+150.9	−0.72	+10.0	−4.48		+7.2	−3.02	−19.7	−0.56
150	+6.6	+0.22	+145.1	−1.07	−15.0	−3.95		−10.2	−2.32	−15.3	+1.89
156	+7.7	+0.14	+138.1	−1.29	−37.4	−3.60		−17.6	+0.06	+0.4	+2.90
162	+8.3	+0.07	+129.6	−1.48	−58.2	−3.43		−9.5	+2.39	+15.7	+1.78
168	+8.5	+0.02	+120.3	−1.71	−78.6	−3.40		+8.0	+3.01	+19.2	−0.71
174	+8.5	−0.01	+109.1	−2.10	−99.0	−3.47		+22.8	+1.51	+7.2	−3.00
180	+8.4	−0.02	+95.0	−2.68	−120.2	−3.53		+23.8	−1.20	−13.4	−3.36
186	+8.3	−0.02	+76.8	−3.46	−141.4	−3.47		+8.4	−3.54	−29.1	−1.48
192	+8.2	−0.02	+53.5	−4.38	−161.8	−3.22		−15.0	−3.73	−29.0	+1.60
198	+8.1	0.00	+24.3	−5.41	−180.0	−2.66		−32.2	−1.58	−11.4	+3.87
204	+8.2	+0.02	−11.4	−6.42	−193.7	−1.73		−32.1	+1.61	+13.6	+3.98
210	+8.4	+0.05	−52.7	−7.27	−200.8	−0.48		−14.4	+3.96	+32.2	+1.78
216	+8.8	+0.09	−98.6	−7.82	−199.4	+1.12		+11.4	+4.08	+33.1	−1.49
222	+9.5	+0.11	−146.6	−8.05	−187.4	+3.00		+30.4	+1.88	+15.9	−3.86
228	+10.1	+0.11	−195.2	−7.82	−163.4	+5.00		+32.2	−1.34	−9.3	−4.03
234	+10.8	+0.12	−240.4	−6.98	−127.4	+7.01		+16.0	−3.65	−28.2	−1.89
240	+11.5	+0.12	−279.0	−5.64	−79.3	+8.91		−7.6	−3.75	−30.2	+1.19
246	+12.3	+0.13	−308.1	−3.79	−20.5	+10.57		−25.2	−1.77	−15.6	+3.31
252	+13.1	+0.12	−324.5	−1.49	+47.5	+11.78		−27.4	+1.01	+5.8	+3.38
258	+13.7	+0.11	−326.0	+1.16	+120.9	+12.44		−14.6	+2.90	+21.5	+1.47
264	+14.4	+0.12	−310.6	+4.07	+196.8	+12.65		+4.0	+2.90	+23.4	−0.89
270	+15.2	+0.10	−277.2	+7.08	+271.2	+11.97		+17.2	+1.18	+12.4	−2.47
276	+15.6	+0.06	−225.6	+10.00	+339.0	+10.59		+18.2	−0.85	−3.2	−2.35
282	+15.9	+0.04	−157.2	+12.65	+396.7	+8.43		+8.6	−2.06	−13.3	−0.80
288	+16.1	0.00	−73.8	+14.99	+438.6	+5.39		−3.8	−1.74	−12.8	+0.92
294	+15.9	−0.06	+21.3	+16.58	+461.4	+1.87		−10.4	−0.34	−3.9	+1.74
300	+15.4	−0.12	+123.2	+17.21	+461.0	−2.16		−7.9	+1.04	+5.7	+1.20
306	+14.4	−0.19	+225.8	+16.84	+435.5	−6.39		+0.4	+1.46	+9.0	−0.10
312	+13.1	−0.26	+323.0	+15.33	+384.3	−10.58		+7.6	+0.66	+4.5	−1.22
318	+11.3	−0.32	+407.4	+12.61	+308.5	−14.47		+8.3	−0.45	−3.8	−1.28
324	+9.2	−0.41	+472.3	+8.89	+212.2	−17.49		+2.2	−1.28	−9.1	−0.31
330	+6.4	−0.46	+512.5	+4.32	+100.6	−19.49		−5.4	−1.07	−7.5	+0.72
336	+3.7	−0.48	+524.1	−0.56	−19.0	−20.13		−9.2	−0.02	−0.4	+1.32
342	+0.7	−0.52	+505.8	−5.46	−138.2	−19.36		−5.7	+1.03	+6.5	+0.70
348	−2.5	−0.52	+458.6	−10.08	−248.8	−17.31		+1.6	+1.20	+8.0	−0.31
354	−5.5	−0.48	+386.4	−13.82	−343.8	−14.17		+7.0	+0.33	+2.8	−1.23
360	−8.3	−0.45	+294.8	−16.55	−417.2	−10.05		+5.6	−0.72	−4.8	−1.06

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (139) Juewa—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit of *a* and *b*=0°.001.

i	2				3			
g'	a_2	Diff. for 1°	b_2	Diff. for 1°	a_3	Diff. for 1°	b_3	Diff. for 1°
°								
0	+636.4	+143.41	+1661.9	−52.73	+53.6	+14.67	+190.9	−2.32
3	+1040.7	+125.49	+1447.6	−87.73	+99.5	+15.20	+178.5	−5.98
6	+1380.8	+98.69	+1141.6	−116.45	+143.3	+13.73	+155.0	−9.92
9	+1626.8	+65.96	+756.2	−137.99	+181.9	+11.45	+119.0	−13.63
12	+1772.2	+28.66	+323.2	−149.59	+212.0	+7.88	+73.2	−16.83
15	+1797.1	−10.13	−132.0	−152.05	+229.2	+3.42	+18.0	−19.36
18	+1711.4	−48.29	−578.7	−143.70	+232.5	−1.83	−41.6	−20.26
21	+1510.5	−83.22	−985.4	−126.75	+218.2	−7.35	−102.1	−19.76
24	+1218.0	−111.94	−1330.7	−100.91	+188.4	−12.68	−158.4	−17.42
27	+846.0	−133.70	−1584.8	−69.12	+142.1	−17.35	−205.2	−13.67
30	+425.1	−145.78	−1741.0	−32.69	+84.3	−21.14	−239.0	−8.25
33	−19.5	−148.88	−1779.2	+5.33	+17.0	−23.11	−254.7	−2.23
36	−458.0	−141.37	−1709.0	+42.79	−51.4	−21.69	−252.4	+4.22
39	−858.9	−125.23	−1525.5	+77.13	−111.8	−19.00	−229.4	+10.48
42	−1201.0	−100.38	−1252.0	+105.44	−165.4	−17.16	−189.5	+15.92
45	−1455.2	−69.68	−899.8	+126.99	−213.4	−14.07	−133.9	+20.38
48	−1614.6	−34.33	−499.2	+139.03	−246.4	−6.67	−69.0	+22.74
51	−1659.5	+2.53	−74.6	+142.25	−253.4	+0.97	+0.8	+23.41
54	−1599.4	+38.85	−344.3	+135.02	−240.6	+7.42	+69.4	+21.89
57	−1429.4	+72.11	+727.0	+119.47	−208.9	+12.97	+130.5	+18.79
60	−1172.4	+99.44	+1052.9	+95.36	−162.8	+17.57	+180.6	+13.90
63	−839.6	+120.09	+1293.3	+65.51	−104.9	+20.57	+213.9	+8.33
66	−460.8	+131.44	+1441.7	+31.24	−41.2	+21.62	+230.6	+2.30
69	−59.8	+134.17	+1479.1	−4.47	+23.2	+21.09	+227.7	−3.70
72	+334.4	+126.65	+1414.9	−39.57	+83.6	+18.53	+208.4	−9.03
75	+691.7	+110.92	+1244.7	−71.56	+134.4	+15.03	+173.5	−13.50
78	+991.9	+86.81	+991.2	−97.63	+173.8	+10.55	+127.4	−16.68
81	+1207.0	+57.26	+665.7	−117.06	+197.7	+5.50	+73.4	−18.83
84	+1331.4	+23.47	+297.8	−127.14	+206.8	+0.32	+16.0	−18.92
87	+1346.4	−11.57	−88.4	−128.68	+199.6	−4.67	−40.1	−17.97
90	+1262.0	−45.86	−464.6	−120.17	+178.8	−9.03	−91.8	−15.78
93	+1074.4	−76.87	−801.2	−103.67	+145.1	−12.67	−134.8	−12.67
96	+806.6	−101.81	−1078.7	−78.90	+102.8	−15.28	−167.8	−8.83
99	+470.4	−120.03	−1269.1	−48.74	+53.7	−16.87	−187.8	−4.55
102	+95.3	−128.99	−1367.4	−14.43	+1.6	−17.30	−195.1	−0.10
105	−294.8	−129.37	−1355.7	+20.50	−50.1	−16.70	−188.4	+4.32
108	−671.2	−119.59	−1244.4	+54.78	−98.6	−15.08	−169.2	+8.40
111	−1004.2	−101.87	−1030.3	+85.62	−140.6	−12.53	−138.0	+11.97
114	−1274.6	−75.98	−736.6	+110.25	−173.8	−9.10	−97.4	+14.80
117	−1454.7	−44.82	−375.8	+128.01	−195.2	−5.05	−49.2	+16.77
120	−1539.8	−9.60	+22.4	+136.33	−204.1	−0.60	+3.2	+17.72
123	−1512.3	+26.17	+433.3	+135.96	−198.8	+3.98	+57.1	+17.57
126	−1382.8	+61.28	+828.4	+125.43	−180.2	+8.50	+108.6	+16.15
129	−1148.1	+92.79	+1177.6	+106.81	−147.8	+12.57	+154.0	+13.63
132	−832.2	+117.91	+1461.4	+80.03	−104.8	+15.87	+190.4	+9.98
135	−447.8	+136.06	+1652.3	+47.93	−52.6	+18.23	+213.9	+5.57
138	−25.0	+144.66	+1745.2	+11.67	+4.6	+19.57	+223.8	+0.60
141	+411.2	+144.51	+1722.3	−25.13	+63.5	+19.39	+217.5	−4.57
144	+832.2	+134.12	+1594.4	−61.24	+119.4	+17.37	+196.4	−9.60
147	+1207.5	+115.50	+1358.3	−93.77	+167.7	+14.32	+159.9	−14.07
150	+1517.2	+88.53	+1037.8	−119.97	+205.3	+10.15	+112.0	−17.48
153	+1733.1	+56.11	+645.6	−139.16	+228.0	+5.15	+55.0	−19.96
156	+1850.0	+19.67	+212.0	−148.78	+235.6	−0.38	−6.2	−20.61
159	+1849.8	−17.88	−238.1	−149.59	+225.7	−5.83	−67.2	−19.84
162	+1742.7	−54.66	−675.6	−140.06	+200.6	−10.87	−123.6	−17.18
165	+1525.2	−87.94	−1070.0	−122.29	+160.5	−15.32	−170.3	−13.60
168	+1221.0	−115.05	−1401.2	−96.05	+110.0	−18.24	−205.2	−8.97
171	+842.0	−135.25	−1640.6	−64.24	+52.4	−19.87	−224.1	−3.77
174	+418.6	−145.96	−1782.6	−28.26	−7.6	−19.82	−227.8	+1.55
177	−24.8	−147.93	−1808.7	+9.02	−65.2	−18.27	−214.8	+6.63
180	−459.0	−139.54	−1728.5	+45.61	−117.2	−15.63	−188.0	+11.07

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (139) Juewa—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit of a and b=0″.001

i	2				3			
g'	a_2	Diff. for 1°	b_2	Diff. for 1°	a_3	Diff. for 1°	b_3	Diff. for 1°
°								
180	−459.0	−139.54	−1728.5	+45.61	−117.2	−15.63	−188.0	+11.07
183	−853.6	−122.93	−1538.2	+78.92	−159.0	−12.00	−148.4	+14.60
186	−1188.4	−97.84	−1260.8	+106.17	−189.2	−7.60	−100.4	+16.85
189	−1434.9	−61.16	−908.0	+126.72	−204.6	−2.87	−47.3	+17.92
192	−1587.2	−32.21	−509.4	+137.95	−206.4	+1.82	+7.2	+17.72
195	−1626.6	+4.10	−89.1	+140.54	−193.7	+6.23	+59.0	+16.42
198	−1562.6	+39.77	+324.0	+132.86	−169.0	+10.02	+105.7	+14.10
201	−1391.0	+72.32	+699.7	+117.00	−133.6	+13.07	+143.6	+10.95
204	−1134.3	+99.00	+1018.0	+92.82	−90.6	+15.22	+171.4	+7.20
207	−803.8	+119.05	+1251.0	+63.11	−42.3	+16.43	+186.8	+3.10
210	−428.9	+129.82	+1392.6	+29.13	+8.0	+16.55	+190.0	−1.10
213	−33.6	+132.08	+1424.3	−6.17	+57.0	+15.70	+180.2	−5.20
216	+353.9	+124.25	+1355.6	−40.81	+102.2	+13.97	+158.8	−8.98
219	+703.7	+108.38	+1182.5	−72.31	+140.8	+11.40	+126.3	−12.27
222	+996.3	+84.29	+927.4	−97.91	+170.6	+8.00	+85.2	−14.92
225	+1203.9	+54.74	+601.8	−116.85	+188.8	+4.00	+36.8	−16.72
228	+1320.8	+21.07	+235.1	−126.59	+194.6	−0.52	−15.1	−17.48
231	+1329.0	−13.73	−149.1	−127.88	+185.7	−5.17	−68.1	−17.15
234	+1238.4	−47.83	−522.5	−119.08	+163.6	−9.67	−118.0	−15.52
237	+1045.2	−78.64	−855.4	−102.30	+127.7	−13.73	−161.2	−12.73
240	+772.4	−103.41	−1128.5	−77.38	+81.2	−17.08	−194.4	−8.77
243	+431.7	−121.42	−1314.2	−47.11	+25.2	−19.63	−213.8	−3.97
246	+52.9	−130.04	−1407.4	−12.72	−35.0	−20.40	−218.2	+1.53
249	−339.8	−130.12	−1390.5	+22.27	−95.7	−19.74	−204.6	+7.20
252	−718.1	−120.09	−1273.8	+56.65	−151.8	−17.34	−175.0	+12.60
255	−1052.1	−102.04	−1054.0	+87.51	−198.3	−13.54	−129.0	+17.27
258	−1322.5	−75.82	−754.8	+112.06	−231.6	−8.03	−71.4	+20.92
261	−1501.6	−44.35	−388.7	+129.69	−246.5	−1.95	−5.0	+22.89
264	−1584.8	−8.73	+14.2	+137.79	−243.3	+4.57	+64.0	+22.82
267	−1554.0	+27.63	+429.1	+137.13	−219.1	+10.88	+130.1	+21.01
270	−1420.4	+62.72	+827.0	+126.07	−178.0	+16.42	+188.1	+17.10
273	−1181.3	+94.26	+1177.2	+106.88	−120.6	+21.08	+231.3	+11.65
276	−861.0	+119.37	+1460.4	+79.49	−53.4	+23.56	+258.0	+5.32
279	−472.4	+137.29	+1648.7	+46.76	+18.9	+24.26	+263.2	−1.48
282	−46.7	+145.42	+1737.2	+9.90	+90.0	+22.67	+249.1	−8.10
285	+391.0	+144.67	+1708.1	−27.63	+153.2	+19.41	+214.6	−14.28
288	+811.2	+133.36	+1572.8	−63.91	+204.8	+14.23	+164.8	−18.89
291	+1182.6	+113.67	+1328.3	−96.58	+238.6	+8.33	+102.9	−21.93
294	+1485.1	+85.53	+999.7	−122.61	+254.8	+2.00	+35.2	−22.87
297	+1690.2	+51.92	+600.1	−141.35	+250.6	−4.22	−32.6	−22.13
300	+1792.8	+14.12	+161.2	−150.09	+229.5	−9.73	−95.8	−19.27
303	+1774.9	−24.40	−291.1	−149.70	+192.2	−14.48	−148.2	−15.43
306	+1647.8	−61.67	−726.7	−138.56	+141.2	−17.36	−188.4	−10.72
309	+1408.6	−95.30	−1113.8	−118.95	+89.4	−18.95	−212.5	−5.60
312	+1082.4	−122.28	−1432.1	−90.68	+32.1	−18.62	−222.0	−0.57
315	+682.5	−141.89	−1652.1	−56.78	−22.3	−17.32	−215.9	+4.03
318	+240.8	−151.39	−1768.8	−18.55	−71.8	−15.02	−197.8	+7.68
321	−216.4	−151.66	−1763.4	+20.30	−112.4	−12.07	−169.8	+10.47
324	−658.8	−141.11	−1647.0	+58.46	−144.2	−8.88	−135.0	+12.23
327	−1054.2	−121.88	−1416.3	+92.84	−165.7	−5.65	−96.4	+13.22
330	−1381.6	−93.85	−1096.4	+120.54	−178.1	−2.72	−55.7	+13.40
333	−1611.4	−60.07	−700.6	+140.85	−182.0	−0.02	−16.0	+13.05
336	−1737.9	−22.00	−260.9	+151.18	−178.2	+2.32	+22.6	+12.43
339	−1742.0	+17.25	+197.0	+152.24	−168.1	+4.42	+58.6	+11.53
342	−1634.4	+55.68	+642.0	+142.29	−151.7	+6.37	+91.8	+10.53
345	−1411.4	+90.51	+1041.8	+123.61	−129.9	+8.15	+121.8	+9.33
348	−1097.6	+118.79	+1375.2	+96.13	−102.8	+9.93	+147.8	+7.92
351	−706.1	+139.76	+1612.6	+62.79	−70.3	+11.63	+169.3	+6.13
354	−268.6	+150.79	+1747.6	+24.93	−33.0	+13.63	+184.6	+3.85
357	+189.2	+152.59	+1760.6	−14.28	+11.5	+14.43	+192.4	+1.05
360	+636.4	+143.41	+1661.9	−52.73	+53.6	+14.67	+190.9	−2.32

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (139) Juewa—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit of a and b=0.″001.

i	5				6			
g'	a_5	Diff. for 1°	b_5	Diff. for 1°	a_6	Diff. for 1°	b_6	Diff. for 1°
°								
0	+4.5	−0.02	0.0	−0.52	−0.6	+0.03	+0.3	+0.07
6	+3.1	−0.36	−2.9	−0.32	−0.2	+0.08	+0.6	+0.02
12	+0.2	−0.46	−3.9	+0.02	+0.3	+0.07	+0.6	−0.04
18	−2.4	−0.28	−2.6	+0.31	+0.6	+0.02	+0.1	−0.07
24	−3.1	+0.04	−0.2	+0.38	+0.5	−0.03	−0.2	−0.06
30	−1.9	+0.28	+1.9	+0.22	+0.2	−0.07	−0.6	−0.02
36	+0.2	+0.31	+2.5	−0.06	−0.3	−0.06	−0.5	+0.03
42	+1.8	+0.13	+1.2	−0.26	−0.5	−0.01	−0.2	+0.07
48	+1.8	−0.12	−0.6	−0.25	−0.4	+0.03	+0.3	+0.06
54	+0.4	−0.26	−1.8	−0.08	−0.1	+0.05	+0.5	+0.01
60	−1.3	−0.22	−1.5	+0.16	+0.2	+0.04	+0.4	−0.03
66	−2.2	0.00	+0.1	+0.28	+0.4	+0.01	+0.1	−0.05
72	−1.3	+0.22	+1.8	+0.19	+0.3	−0.03	−0.2	−0.03
78	+0.4	+0.29	+2.4	−0.03	0.0	−0.04	−0.3	0.00
84	+2.2	+0.19	+1.4	−0.25	−0.2	−0.02	−0.2	+0.02
90	+2.7	−0.05	−0.6	−0.31	−0.3	0.00	0.0	+0.03
96	+1.6	−0.28	−2.3	−0.18	−0.2	+0.02	+0.2	+0.02
102	−0.6	−0.32	−2.7	+0.07	0.0	+0.03	+0.3	−0.01
108	−2.3	−0.15	−1.5	+0.27	+0.2	+0.01	+0.1	−0.02
114	−2.4	+0.08	+0.5	+0.28	+0.1	−0.01	0.0	−0.02
120	−1.3	+0.23	+1.9	+0.13	+0.1	−0.02	−0.1	−0.01
126	+0.4	+0.25	+2.1	−0.08	−0.1	−0.02	−0.1	+0.01
132	+1.7	+0.09	+0.9	−0.22	−0.1	+0.01	0.0	+0.02
138	+1.5	−0.12	−0.6	−0.19	0.0	+0.02	+0.1	+0.01
144	+0.3	−0.20	−1.4	−0.02	+0.1	+0.01	+0.1	−0.02
150	−0.9	−0.13	−0.9	+0.15	+0.1	−0.01	−0.1	−0.02
156	−1.3	+0.04	+0.4	+0.20	0.0	−0.02	−0.1	−0.01
162	−0.4	+0.19	+1.5	+0.08	−0.1	−0.02	−0.2	+0.01
168	+1.0	+0.17	+1.4	−0.11	−0.3	−0.01	0.0	+0.03
174	+2.0	+0.02	+0.2	−0.25	−0.2	+0.02	+0.2	+0.02
180	+1.7	−0.16	−1.6	−0.24	0.0	+0.03	+0.3	0.00
186	+0.1	−0.31	−2.7	−0.04	+0.2	+0.02	+0.2	−0.02
192	−2.0	−0.25	−2.1	+0.21	+0.3	0.00	0.0	−0.04
198	−2.9	−0.02	−0.2	+0.34	+0.2	−0.03	−0.3	−0.03
204	−2.3	+0.22	+2.0	+0.28	−0.1	−0.05	−0.4	+0.01
210	−0.3	+0.34	+3.1	+0.04	−0.4	−0.03	−0.2	+0.04
216	+1.8	+0.28	+2.5	−0.21	−0.5	+0.01	+0.1	+0.05
222	+3.0	+0.05	+0.6	−0.33	−0.3	+0.06	+0.4	+0.03
228	+2.4	−0.20	−1.5	−0.28	+0.2	+0.07	+0.5	−0.01
234	+0.6	−0.31	−2.6	−0.03	+0.5	+0.03	+0.3	−0.06
240	−1.3	−0.22	−1.9	+0.20	+0.6	−0.02	−0.2	−0.07
246	−2.0	0.00	−0.2	+0.26	+0.2	−0.06	−0.5	−0.03
252	−1.3	+0.18	+1.2	+0.13	−0.1	−0.07	−0.6	+0.02
258	+0.2	+0.21	+1.4	−0.07	−0.6	−0.04	−0.3	+0.07
264	+1.2	+0.08	+0.4	−0.20	−0.6	+0.02	+0.2	+0.08
270	+1.1	−0.12	−1.0	−0.18	−0.3	+0.07	+0.6	+0.03
276	−0.3	−0.26	−1.7	+0.01	+0.2	+0.08	+0.6	−0.02
282	−2.0	−0.17	−0.9	+0.23	+0.6	+0.03	+0.3	−0.08
288	−2.3	+0.08	+1.1	+0.32	+0.6	−0.02	−0.3	−0.08
294	−1.0	+0.32	+2.9	+0.17	+0.3	−0.08	−0.6	−0.03
300	+1.5	+0.38	+3.1	−0.13	−0.3	−0.08	−0.7	+0.02
306	+3.6	+0.20	+1.3	−0.38	−0.7	−0.03	−0.3	+0.08
312	+3.9	−0.14	−1.5	−0.44	−0.7	+0.04	+0.2	+0.08
318	+1.9	−0.43	−4.0	−0.26	−0.2	+0.08	+0.7	+0.04
324	−1.3	−0.50	−4.6	+0.12	+0.3	+0.08	+0.7	−0.03
330	−4.1	−0.30	−2.5	+0.48	+0.7	+0.02	+0.3	−0.08
336	−4.9	+0.09	+1.0	+0.54	+0.6	−0.03	−0.3	−0.08
342	−3.0	+0.44	+3.9	+0.32	+0.3	−0.08	−0.6	−0.02
348	+0.4	+0.53	+4.8	−0.06	−0.3	−0.08	−0.6	+0.03
354	+3 4	+0.34	+3.2	−0.40	−0.6	−0.02	−0.2	+0.08
360	+4.5	−0.02	0.0	−0.52	−0.6	+0.03	+0.3	+0.07

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (139) Juewa—Continued.

TABLE III.—∂ log r.

PERIODIC TERMS.

Unit of a and b=0.00001.

i	0		1				2			
g' °	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
0	+1.4	0.00	−23.0	−1.00	−31.1	+0.27	+ 63.2	−1.66	− 35.8	−5.82
6	+1.4	0.00	−29.4	−1.09	−28.9	+0.49	+ 45.0	−4.28	− 67.6	−4.51
12	+1.4	0.00	−36.1	−1.08	−25.2	+0.78	+ 13.5	−6.00	− 88.2	−2.12
18	+1.3	−0.02	−42.3	−0.93	−19.6	+1.08	− 24.6	−6.45	− 93.2	+0.58
24	+1.2	−0.02	−47.3	−0.68	−12.2	+1.34	− 61.6	−5.65	− 81.3	+3.29
30	+1.1	−0.02	−50.5	−0.37	− 3.5	+1.50	− 90.4	−3.68	− 55.0	+5.27
36	+0.9	−0.03	−51.7	+0.02	+ 5.8	+1.58	−105.7	−1.28	− 19.9	+6.23
42	+0.7	−0.04	−50.3	+0.40	+15.5	+1.55	−105.7	+1.15	+ 17.5	+6.01
48	+0.4	−0.06	−46.9	+0.74	+24.4	+1.40	− 91.9	+3.25	+ 50.2	+4.64
54	0.0	−0.08	−41.4	+1.03	+32.3	+1.19	− 68.4	+4.39	+ 73.2	+2.88
60	−0.5	−0.09	−34.5	+1.27	+38.7	+0.96	− 41.0	+4.58	+ 84.7	+1.02
66	−1.1	−0.10	−26.2	+1.45	+43.8	+0.68	− 15.0	+3.89	+ 85.4	−0.52
72	−1.7	−0.11	−17.1	+1.55	+46.8	+0.37	+ 5.7	+2.85	+ 78.4	−1.54
78	−2.4	−0.11	− 7.6	+1.61	+48.2	+0.06	+ 19.2	+1.77	+ 68.4	−1.62
84	−3.0	−0.10	+ 2.2	+1.63	+47.6	−0.28	+ 26.9	+1.03	+ 59.0	−1.27
90	−3.6	−0.10	+12.0	+1.58	+44.9	−0.63	+ 31.6	+0.84	+ 53.2	−0.65
96	−4.2	−0.08	+21.1	+1.44	+40.0	−0.98	+ 37.0	+1.21	+ 51.2	−0.22
102	−4.6	−0.06	+29.3	+1.21	+33.2	−1.31	+ 46.1	+1.94	+ 50.6	−0.26
108	−4.8	−0.03	+35.6	+0.88	+24.3	−1.62	+ 60.3	+2.69	+ 48.1	−0.92
114	−5.0	−0.02	+39.9	+0.46	+13.7	−1.82	+ 78.4	+3.16	+ 39.6	−2.18
120	−5.0	+0.02	+41.1	−0.04	+ 2.4	−1.90	+ 96.8	+2.84	+ 22.0	−3.73
126	−4.7	+0.07	+39.4	−0.56	− 9.1	−1.86	+110.7	+1.61	− 5.2	−5.21
132	−4.2	+0.08	+34.4	−1.05	−19.9	−1.66	+114.6	−0.50	− 40.5	−6.28
138	−3.7	+0.08	+26.8	−1.46	−29.0	−1.30	+104.7	−2.92	− 78.7	−6.24
144	−3.2	+0.09	+16.9	−1.78	−35.5	−0.83	+ 79.6	−5.28	−113.4	−5.13
150	−2.6	+0.10	+ 5.5	−1.94	−39.0	−0.31	+ 41.4	−7.20	−138.2	−2.97
156	−2.0	+0.09	− 6.4	−1.93	−39.2	+0.23	− 4.8	−8.10	−147.7	−0.08
162	−1.5	+0.07	−17.7	−1.79	−36.2	+0.75	− 53.1	−7.56	−139.3	+2.80
168	−1.2	+0.06	−27.9	−1.52	−30.2	+1.22	− 93.4	−5.83	−114.1	+5.40
174	−0.8	+0.04	−35.9	−1.13	−21.5	+1.56	−121.6	−3.33	− 76.2	+6.99
180	−0.7	+0.02	−41.5	−0.68	−11.5	+1.78	−133.4	−0.58	− 32.6	+7.36
186	−0.5	0.00	−44.1	−0.19	− 0.1	+1.91	−128.6	+2.01	+ 9.7	+6.51
192	−0.7	−0.02	−43.8	+0.29	+11.4	+1.88	−110.5	+3.81	+ 44.0	+4.76
198	−0.8	−0.03	−40.6	+0.74	+22.5	+1.75	− 84.7	+4.61	+ 66.8	+2.75
204	−1.1	−0.03	−34.9	+1.13	+32.4	+1.51	− 57.0	+4.44	+ 77.0	+0.88
210	−1.2	−0.03	−27.0	+1.46	+40.6	+1.21	− 33.0	+3.44	+ 77.3	−0.54
216	−1.5	−0.04	−17.4	+1.68	+46.9	+0.85	− 15.7	+2.32	+ 71.9	−1.11
222	−1.7	−0.03	− 6.9	+1.82	+50.8	+0.46	− 5.2	+1.39	+ 65.4	−0.87
228	−1.9	−0.03	+ 4.5	+1.90	+52.4	+0.06	+ 1.0	+0.96	+ 61.5	−0.30
234	−2.1	−0.03	+15.9	+1.85	+51.5	−0.34	+ 6.3	+1.15	+ 61.8	+0.29
240	−2.3	−0.02	+26.7	+1.73	+48.3	−0.72	+ 14.8	+1.83	+ 65.0	+0.52
246	−2.4	−0.01	+36.7	+1.53	+42.9	−1.07	+ 28.3	+2.69	+ 68.1	+0.13
252	−2.4	−0.01	+45.1	+1.26	+35.5	−1.38	+ 47.1	+3.38	+ 66.6	−0.91
258	−2.5	0.00	+51.8	+0.93	+26.4	−1.62	+ 68.8	+3.57	+ 57.2	−2.38
264	−2.4	+0.02	+56.3	+0.55	+16.1	−1.76	+ 88.3	+2.81	+ 38.1	−3.93
270	−2.3	+0.02	+58.4	+0.10	+ 5.3	−1.83	+100.8	+1.13	+ 10.0	−5.26
276	−2.1	+0.03	+57.5	−0.32	− 5.9	−1.78	+101.9	−0.95	− 23.5	−5.67
282	−1.9	+0.03	+54.6	−0.71	−16.1	−1.59	+ 89.4	−3.15	− 56.4	−5.15
288	−1.7	+0.06	+49.0	−1.08	−25.0	−1.33	+ 64.1	−5.11	− 83.2	−3.59
294	−1.2	+0.07	+41.7	−1.31	−32.1	−0.98	+ 29.6	−6.21	− 97.8	−1.15
300	−0.9	+0.06	+33.3	−1.39	−36.8	−0.61	− 8.3	−6.18	− 97.0	+1.42
306	−0.5	+0.06	+25.0	−1.36	−39.4	−0.28	− 42.2	−4.92	− 80.6	+3.86
312	−0.2	+0.08	+17.0	−1.26	−40.1	+0.02	− 65.5	−2.62	− 52.1	+5.49
318	+0.4	+0.08	+ 9.9	−1.08	−39.1	+0.22	− 73.7	+0.02	− 17.0	+6.00
324	+0.8	+0.06	+ 4.0	−0.89	−37.4	+0.29	− 65.3	+2.58	+ 17.4	+5.25
330	+1.1	+0.03	− 0.8	−0.72	−35.6	+0.27	− 42.7	+4.70	+ 43.7	+3.30
336	+1.2	+0.02	− 4.7	−0.64	−34.2	+0.22	− 10.9	+5.66	+ 55.7	+0.64
342	+1.4	+0.02	− 8.5	−0.64	−33.0	+0.13	+ 22.7	+5.30	+ 51.4	−2.06
348	+1.5	0.00	−12.4	−0.74	−32.6	+0.08	+ 50.3	+3.67	+ 31.0	−4.48
354	+1.4	−0.01	−17.4	−0.88	−32.1	+0.12	+ 64.9	+1.08	− 0.3	−5.79
360	+1.4	0.00	−23.0	−1.00	−31.1	+0.27	+ 63.2	−1.66	− 35.8	−5.82

[$n\partial z$, ∂ log r, and u/cos i are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (139) Juewa—Continued.

TABLE III.—δ log r—Continued.

PERIODIC TERMS.

Unit of a and b=0.00001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	+85.7	−3.39	−41.7	−7.03	+ 1.1	−0.28	− 2.3	+0.05
6	+55.9	−6.31	−77.2	−4.55	− 0.1	−0.02	− 1.0	+0.22
12	+13.0	−7.67	−94.4	−1.04	+ 0.8	+0.22	+ 0.3	+0.06
18	−32.7	−7.24	−89.7	+2.56	+ 2.6	+0.23	− 0.3	−0.28
24	−70.6	−5.14	−63.7	+5.78	+ 3.6	−0.10	− 3.1	−0.53
30	−92.0	−1.72	−23.0	+7.49	+ 1.4	−0.60	− 6.7	−0.39
36	−91.3	+1.96	+22.8	+7.46	− 3.6	−0.88	− 7.8	+0.17
42	−68.5	+5.37	+62.9	+5.58	− 9.2	−0.68	− 4.7	+0.84
48	−29.4	+7.42	+87.0	+2.13	−11.7	+0.06	+ 2.4	+1.22
54	+16.8	+7.57	+88.5	−1.70	− 8.5	+0.95	+10.0	+0.96
60	+57.5	+5.62	+66.6	−5.35	− 0.3	+1.45	+13.8	+0.09
66	+81.2	+1.96	+27.0	−7.49	+ 8.9	+1.20	+11.1	−0.95
72	+81.0	−2.05	−19.1	−7.45	+14.1	+0.28	+ 2.4	−1.58
78	+56.6	−5.75	−58.1	−5.15	+12.3	−0.86	− 7.9	−1.37
84	+15.4	−7.58	−77.8	−1.18	+ 3.8	−1.61	−14.0	−0.41
90	−29.9	−7.05	−72.2	+3.04	− 7.0	−1.50	−12.8	+0.79
96	−65.0	−4.29	−43.0	+6.36	14.1	−0.55	− 4.5	+1.58
102	−78.7	−0.13	+ 0.3	+7.64	−13.6	+0.68	+ 6.2	+1.52
108	−66.6	+4.02	+44.1	+6.53	− 6.1	+1.48	+13.8	+0.68
114	−33.0	+6.83	+74.9	+3.41	+ 4.2	+1.48	+14.4	−0.48
120	+11.4	+7.58	+83.2	−0.63	+11.8	+0.76	+ 8.1	−1.29
126	+53.8	+6.17	+67.3	−4.47	+13.3	−0.28	− 1.1	−1.34
132	+82.2	+3.05	+32.1	−6.93	+ 8.5	−0.98	− 8.0	−0.68
138	+89.0	−0.74	−12.3	−7.48	+ 1.5	−0.99	− 9.3	+0.18
144	+73.3	−4.30	−53.9	−6.11	− 3.4	−0.42	− 5.9	+0.68
150	+39.6	−6.67	−82.9	−3.31	− 3.6	+0.26	− 1.2	+0.58
156	− 3.6	−7.40	−92.2	+0.24	− 0.3	+0.52	+ 1.0	+0.01
162	−45.9	−6.42	−80.0	+3.74	+ 2.8	+0.22	− 1.1	−0.54
168	−77.6	−3.90	−49.0	+6.35	+ 2.4	−0.44	− 5.5	−0.61
174	−90.8	−0.36	− 6.7	+7.47	− 2.6	−0.96	− 8.4	−0.08
180	−81.9	+3.32	+37.1	+6.77	− 9.1	−0.87	− 6.5	+0.74
186	−52.4	+6.28	+71.1	+4.25	−13.0	−0.15	+ 0.5	+1.31
192	− 9.6	+7.63	+85.8	+0.46	−10.9	+0.86	+ 9.2	+1.18
198	+35.0	+6.83	+76.6	−3.50	− 2.7	+1.52	+14.7	+0.34
204	+68.5	+3.99	+45.6	−6.58	+ 7.4	+1.41	+13.3	−0.78
210	+80.5	−0.14	+ 1.4	−7.71	+14.2	+0.53	+ 5.3	−1.54
216	+66.8	−4.29	−42.4	−6.46	+13.8	−0.64	− 5.2	−1.50
222	+31.5	−7.10	−72.2	−3.11	+ 6.5	−1.46	−12.7	−0.68
228	−14.1	−7.67	−77.8	+1.20	− 3.8	−1.52	−13.4	+0.48
234	−55.8	−5.78	−57.8	+5.24	−11.7	−0.77	− 7.0	+1.33
240	80.0	−1.97	−18.0	+7.57	−13.0	+0.33	+ 2.6	+1.43
246	−79.4	+2.29	+28.5	+7.48	− 7.7	+1.14	+10.2	+0.79
252	−53.9	+5.93	+67.6	+5.19	+ 0.8	+1.28	+12.1	−0.17
258	−11.7	+7.73	+87.9	+1.32	+ 7.7	+0.78	+ 8.2	−0.90
264	+34.7	+7.33	+83.5	−2.76	+10.0	−0.02	+ 1.3	−1.06
270	+72.5	+4.97	+56.5	−6.00	+ 7.4	−0.62	− 4.5	−0.65
276	+91.9	+1.31	+14.6	−7.61	+ 2.6	−0.73	− 6.5	−0.02
282	+88.2	−2.49	−31.1	−7.27	− 1.4	−0.43	− 4.8	+0.39
288	+63.4	−5.61	−69.3	−5.19	− 2.6	+0.02	− 1.8	+0.40
294	+23.5	−7.38	−91.1	−1.86	− 1.2	+0.26	0.0	+0.12
300	−21.8	−7.42	−91.6	+1.69	+ 0.5	+0.14	− 0.4	−0.17
306	−62.2	−5.74	−70.8	+5.02	+ 0.5	−0.17	− 2.0	−0.22
312	−88.0	−2.60	−33.5	+7.14	− 1.5	−0.37	− 3.1	0.00
318	−93.4	+0.94	+11.8	+7.63	− 3.9	−0.28	− 2.0	+0.35
324	−76.7	+4.49	+54.6	+6.33	− 4.9	+0.05	+ 1.1	+0.52
330	−41.5	+6.95	+84.7	+3.46	− 3.3	+0.41	+ 4.2	+0.37
336	+ 3.6	+7.79	+94.4	−0.28	0.0	+0.55	+ 5.5	−0.01
342	+48.4	+6.77	+81.3	−3.99	+ 3.3	+0.38	+ 4.1	−0.38
348	+81.6	+4.03	+48.5	−6.71	+ 4.5	0.00	+ 0.9	−0.48
354	+95.0	+0.34	+ 3.9	−7.82	+ 3.3	−0.28	− 1.6	−0.26
360	+85.7	−3.39	−41.7	−7.03	+ 1.1	−0.28	− 2.3	+0.05

[$n\delta z$, δ log r, and u cos i are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (139) Juewa—Continued.

TABLE III.—$\delta \log r$—Continued.

PERIODIC TERMS. Unit of a and b=0.00001.

i	5				6			
g'	a_5	Diff. for 1°	b_5	Diff. for 1°	a_6	Diff. for 1°	b_6	Diff. for 1°
°								
0	+0.6	−0.32	−2.9	−0.02	+0.5		+0.1	
6	−1.3	−0.23	−2.3	+0.18	+0.5		−0.2	
12	−2.2	−0.02	−0.7	+0.27	+0.2		−0.5	
18	−1.6	+0.14	+0.9	+0.18	−0.2		−0.6	
24	−0.5	+0.19	+1.4	+0.01	−0.5		−0.4	
30	+0.7	+0.12	+1.0	−0.13	−0.6		0.0	
36	+1.0	−0.03	−0.2	−0.15	−0.5		+0.4	
42	+0.3	−0.12	−0.8	−0.05	−0.2		+0.5	
48	−0.5	−0.12	−0.8	+0.08	+0.2		+0.5	
54	−1.1	−0.01	+0.2	+0.16	+0.5		+0.3	
60	−0.6	+0.13	+1.1	+0.09	+0.5		0.0	
66	+0.5	+0.17	+1.3	−0.05	+0.4		−0.3	
72	+1.4	+0.08	+0.5	−0.18	+0.2		−0.3	
78	+1.5	−0.08	−0.8	−0.18	0.0		−0.3	
84	+0.5	−0.19	−1.7	−0.08	−0.2		−0.2	
90	−0.8	−0.21	−1.7	+0.08	−0.2		−0.2	
96	−2.0	−0.10	−0.7	+0.22	−0.2		0.0	
102	−2.0	+0.09	+0.9	+0.22	−0.2		+0.1	
108	−0.9	+0.22	+2.0	+0.09	−0.2		+0.2	
114	+0.7	+0.22	+2.0	−0.08	−0.1		+0.3	
120	+1.7	+0.09	+1.1	−0.20	+0.1		+0.3	
126	+1.8	−0.06	−0.4	−0.20	+0.3		+0.2	
132	+1.0	−0.16	−1.3	−0.08	+0.4		0.0	
138	−0.1	−0.15	−1.4	+0.07	+0.3		−0.2	
144	−0.8	−0.03	−0.5	+0.12	+0.2		−0.3	
150	−0.5	+0.08	+0.2	+0.08	−0.1		−0.3	
156	+0.2	+0.12	+0.5	−0.02	−0.2		−0:2	
162	+0.9	+0.05	0.0	−0.13	−0.3		−0.1	
168	+0.8	−0.10	−1.1	−0.13	−0.2		+0.2	
174	−0.3	−0.19	−1.6	−0.01	−0.1		+0.2	
180	−1.5	−0.18	−1.2	+0.15	0.0		+0.1	
186	−2.4	−0.02	+0.2	+0.24	0.0		+0.1	
192	−1.7	+0.16	+1.7	+0.20	−0.1		+0.1	
198	−0.4	+0.27	+2.6	+0.05	−0.1		+0.2	
204	+1.5	+0.24	+2.3	−0.16	0.0		+0.2	
210	+2.5	+0.07	+0.7	−0.28	+0.3		+0.3	
216	+2.3	−0.12	−1.1	−0.25	+0.5		+0.1	
222	+1.1	−0.25	−2.3	−0.08	+0.5		−0.2	
228	−0.7	−0.23	−2.1	+0.12	+0.2		−0.6	
234	−1.7	−0.08	−0.9	+0.22	−0.2		−0.6	
240	−1.7	+0.08	+0.5	+0.18	−0.6		−0.5	
246	−0.8	+0.18	+1.3	+0.05	−0.7		−0.1	
252	+0.4	+0.14	+1.1	−0.07	−0.6		+0.5	
258	+0.9	+0.02	+0.5	−0.12	−0.2		+0.8	
264	+0.6	−0.08	−0.4	−0.08	+0.3		+0.7	
270	−0.1	−0.09	−0.5	+0.04	+0.7		+0.3	
276	−0.5	−0.01	+0.1	+0.11	+0.7		−0.2	
282	−0.2	+0.11	+0.8	+0.06	+0.4		−0.5	
288	+0.8	+0.15	+0.8	−0 06	−0.2		−0.6	
294	+1.6	+0.05	+0.1	−0.18	−0.4		−0.5	
300	+1.4	−0.11	−1.3	−0.20	−0.5		0.0	
306	+0.3	−0.23	−2.4	−0.08	−0.3		+0.2	
312	−1.4	−0.28	−2.4	+0.12	−0.1		+0.3	
318	−3.0	−0.14	−0.9	+0.30	+0.2		+0.2	
324	−3.1	+0.11	+1.3	+0.33	+0.2		0.0	
330	−1.7	+0.32	+3.1	+0.19	0.0		−0.2	
336	+0.8	+0.37	+3.6	−0.07	−0.2		−0.1	
342	+2.7	+0.22	+2.3	−0.28	−0.2		+0.2	
348	+3.5	−0.01	+0.2	−0.36	0.0		+0.3	
354	+2.6	−0.24	−2.0	−0.26	+0.2		+0.3	
360	+0.6	−0.32	−2.9	−0.02	+0.5		+0.1	

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (139) Juewa—Continued.

TABLE IV.—u/cos i.

PERIODIC TERMS.

Unit of *a* and *b*=0°.001

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	− 0.5	−0.15	− 7.4	+1.06	+15.8	+0.02	+ 5.2	−0.70	−13.7	−0.21
6	− 1.8	−0.22	− 0.9	+0.96	+14.6	−0.39	+ 0.8	−0.69	−14.1	+0.07
12	− 3.2	−0.26	+ 4.2	+0.64	+11.1	−0.72	− 3.1	−0.59	−12.9	+0.28
18	− 4.9	−0.28	+ 6.8	+0.28	+ 6.0	−0.87	− 6.3	−0.46	−10.8	+0.42
24	− 6.6	−0.25	+ 7.5	−0.08	+ 0.7	−0.78	− 8.6	−0.28	− 7.8	+0.52
30	− 7.9	−0.20	+ 6.0	−0.34	− 3.4	−0.56	− 9.6	−0.08	− 4.6	+0.53
36	− 9.0	−0.12	+ 3.5	−0.47	− 5.9	−0.22	− 9.6	+0.08	− 1.4	+0.51
42	− 9.4	−0.02	+ 0.4	−0.42	− 6.1	+0.08	− 8.7	+0.20	+ 1.5	+0.44
48	− 9.4	+0.06	− 1.6	−0.22	− 4.9	+0.30	− 7.2	+0.31	+ 3.9	+0.35
54	− 8.8	+0.13	− 2.2	+0.04	− 2.6	+0.42	− 5.0	+0.39	+ 5.7	+0.24
60	− 7.8	+0.21	− 1.1	+0.32	+ 0.2	+0.36	− 2.5	+0.42	+ 6.8	+0.11
66	− 6.3	+0.26	+ 1.7	+0.51	+ 1.7	+0.15	+ 0.1	+0.43	+ 7.0	−0.03
72	− 4.7	+0.28	+ 5.0	+0.55	+ 2.0	−0.08	+ 2.7	+0.41	+ 6.4	−0.18
78	− 3.0	+0.29	+ 8.3	+0.44	+ 0.7	−0.34	+ 5.0	+0.34	+ 4.9	−0.32
84	− 1.2	+0.30	+10.4	+0.18	− 2.1	−0.50	+ 6.8	+0.21	+ 2.6	−0.41
90	+ 0.6	+0.30	+10.5	−0.14	− 5.3	−0.52	+ 7.5	+0.02	0.0	−0.45
96	+ 2.4	+0.30	+ 8.7	−0.41	− 8.4	−0.42	+ 7.1	−0.13	− 2.8	−0.42
102	+ 4.2	+0.27	+ 5.6	−0.58	−10.4	−0.17	+ 5.9	−0.29	− 5.1	−0.32
108	+ 5.6	+0.22	+ 1.7	−0.65	−10.4	+0.13	+ 3.6	−0.38	− 6.7	−0.20
114	+ 6.9	+0.18	− 2.2	−0.55	− 8.8	+0.40	+ 1.3	−0.38	− 7.5	−0.03
120	+ 7.8	+0.12	− 4.9	−0.33	− 5.6	+0.57	− 0.9	−0.34	− 7.1	+0.12
126	+ 8.3	+0.02	− 6.2	−0.07	− 2.0	+0.58	− 2.8	−0.23	− 6.0	+0.22
132	+ 8.2	−0.08	− 5.7	+0.19	+ 1.4	+0.48	− 3.7	−0.11	− 4.5	+0.24
138	+ 7.5	−0.17	− 3.9	+0.36	+ 3.8	+0.27	− 4.1	−0.03	− 3.1	+0.21
144	+ 6.2	−0.25	− 1.4	+0.42	+ 4.6	−0.02	− 4.1	+0.02	− 2.0	+0.13
150	+ 4.5	−0.32	+ 1.1	+0.32	+ 3.6	−0.28	− 3.8	+0.04	− 1.5	+0.07
156	+ 2.3	−0.39	+ 2.5	+0.12	+ 1.3	−0.41	− 3.6	+0.02	− 1.2	+0.04
162	− 0.2	−0.39	+ 2.5	−0.13	− 1.3	−0.41	− 3.7	−0.06	− 1.0	+0.06
168	− 2.4	−0.37	+ 0.9	−0.34	− 3.6	−0.31	− 4.3	−0.11	− 0.5	+0.12
174	− 4.6	−0.32	− 1.6	−0.44	− 5.0	−0.08	− 5.0	−0.09	+ 0.4	+0.21
180	− 6.3	−0.23	− 4.4	−0.42	− 4.6	+0.22	− 5.4	0.00	+ 2.0	+0.29
186	− 7.4	−0.14	− 6.7	−0.25	− 2.4	+0.46	− 5.0	+0.14	+ 3.9	+0.31
192	− 8.0	−0.06	− 7.4	+0.02	+ 0.9	+0.58	− 3.7	+0.29	+ 5.7	+0.26
198	− 8.1	+0.02	− 6.5	+0.29	+ 4.6	+0.58	− 1.5	+0.41	+ 7.0	+0.14
204	− 7.6	+0.12	− 3.9	+0.54	+ 7.9	+0.43	+ 1.2	+0.46	+ 7.4	−0.05
210	− 6.7	+0.18	0.0	+0.67	+ 9.8	+0.18	+ 4.0	+0.42	+ 6.4	−0.25
216	− 5.4	+0.24	+ 4.1	+0.65	+10.1	−0.10	+ 6.2	+0.28	+ 4.4	−0.41
222	− 3.8	+0.28	+ 7.8	+0.52	+ 8.6	−0.34	+ 7.3	+0.07	+ 1.5	−0.48
228	− 2.0	+0.30	+10.4	+0.27	+ 6.0	−0.47	+ 7.0	−0.12	− 1.3	−0.47
234	− 0.2	+0.33	+11.0	−0.04	+ 3.0	−0.50	+ 5.8	−0.29	− 4.1	−0.38
240	+ 2.0	+0.35	+ 9.9	−0.29	0.0	−0.39	+ 3.5	−0.41	− 5.8	−0.19
246	+ 4.0	+0.34	+ 7.5	−0.42	− 1.7	−0.13	+ 0.9	−0.43	− 6.4	−0.02
252	+ 6.1	+0.32	+ 4.8	−0.45	− 1.6	+0 11	− 1.7	−0.39	− 6.0	+0.14
258	+ 7.8	+0.26	+ 2.1	−0.32	− 0.4	+0.30	− 3.8	−0.31	− 4.7	+0.27
264	+ 9.2	+0.20	+ 1.0	−0.07	+ 2.0	+0.38	− 5.4	−0.19	− 2.8	+0.34
270	+10.2	+0.10	+ 1.3	+0.16	+ 4.1	+0.28	− 6.1	−0.06	− 0.6	+0.35
276	+10.4	0.00	+ 2.9	+0.34	+ 5.3	+0.09	− 6.1	+0.05	+ 1.4	+0.34
282	+10.2	−0.08	+ 5.4	+0.38	+ 5.2	−0.19	− 5.5	+0.12	+ 3.5	+0.32
288	+ 9.4	−0.18	+ 7.5	+0.27	+ 3.0	−0.52	− 4.6	+0.20	+ 5.3	+0.30
294	+ 8.1	−0.25	+ 8.6	+0.02	− 1.0	−0.72	− 3.1	+0.29	+ 7.1	+0.27
300	+ 6.4	−0.27	+ 7.8	−0.33	− 5.6	−0.77	− 1.1	+0.38	+ 8.5	+0.19
306	+ 4.9	−0.25	+ 4.6	−0.69	−10.2	−0.67	+ 1.4	+0.45	+ 9.4	+0.08
312	+ 3.4	−0.22	− 0.5	−0.96	−13.6	−0.37	+ 4.3	+0.51	+ 9.5	−0.06
318	+ 2.3	−0.17	− 6.9	−1.08	−14.6	+0.05	+ 7.5	+0.52	+ 8.7	−0.22
324	+ 1.4	−0.12	−13.4	−0.98	−13.0	+0.50	+10.5	+0.44	+ 6.8	−0.42
330	+ 0.9	−0.05	−18.7	−0.69	− 8.6	+0.88	+12.8	+0.31	+ 3.7	−0.60
336	+ 0.8	−0.01	−21.7	−0.27	− 2.4	+1.06	+14.2	+0.09	− 0.4	−0.69
342	+ 0.8	−0.02	−21.9	+0.23	+ 4.1	+1.05	+13.9	−0.18	− 4.6	−0.68
348	+ 0.6	−0.07	−18.9	+0.69	+10.2	+0.86	+12.0	−0.39	− 8.5	−0.58
354	0.0	−0.09	−13.6	+0.96	+14.4	+0.47	+ 9.2	−0.57	−11.6	−0.43
360	− 0.5	−0.15	− 7.4	+1.06	+15.8	+0.02	+ 5.2	−0.70	−13.7	−0.21

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (139) Juewa—Continued.

TABLE IV.—$u/\cos i$—Continued.

PERIODIC TERMS. Unit of *a* and *b*=0°.0001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	−4.8	−1.13	−14.1	+0.37	−0.1		−1.0	
6	−11.0	−0.81	−10.2	+0.88	−0.5		−1.0	
12	−14.5	−0.30	−3.5	+1.18	−0.9		−0.6	
18	−14.6	+0.31	+4.0	+1.17	−1.2		−0.1	
24	−10.8	+0.85	+10.5	+0.87	−1.2		+0.5	
30	−4.4	+1.16	+14.4	+0.36	−0.8		+1.0	
36	+3.1	+1.19	+14.8	−0.26	−0.2		+1.3	
42	+9.9	+0.92	+11.3	−0.81	+0.5		+1.3	
48	+14.1	+0.39	+5.1	−1.16	+1.1		+0.9	
54	+14.6	−0.24	−2.6	−1.22	+1.5		+0.1	
60	+11.2	−0.80	−9.5	−0.92	+1.4		−0.5	
66	+5.0	−1.16	−13.7	−0.39	+0.9		−1.2	
72	−2.7	−1.21	−14.2	+0.25	+0.1		−1.5	
78	−9.5	−0.91	−10.7	+0.82	−0.7		−1.4	
84	−13.6	−0.38	−4.4	+1.18	−1.3		−0.8	
90	−13.9	+0.28	+3.4	+1.22	−1.5		0.0	
96	−10.2	+0.88	+10.2	+0.88	−1.3		+0.8	
102	−3.4	+1.22	+14.0	+0.31	−0.6		+1.3	
108	+4.5	+1.21	+13.9	−0.35	+0.2		+1.5	
114	+11.1	+0.86	+9.8	−0.94	+1.0		+1.1	
120	+14.8	+0.27	+2.6	−1.28	+1.3		+0.5	
126	+14.3	−0.44	−5.6	−1.22	+1.4		−0.5	
132	+9.5	−1.02	−12.1	−0.82	+0.9		−1.1	
138	+2.1	−1.30	−15.5	−0.22	+0.2		−1.4	
144	−6.1	−1.23	−14.7	+0.49	−0.7		−1.3	
150	−12.7	−0.82	−9.6	+1.08	−1.2		−0.8	
156	−15.9	−0.17	−1.8	+1.33	−1.4		0.0	
162	−14.7	+0.54	+6.4	+1.22	−1.5		+0.8	
168	−9.4	+1.09	+12.8	+0.77	−0.5		+1.4	
174	−1.6	+1.32	+15.6	+0.11	+0.4		+1.3	
180	+6.4	+1.18	+14.1	−0.58	+1.1		+1.0	
186	+12.6	+0.72	+8.6	−1.08	+1.5		+0.3	
192	+15.1	+0.05	+1.1	−1.28	+1.3		−0.6	
198	+13.2	−0.62	−6.8	−1.13	+0.8		−1.3	
204	+7.6	−1.10	−12.5	−0.68	0.0		−1.5	
210	0.0	−1.26	−14.4	+0.02	−0.8		−1.2	
216	−7.5	−1.05	−12.2	+0.66	−1.4		−0.7	
222	−12.6	−0.57	−6.5	+1.11	−1.5		+0.1	
228	−14.3	+0.05	+1.1	+1.24	−1.2		+0.9	
234	−12.0	+0.71	+8.4	+1.02	−0.5		+1.3	
240	−5.8	+1.15	+13.3	+0.51	+0.2		+1.5	
246	+1.8	+1.22	+14.5	−0.12	+0.9		+1.0	
252	+8.9	+0.99	+11.8	−0.72	+1.3		+0.5	
258	+13.7	+0.51	+5.9	−1.13	+1.3		−0.2	
264	+15.0	−0.12	−1.8	−1.24	+0.9		−0.8	
270	+12.3	−0.73	−9.0	−1.00	+0.5		−1.2	
276	+6.2	−1.12	−13.8	−0.52	−0.1		−1.2	
282	−1.2	−1.21	−15.2	+0.09	−0.6		−0.9	
288	−8.3	−1.02	−12.7	+0.68	−1.0		−0.5	
294	−13.5	−0.58	−7.0	+1.08	−1.0		−0.1	
300	−15.2	+0.03	+0.2	+1.20	−0.9		+0.5	
306	−13.1	+0.61	+7.4	+1.06	−0.6		+0.7	
312	−7.9	+1.03	+12.9	+0.62	−0.3		+0.9	
318	−0.7	+1.20	+14.9	+0.04	+0.2		+0.8	
324	+6.5	+1.07	+13.4	−0.52	+0.5		+0.7	
330	+12.1	+0.68	+8.6	−0.97	+0.8		+0.4	
336	+14.7	+0.13	+1.8	−1.18	+0.8		0.0	
342	+13.7	−0.46	−5.6	−1.12	+0.9		−0.4	
348	+9.2	−0.92	−11.6	−0.75	+0.7		−0.6	
354	+2.6	−1.17	−14.6	−0.21	+0.4		−0.9	
360	−4.8	−1.13	−14.1	+0.37	−0.1		−1.0	

[$n\delta z$, $\partial \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (139) Juewa—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY $T=(t-t_0)$ IN JULIAN YEARS.

g	$n\delta z$ Unit of c=0°.001		$\delta \log r$ Unit of c=0.00001		$u/\cos i$ Unit of c=0°.001	
	c	Diff. for 1°	c	Diff. for 1°	c	Diff. for 1°
°						
0	−7.00	−0.013	+0.33	−0.052	−2.44	−.019
6	−7.04	0.000	+0.02	−0.052	−2.53	−.012
12	−7.00	+0.015	−0.30	−0.052	−2.57	−.002
18	−6.86	+0.030	−0.61	−0.052	−2.56	+.006
24	−6.64	+0.044	−0.92	−0.050	−2.52	+.012
30	−6.33	+0.057	−1.21	−0.045	−2.42	+.019
36	−5.96	+0.068	−1.46	−0.042	−2.29	+.026
42	−5.52	+0.080	−1.70	−0.038	−2.11	+.032
48	−5.01	+0.090	−1.91	−0.032	−1.91	+.036
54	−4.44	+0.098	−2.08	−0.026	−1.68	+.042
60	−3.84	+0.103	−2.22	−0.022	−1.40	+.046
66	−3.20	+0.109	−2.35	−0.018	−1.12	+.048
72	−2.53	+0.112	−2.43	−0.010	−0.83	+.050
78	−1.86	+0.114	−2.47	−0.006	−0.53	+.052
84	−1.16	+0.117	−2.50	−0.002	−0.21	+.052
90	−0.46	+0.116	−2.50	+0.002	+0.10	+.052
96	+0.23	+0.115	−2.47	+0.007	+0.42	+.052
102	+0.92	+0.112	−2.42	+0.010	+0.72	+.050
108	+1.58	+0.108	−2.35	+0.015	+1.02	+.049
114	+2.22	+0.104	−2.24	+0.018	+1.31	+.047
120	+2.83	+0.099	−2.13	+0.020	+1.58	+.046
126	+3.41	+0.092	−2.00	+0.023	+1.86	+.043
132	+3.94	+0.086	−1.85	+0.026	+2.10	+.040
138	+4.44	+0.079	−1.69	+0.028	+2.34	+.038
144	+4.89	+0.070	−1.52	+0.030	+2.56	+.035
150	+5.28	+0.062	−1.33	+0.034	+2.76	+.030
156	+5.63	+0.052	−1.11	+0.035	+2.92	+.029
162	+5.91	+0.042	−0.91	+0.034	+3.11	+.027
168	+6.14	+0.033	−0.70	+0.037	+3.24	+.021
174	+6.31	+0.023	−0.47	+0.038	+3.36	+.018
180	+6.42	+0.012	−0.24	+0.038	+3.46	+.014
186	+6.46	+0.002	−0.02	+0.038	+3.53	+.010
192	+6.44	−0.008	+0.21	+0.039	+3.58	+.006
198	+6.36	−0.020	+0.45	+0.039	+3.60	+.002
204	+6.20	−0.031	+0.68	+0.037	+3.60	−.002
210	+5.99	−0.040	+0.89	+0.036	+3.56	−.008
216	+5.72	−0.049	+1.11	+0.036	+3.51	−.011
222	+5.40	−0.059	+1.32	+0.034	+3.43	−.015
228	+5.01	−0.070	+1.52	+0.032	+3.33	−.019
234	+4.56	−0.078	+1.71	+0.029	+3.20	−.024
240	+4.08	−0.085	+1.87	+0.027	+3.04	−.028
246	+3.54	−0.092	+2.03	+0.026	+2.86	−.032
252	+2.97	−0.098	+2.18	+0.022	+2.65	−.036
258	+2.36	−0.104	+2.30	+0.019	+2.43	−.038
264	+1.72	−0.110	+2.41	+0.017	+2.19	−.042
270	+1.04	−0.114	+2.50	+0.012	+1.92	−.048
276	+0.35	−0.117	+2.56	+0.008	+1.62	−.050
282	−0.36	−0.119	+2.60	+0.004	+1.32	−.052
288	−1.08	−0.118	+2.61	−0.002	+1.00	−.056
294	−1.78	−0.118	+2.58	−0.006	+0.65	−.057
300	−2.49	−0.116	+2.54	−0.012	+0.32	−.056
306	−3.17	−0.111	+2.44	−0.018	−0.02	−.058
312	−3.82	−0.106	+2.32	−0.022	−0.38	−.058
318	−4.44	−0.099	+2.18	−0.028	−0.72	−.055
324	−5.01	−0.090	+1.99	−0.034	−1.04	−.053
330	−5.52	−0.080	+1.77	−0.039	−1.36	−.048
336	−5.97	−0.069	+1.52	−0.044	−1.62	−.044
342	−6.35	−0.056	+1.24	−0.047	−1.89	−.040
348	−6.64	−0.044	+0.96	−0.049	−2.10	−.034
354	−6.88	−0.030	+0.65	−0.052	−2.30	−.028
360	−7.00	−0.013	+0.33	−0.052	−2.44	−.019

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (139) Juewa—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	A'	B'	C'	log sin a	log sin b	log sin c
	°	°	°			
1874. 0	254. 2692	164. 5411	163. 6877	9. 99999	9. 91669	9. 75166
5	254. 2829	164. 5566	163. 6975	9. 99999	9. 91669	9. 75166
6	2966	5721	7074	99	69	65
7	3103	5876	7172	99	69	65
8	3240	6031	7271	99	70	65
9	3377	6186	7370	99	70	65
1880	254. 3514	164. 6341	163. 7468	9. 99999	9. 91670	9. 75165
1	3651	6496	7567	99	70	65
2	3788	6651	7666	99	70	65
3	3925	6806	7764	99	70	65
4	4062	6961	7863	99	70	65
1885	254. 4199	164. 7116	163. 7961	9. 99999	9. 91670	9. 75164
6	4336	7271	8060	99	70	64
7	4473	7425	8159	99	70	64
8	4610	7580	8257	99	70	64
9	4747	7735	8356	99	70	64
1890	254. 4884	164. 7890	163. 8455	9. 99999	9. 91670	9. 75164
1	5021	8045	8554	99	70	64
2	5158	8200	8652	99	70	64
3	5295	8355	8751	99	71	64
4	5432	8510	8850	99	71	64
1895	254. 5569	164. 8665	163. 8948	9. 99999	9. 91671	9. 75164
6	5706	8820	9047	99	71	63
7	5843	8975	9146	99	71	63
8	5980	9130	9244	99	71	63
9	6117	9285	9343	99	71	63
1900	254. 6254	164. 9440	163. 9441	9. 99999	9. 91671	9. 75163
1	6391	9595	9540	99	71	63
2	6528	9750	9638	99	71	63
3	6665	164. 9905	9737	99	71	63
4	6803	165. 0060	9836	99	71	63
1905	254. 6940	165. 0215	163. 9934	9. 99999	9. 91671	9. 75162
6	7077	0370	164. 0033	99	71	62
7	7214	0525	0131	99	71	62
8	7351	0681	0230	99	72	62
9	7488	0836	0329	99	72	62
1910	254. 7625	165. 0991	164. 0427	9. 99999	9. 91672	9. 75162
1	7762	1146	0526	99	72	62
2	7900	1301	0625	99	72	62
3	8037	1456	0723	99	72	62
4	8174	1611	0822	99	72	62
1915	254. 8311	165. 1766	164. 0920	9. 99998	9. 91672	9. 75162
6	8448	1921	1019	98	72	61
7	8585	2076	1118	98	72	61
8	8722	2231	1216	98	72	61
9	8859	2386	1315	98	72	61
1920	254. 8997	165. 2541	164. 1414	9. 99998	9. 91672	9. 75161
1	9134	2696	1512	98	72	61
2	9271	2852	1611	98	72	61
3	9408	3007	1710	98	73	61
4	9545	3162	1808	98	73	61
1925	254. 9682	165. 3317	164. 1907	9. 99998	9. 91673	9. 75160
6	9819	3472	2005	98	73	60
7	254. 9957	3627	2104	98	73	60
8	255. 0094	3782	2203	98	73	60
9	0231	3937	2301	98	73	60
1930	255. 0368	165. 4092	164. 2400	9. 99998	9. 91673	9. 75160

Year	log cos a	log cos b	log cos c
1874. 0	7. 824 n	9. 752 n	9. 917
1930. 0	7. 978 n	9. 752 n	9. 917

TABLES OF (161) ATHOR.

MEAN ELEMENTS.

Epoch, 1896, Apr. 14.0, M. T. Berlin=1896.285, M. T. Berlin.

$$
\begin{array}{rrrrl}
 & {}^{\circ} & {}' & {}'' & \\
g_0= & 72 & 49 & 13= & 72^{\circ}.8202 \\
\omega= & 291 & 46 & 24= & 291.7733 \\
\Omega= & 18 & 39 & 54= & 18.6651 \\
i= & 9 & 3 & 26= & 9.0573 \\
\varphi= & 7 & 57 & 47= & 7.9631 \\
n= & \multicolumn{3}{r}{966''.6573=} & 0.26851592
\end{array}
\left.\begin{array}{l} \\ \\ \\ \end{array}\right\}\text{Mean equinox and ecliptic 1900.0.}
$$

The elements are based on oppositions extending from 1876 to 1903 and on the perturbations of the first order by *Jupiter*, as given on page 292.

AUXILIARY QUANTITIES.

$\log a=0.37649$ $\quad\log 57.2958\, e=0.89968$ $\quad\log\sqrt{\frac{1-e}{1+e}}=9.93945$

$\log e=9.14156$ $\quad\log p=0.36807$

TABLE I.—MEAN ANOMALY (g).

Jan. 0.0 of common years; Jan. 1.0 of leap years

Year	g	Year	g
	°		°
B 1876	243.38573	1903	10.95271
7	341.39404	B 4	109.22953
8	79.40235	5	207.23784
9	177.41066	6	305.24616
B 1880	275.68749	7	43.25447
1	13.69580	B 8	141.53129
2	111.70411	9	239.53960
3	209.71242	1910	337.54792
B 4	307.98925	1	75.55623
5	45.99756	B 2	173.83305
6	144.00587	3	271.84136
7	242.01418	4	9.84968
B 8	340.29101	5	107.85799
9	78.29932	B 6	206.13481
1890	176.30763	7	304.14312
1	274.31594	8	42.15144
B 2	12.59277	9	140.15975
3	110.60108	B 1920	238.43657
4	208.60939	1	336.44488
5	306.61770	2	74.45320
B 6	44.89453	3	172.46151
7	142.90284	B 4	270.73833
8	240.91115	5	8.74664
9	338.91946	6	106.75496
1900	76.92777	7	204.76327
1	174.93608	B 8	303.04009
2	272.94440	9	41.04840
3	10.95271	1930	139.05672

NOTE.—When g is used as an argument of the perturbations add to the g of this table $\Delta\pi=\pi-\pi_0=-0^{\circ}.0716$. For explanation see page 203.

Table for beginning of month

Month	g
	°
Jan. 1.0 Jan. 0.0	0.00000
Feb. 1.0 Feb. 0.0	8.32399
Mar. 0.0	15.84244
Apr. 0.0	24.16643
May 0.0	32.22191
June 0.0	40.54590
July 0.0	48.60138
Aug. 0.0	56.92537
Sept. 0.0	65.24936
Oct. 0.0	73.30484
Nov. 0.0	81.62883
Dec. 0.0	89.68431

Change for n days[a]

n	g	n	g
	°		°
1	0.26852	16	4.29626
2	0.53703	17	4.56477
3	0.80555	18	4.83329
4	1.07406	19	5.10180
5	1.34258	20	5.37032
6	1.61112	21	5.63884
7	1.87961	22	5.90735
8	2.14813	23	6.17587
9	2.41664	24	6.44438
10	2.68516	25	6.71290
11	2.95368	26	6.98142
12	3.22219	27	7.24993
13	3.49071	28	7.51845
14	3.75922	29	7.78696
15	4.02774	30	8.05548

[a] For days during January and February of leap years subtract one day before entering this table.

Tables of (161) Athor—Continued.

PERTURBATIONS.

Arg. $ig-i'g'$.		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	0				− 4		
0	0				− 0.02nt		− 0.35nt
+1	0				+ 4		
+1		+ 0.46nt	− 4.78nt	− 2.39nt	− 0.23nt	+ 3.24nt	+ 1.69nt
+2		+ 0.01nt	− 0.16nt	− 0.16nt	− 0.01nt	+ 0.22nt	+ 0.12nt
+3	0		− 0.01nt	− 0.01nt		+ 0.02nt	+ 0.01nt
0	+1	− 10	+ 23			+ 5	
+1		− 49	+103	+ 38	+17	− 2	
+2	+1	− 2	+ 4	+ 4	+ 1	− 1	− 1
0	+2	+ 6	+ 4	− 3	+ 3		+ 5
+1		−128	−152	− 39	+37	+ 3	− 7
+2		− 78	−113	− 70	+49		− 3
+3	+2	− 3	− 6	− 6	+ 4	− 1	
0	+3	− 1	+ 6	− 3		− 3	
+1		+ 55	−502	− 32	− 7	− 1	− 4
+2		+181	−200	−103	−92	+18	+21
+3		− 7	− 6	− 6	+ 3	+ 1	+ 1
+4	+3	− 7	− 1	− 1	+ 1		
+2	+4	− 20	− 12	− 5	+ 9		
+3		− 3	− 10	− 6	+ 2	+ 1	
+4	+4	− 1	+ 3	+ 2	+ 1		
+3	+5	+ 4	− 1	− 1	− 2		
+4		− 2			+ 2		
+5	+5			+ 1			

Tables of (161) Athor—Continued.

TABLE II.—$n\delta z$.

PERIODIC TERMS.

Unit of a and b=0°.001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	+9.1	+0.01	−126.8	−8.01	−287.0	+0.70	+19.1	−4.12	−93.1	−1.46
6	+9.0	−0.04	−174.8	−7.72	−275.2	+3.14	−7.2	−4.42	−98.1	−0.18
12	+8.6	−0.08	−218.0	−6.47	−249.3	+5.36	−34.0	−4.33	−95.2	+1.12
18	+8.0	−0.12	−252.4	−4.68	−210.9	+7.18	−59.2	−3.87	−84.6	+2.34
24	+7.2	−0.13	−274.2	−2.42	−163.2	+8.51	−80.4	−3.07	−67.1	+3.38
30	+6.4	−0.17	−281.5	+0.11	−110.2	+9.02	−96.1	−2.02	−44.1	+4.15
36	+5.2	−0.18	−272.9	+2.72	−56.6	+8.74	−104.6	−0.78	−17.3	+4.58
42	+4.2	−0.15	−248.8	+5.12	−6.8	+7.71	−105.4	+0.52	+10.9	+4.62
48	+3.4	−0.12	−211.4	+7.12	+34.5	+5.87	−98.4	+1.80	+38.1	+4.31
54	+2.7	−0.12	−163.3	+8.69	+63.6	+3.66	−83.8	+2.92	+62.6	+3.68
60	+1.9	−0.10	−108.6	+9.42	+78.4	+1.13	−63.4	+3.81	+82.3	+2.74
66	+1.5	−0.05	−51.8	+9.38	+77.2	−1.53	−38.1	+4.43	+95.5	+1.61
72	+1.3	−0.02	+2.4	+8.57	+60.0	−4.05	−10.2	+4.71	+101.6	+0.34
78	+1.2	−0.01	+49.6	+6.95	+28.6	−6.22	+18.4	+4.62	+99.6	−0.96
84	+1.2	+0.02	+85.8	+4.88	−14.6	−7.94	+45.2	+4.18	+90.1	−2.17
90	+1.4	+0.04	+108.2	+2.48	−65.4	−8.90	+68.6	+3.43	+73.6	−3.22
96	+1.7	+0.04	+115.5	−0.08	−119.9	−9.11	+86.4	+2.43	+51.4	−4.03
102	+1.9	+0.02	+107.2	−2.54	−173.2	−8.52	+97.8	+1.25	+25.2	−4.52
108	+2.0	+0.01	+85.0	−4.70	−220.8	−7.17	+101.4	−0.07	−2.9	−4.66
114	+2.0	−0.02	+50.8	−6.38	−259.2	−5.38	+97.0	−1.34	−30.8	−4.46
120	+1.7	−0.05	+8.4	−7.53	−285.4	−3.20	+85.3	−2.51	−56.5	−3.90
126	+1.4	−0.08	−38.2	−7.90	−297.6	−0.88	+66.9	−3.48	−77.6	−3.01
132	+0.8	−0.12	−84.8	−7.38	−296.0	+1.38	+43.6	−4.14	−92.6	−1.90
138	0.0	−0.14	−126.8	−6.35	−281.0	+3.42	+17.2	−4.46	−100.4	−0.65
144	−0.9	−0.16	−161.0	−4.81	−255.0	+4.97	−9.9	−4.41	−100.4	+0.65
150	−1.9	−0.18	−184.5	−2.88	−221.4	+5.93	−35.7	−3.99	−92.6	+1.88
156	−3.1	−0.19	−195.6	−0.81	−183.8	+6.36	−57.8	−3.21	−77.8	+2.92
162	−4.2	−0.18	−194.2	+1.20	−146.4	+5.90	−74.2	−2.16	−57.6	+3.66
168	−5.2	−0.16	−181.2	+2.96	−113.0	+4.96	−83.7	−0.95	−33.9	+4.06
174	−6.1	−0.14	−158.7	+4.30	−86.9	+3.53	−85.6	+0.32	−8.9	+4.07
180	−6.9	−0.12	−129.6	+5.08	−70.6	+1.77	−79.9	+1.52	+14.9	+3.68
186	−7.6	−0.09	−97.8	+5.23	−65.6	−0.12	−67.4	+2.52	+35.2	+2.96
192	−8.0	−0.05	−66.8	+4.78	−72.0	−1.93	−49.6	+3.23	+50.4	+1.95
198	−8.2	−0.02	−40.4	+3.75	−88.8	−3.47	−28.6	+3.57	+58.6	+0.78
204	−8.2	+0.02	−21.8	+2.29	−113.6	−4.55	−6.8	+3.52	+59.7	−0.41
210	−8.0	+0.05	−12.9	+0.56	−143.4	−5.10	+13.7	+3.10	+53.7	−1.52
216	−7.6	+0.07	−15.1	−1.28	−174.9	−5.07	+30.4	+2.32	+41.5	−2.41
222	−7.2	+0.07	−28.2	−2.98	−204.2	−4.42	+41.6	+1.32	+24.8	−2.97
228	−6.8	+0.08	−50.8	−4.38	−227.8	−3.22	+46.3	+0.20	+5.9	−3.15
234	−6.2	+0.09	−80.7	−5.32	−242.8	−1.63	+44.0	−0.91	−13.0	−2.95
240	−5.7	+0.08	−114.6	−5.69	−247.4	+0.20	+35.4	−1.88	−29.5	−2.38
246	−5.3	+0.07	−149.0	−5.47	−240.4	+2.08	+21.5	−2.58	−41.5	−1.52
252	−4.9	+0.08	−180.2	−4.62	−222.5	+3.78	+4.4	−2.92	−47.8	−0.49
258	−4.4	+0.08	−204.5	−3.25	−195.0	+5.16	−13.6	−2.88	−47.4	+0.64
264	−4.0	+0.07	−219.2	−1.51	−160.6	+6.03	−30.2	−2.48	−40.1	+1.67
270	−3.6	+0.08	−222.6	+0.46	−122.6	+6.30	−43.4	−1.73	−27.4	+2.47
276	−3.1	+0.09	−213.7	+2.45	−85.0	+5.94	−51.0	−0.73	−10.4	+2.98
282	−2.5	+0.11	−193.2	+4.22	−51.3	+4.97	−52.2	+0.38	+8.4	+3.11
288	−1.8	+0.12	−163.0	+5.63	−25.3	+3.44	−46.4	+1.50	+26.9	+2.85
294	−1.0	+0.14	−125.6	+6.52	−10.0	+1.54	−34.2	+2.46	+42.6	+2.23
300	−0.1	+0.17	−84.8	+6.86	−6.8	−0.55	−16.9	+3.16	+53.7	+1.30
306	+1.0	+0.19	−44.6	+6.32	−16.6	−2.67	+3.7	+3.52	+58.2	+0.17
312	+2.2	+0.20	−9.0	+5.23	−38.8	−4.58	+25.4	+3.47	+55.7	−1.02
318	+3.4	+0.19	+18.2	+3.60	−71.6	−6.07	+45.4	+3.02	+46.0	−2.17
324	+4.5	+0.19	+34.2	+1.56	−111.6	−6.98	+61.7	+2.26	+29.7	−3.12
330	+5.7	+0.20	+36.9	+0.72	−155.4	−7.37	+72.5	+1.19	+8.6	−3.76
336	+6.9	+0.18	+25.6	−2.98	−198.6	−6.92	+76.0	−0.04	−15.4	−4.03
342	+7.8	+0.12	+1.1	−5.03	−237.0	−5.64	+72.0	−1.30	−39.8	−3.91
348	+8.4	+0.09	−34.8	−6.65	−266.3	−3.88	+60.4	−2.48	−62.3	−3.41
354	+8.9	+0.06	−78.7	−7.77	−283.6	−1.72	+42.2	−3.44	−80.7	−2.57
360	+9.1	+0.01	−126.8	−8.01	−287.0	+0.70	+19.1	−4.12	−93.1	−1.46

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (161) Athor—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS. Unit of a and b=0°.001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	−2.8	−0.35	−6.5	+0.08	−1.0	+0.02	+0.4	+0.08
6	−4.8	−0.31	−5.6	+0.22	−0.8	+0.06	+0.8	+0.05
12	−6.5	−0.22	−3.8	+0.33	−0.3	+0.08	+1.0	+0.02
18	−7.4	−0.08	−1.6	+0.39	+0.2	+0.08	+1.0	−0.02
24	−7.5	+0.06	+0.9	+0.42	+0.6	+0.06	+0.8	−0.05
30	−6.7	+0.20	+3.4	+0.37	+0.9	+0.03	+0.4	−0.07
36	−5.1	+0.33	+5.4	+0.28	+1.0	−0.01	0.0	−0.08
42	−2.7	+0.42	+6.6	+0.11	+0.8	−0.05	−0.5	−0.07
48	−0.1	+0.42	+6.7	−0.06	+0.4	−0.07	−0.8	−0.03
54	+2.3	+0.36	+5.9	−0.19	0.0	−0.08	−0.9	0.00
60	+4.2	+0.24	+4.4	−0.30	−0.5	−0.06	−0.8	+0.03
66	+5.2	+0.10	+2.3	−0.38	−0.7	−0.03	−0.5	+0.07
72	+5.4	−0.06	0.0	−0.38	−0.9	−0.01	0.0	+0.08
78	+4.5	−0.20	−2.1	−0.30	−0.8	+0.04	+0.5	+0.07
84	+3.0	−0.29	−3.6	−0.18	−0.4	+0.07	+0.8	+0.04
90	+1.0	−0.31	−4.2	−0.02	0.0	+0.07	+1.0	0.00
96	−0.7	−0.28	−3.9	+0.11	+0.4	+0.07	+0.8	−0.04
102	−2.2	−0.19	−2.9	+0.21	+0.8	+0.06	+0.5	−0.06
108	−3.0	−0.08	−1.4	+0.25	+1.1	+0.02	+0.1	−0.08
114	−3.1	+0.05	+0.1	+0.25	+1.0	−0.03	−0.4	−0.08
120	−2.4	+0.16	+1.5	+0.19	+0.7	−0.07	−0.8	−0.05
126	−1.2	+0.22	+2.3	+0.08	+0.2	−0.08	−1.0	−0.02
132	+0.2	+0.22	+2.5	−0.02	−0.3	−0.08	−1.0	+0.01
138	+1.5	+0.20	+2.1	−0.12	−0.7	−0.06	−0.9	+0.04
144	+2.5	+0.10	+1.1	−0.18	−1.0	−0.03	−0.5	+0.08
150	+2.7	0.00	−0.1	−0.21	−1.1	+0.01	0.0	+0.08
156	+2.5	−0.07	−1.4	−0.18	−0.9	+0.04	+0.5	+0.08
162	+1.9	−0.13	−2.3	−0.12	−0.6	+0.05	+0.9	+0.04
168	+0.9	−0.18	−2.9	−0.06	−0.3	+0.07	+1.1	+0.01
174	−0.2	−0.18	−3.0	+0.02	+0.2	+0.08	+1.0	−0.02
180	−1.2	−0.13	−2.7	+0.08	+0.6	+0.05	+0.8	−0.05
186	−1.8	−0.08	−2.0	+0.12	+0.8	+0.02	+0.4	−0.07
192	−2.1	−0.02	−1.2	+0.12	+0.9	0.00	0.0	−0.05
198	−2.0	+0.02	−0.6	+0.09	+0.8	−0.02	−0.2	−0.03
204	−1.8	+0.06	−0.1	+0.07	+0.6	−0.04	−0.4	−0.03
210	−1.3	+0.08	+0.2	+0.02	+0.3	−0.05	−0.6	−0.02
216	−0.9	+0.05	+0.2	−0.02	0.0	−0.04	−0.6	+0.01
222	−0.7	+0.02	0.0	−0.04	−0.2	−0.02	−0.5	+0.02
228	−0.7	−0.02	−0.3	−0.04	−0.2	0.00	−0.4	+0.02
234	−0.9	−0.04	−0.5	−0.01	−0.2	−0.01	−0.3	+0.02
240	−1.2	−0.06	−0.4	+0.02	−0.3	−0.01	−0.2	+0.02
246	−1.6	−0.05	−0.3	+0.05	−0.3	0.00	−0.1	+0.02
252	−1.8	−0.02	+0.2	+0.08	−0.3	−0.01	0.0	0.00
258	−1.9	0.00	+0.7	+0.08	−0.4	−0.01	−0.1	0.00
264	−1.8	+0.02	+1.2	+0.09	−0.4	0.00	0.0	+0.02
270	−1.6	+0.07	+1.8	+0.09	−0.4	0.00	+0.2	+0.03
276	−1.0	+0.10	+2.3	+0.08	−0.4	+0.02	+0.4	+0.02
282	−0.4	+0.12	+2.7	+0.04	−0.2	+0.02	+0.5	+0.02
288	+0.4	+0.12	+2.8	0.00	−0.1	+0.03	+0.7	+0.02
294	+1.1	+0.13	+2.7	−0.02	+0.2	+0.05	+0.8	−0.01
300	+2.0	+0.14	+2.5	−0.05	+0.5	+0.05	+0.6	−0.03
306	+2.8	+0.13	+2.1	−0.10	+0.8	+0.03	+0.4	−0.05
312	+3.6	+0.11	+1.3	−0.15	+0.9	+0.01	0.0	−0.06
318	+4.1	+0.08	+0.3	−0.18	+0.9	−0.01	−0.3	−0.06
324	+4.5	+0.02	−0.9	−0.22	+0.8	−0.05	−0.7	−0.06
330	+4.3	−0.05	−2.3	−0.24	+0.3	−0.08	−1.0	−0.03
336	+3.9	−0.12	−3.8	−0.23	−0.1	−0.08	−1.1	+0.01
342	+2.9	−0.22	−5.1	−0.19	−0.6	−0.07	−0.9	+0.04
348	+1.3	−0.29	−6.1	−0.12	−0.9	−0.03	−0.6	+0.06
354	−0.6	−0.34	−6.6	−0.03	−1.0	−0.01	−0.2	+0.08
360	−2.8	−0.35	−6.5	+0.08	−1.0	+0.02	+0.4	+0.08

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (161) Athor—Continued.

TABLE III.—$\delta \log r$.

PERIODIC TERMS. Unit of a and b=0.00001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	+26.4	+0.04	−58.5	+0.26	+45.8	+0.51	−39.8	−0.51	− 4.4	+1.64
6	+26.7	+0.05	−56.5	+0.40	+48.7	+0.42	−41.4	0.00	+ 6.2	+1.78
12	+27.0	+0.03	−53.7	+0.54	+50.9	+0.32	−39.8	+0.52	+17.0	+1.72
18	+27.1	+0.02	−50.0	+0.65	+52.6	+0.19	−35.2	+1.00	+26.9	+1.53
24	+27.2	0.00	−45.9	+0.70	+53.2	+0.02	−27.8	+1.41	+35.4	+1.22
30	+27.1	−0.02	−41.6	+0.72	+52.8	−0.16	−18.3	+1.71	+41.5	+0.78
36	+27.0	−0.02	−37.3	+0.68	+51.3	−0.35	− 7.3	+1.88	+44.8	+0.28
42	+26.8	−0.04	−33.4	+0.59	+48.6	−0.55	+ 4.2	+1.90	+44.9	−0.26
48	+26.5	−0.05	−30.2	+0.46	+44.7	−0.68	+15.5	+1.78	+41.7	−0.78
54	+26.2	−0.05	−27.9	+0.30	+40.5	−0.78	+25.5	+1.50	+35.5	−1.22
60	+25.9	−0.06	−26.6	+0.10	+35.3	−0.87	+33.5	+1.12	+27.0	−1.58
66	+25.5	−0.06	−26.6	−0.12	+30.1	−0.87	+38.9	+0.64	+16.5	−1.83
72	+25.2	−0.05	−28.0	−0.32	+24.9	−0.82	+41.2	+0.12	+ 5.0	−1.96
78	+24.9	−0.04	−30.5	−0.49	+20.2	−0.72	+40.3	−0.40	− 7.0	−1.93
84	+24.7	−0.02	−33.9	−0.63	+16.2	−0.60	+36.4	−0.92	−18.2	−1.74
90	+24.6	−0.02	−38.1	−0.77	+13.0	−0.42	+29.3	−1.35	−27.9	−1.42
96	+24.4	−0.01	−43.1	−0.84	+11.1	−0.22	+20.2	−1.60	−35.3	−1.02
102	+24.5	+0.02	−48.2	−0.84	+10.3	−0.04	+ 9.2	−1.88	−40.1	−0.52
108	+24.6	+0.02	−53.2	−0.80	+10.6	+0.14	− 2.4	−1.92	−41.5	+0.02
114	+24.8	+0.03	−57.8	−0.72	+12.0	+0.32	−13.9	−1.84	−39.8	+0.54
120	+25.0	+0.03	−61.9	−0.62	+14.4	+0.47	−24.5	−1.62	−35.0	+1.01
126	+25.2	+0.04	−65.3	−0.47	+17.6	+0.57	−33.4	−1.26	−27.7	+1.40
132	+25.5	+0.05	−67.5	−0.32	+21.2	+0.62	−39.6	−0.80	−18.2	+1.68
138	+25.8	+0.05	−69.1	−0.17	+25.0	+0.62	−43.0	−0.30	− 7.5	+1.82
144	+26.1	+0.03	−69.5	−0.01	+28.7	+0.60	−43.2	+0.22	+ 3.6	+1.79
150	+26.2	+0.02	−69.2	+0.12	+32.2	+0.55	−40.3	+0.71	+14.0	+1.62
156	+26.4	+0.02	−68.1	+0.21	+35.3	+0.46	−34.7	+1.12	+23.1	+1.32
162	+26.5	+0.01	−66.7	+0.28	+37.7	+0.37	−26.8	+1.42	+29.9	+0.92
168	+26.5	0.00	−64.8	+0.32	+39.7	+0.27	−17.6	+1.59	+34.1	+0.44
174	+26.5	−0.01	−62.9	+0.31	+40.9	+0.15	− 7.7	+1.60	+35.2	−0.06
180	+26.4	−0.01	−61.1	+0.29	+41.5	+0.08	+ 1.6	+1.47	+33.4	−0.52
186	+26.4	−0.02	−59.4	+0.24	+41.8	+0.02	+ 9.9	+1.18	+29.0	−0.92
192	+26.2	−0.02	−58.2	+0.18	+41.7	−0.02	+15.8	+0.79	+22.4	−1.20
198	+26.2	−0.01	−57.2	+0.14	+41.5	−0.04	+19.4	+0.37	+14.6	−1.33
204	+26.1	−0.02	−56.5	+0.08	+41.2	−0.05	+20.2	−0.08	+ 6.4	−1.32
210	+25.9	−0.02	−56.2	+0.05	+40.9	−0.02	+18.4	−0.50	− 1.2	−1.18
216	+25.9	0.00	−55.9	+0.02	+40.9	+0.02	+14.3	−0.82	− 7.7	−0.90
222	+25.9	0.00	−55.9	+0.02	+41.2	+0.05	+ 8.5	−1.04	−12.0	−0.52
228	+25.9	0.00	−55.6	+0.06	+41.5	+0.08	+ 1.8	−1.12	−13.9	−0.12
234	+25.9	0.00	−55.2	+0.08	+42.1	+0.11	− 4.9	−1.05	−13.4	+0.28
240	+25.9	−0.01	−54.7	+0.12	+42.8	+0.10	−10.8	−0.85	−10.5	+0.62
246	+25.8	0.00	−53.7	+0.18	+43.3	+0.08	−15.1	−0.54	− 5.8	+0.89
252	+25.9	0.00	−52.5	+0.21	+43.8	+0.04	−17.3	−0.14	+ 0.2	+1.02
258	+25.8	−0.01	−51.2	+0.22	+43.8	−0.02	−16.8	+0.26	+ 6.4	+0.99
264	+25.8	0.00	−49.8	+0.23	+43.5	−0.08	−14.2	+0.60	+12.1	+0.84
270	+25.8	−0.02	−48.4	+0.22	+42.9	−0.14	− 9.6	+0.90	+16.5	+0.58
276	+25.6	−0.03	−47.1	+0.18	+41.8	−0.22	− 3.5	+1.07	+19.0	+0.20
282	+25.4	−0.02	−46.2	+0.11	+40.3	−0.26	+ 3.2	+1.09	+18.9	−0.22
288	+25.3	−0.02	−45.8	+0.02	+38.7	−0.29	+ 9.6	+1.00	+16.4	−0.61
294	+25.1	−0.02	−45.9	−0.06	+36.8	−0.31	+15.1	+0.75	+11.6	−0.95
300	+25.0	−0.02	−46.5	−0.14	+35.0	−0.28	+18.6	+0.38	+ 5.0	−1.19
306	+24.9	−0.01	−47.7	−0.23	+33.5	−0.22	+19.7	−0.04	− 2.7	−1.32
312	+24.9	0.00	−49.3	−0.30	+32.4	−0.12	+18.1	−0.48	−10.8	−1.28
318	+24.9	0.00	−51.3	−0.36	+32.0	−0.03	+13.9	−0.89	−18.1	−1.09
324	+24.9	+0.01	−53.6	−0.37	+32.0	+0.08	+ 7.4	−1.24	−24.0	−0.78
330	+25.0	+0.03	−55.7	−0.34	+33.0	+0.22	− 1.0	−1.48	−27.5	−0.37
336	+25.3	+0.04	−57.7	−0.28	+34.6	+0.32	−10.3	−1.58	−28.4	+0.11
342	+25.5	+0.04	−59.0	−0.17	+36.8	+0.42	−19.9	−1.51	−26.2	+0.58
348	+25.8	+0.06	−59.7	−0.05	+39.6	+0.48	−28.4	−1.28	−21.4	+1.05
354	+26.2	+0.05	−59.6	+0.10	+42.6	+0.52	−35.3	−0.95	−13.6	+1.42
360	+26.4	+0.04	−58.5	+0.26	+45.8	+0.51	−39.8	−0.51	− 4.4	+1.64

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$

Tables of (161) Athor—Continued.

TABLE III.—$\delta \log r$—Continued.

PERIODIC TERMS. Unit of a and b=0.00001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	−4.3	+0.08	+1.9	+0.22	+0.2	+0.07	+0.8	−0.02
6	−3.6	+0.12	+3.0	+0.18	+0.6	+0.05	+0.6	−0.04
12	−2.8	+0.18	+4.0	+0.13	+0.8	+0.02	+0.3	−0.06
18	−1.4	+0.22	+4.6	+0.06	+0.8	−0.02	−0.1	−0.06
24	−0.1	+0.23	+4.7	−0.02	+0.6	−0.03	−0.4	−0.05
30	+1.4	+0.21	+4.3	−0.10	+0.4	−0.05	−0.7	−0.03
36	+2.4	+0.16	+3.4	−0.16	0.0	−0.07	−0.8	0.00
42	+3.3	+0.10	+2.3	−0.20	−0.4	−0.05	−0.7	+0.03
48	+3.6	0.00	+1.0	−0.22	−0.6	−0.02	−0.4	+0.06
54	+3.3	−0.08	−0.3	−0.20	−0.7	0.00	0.0	+0.06
60	+2.7	−0.13	−1.4	−0.14	−0.6	+0.02	+0.3	+0.04
66	+1.7	−0.16	−2.1	−0.08	−0.4	+0.04	+0.5	+0.03
72	+0.8	−0.17	−2.3	0.00	−0.1	+0.07	+0.7	+0.01
78	−0.3	−0.15	−2.1	+0.04	+0.4	+0.06	+0.6	−0.02
84	−1.0	−0.09	−1.8	+0.08	+0.6	+0.02	+0.4	−0.04
90	−1.4	−0.04	−1.1	+0.12	+0.7	0.00	+0.1	−0.06
96	−1.5	0.00	−0.5	+0.10	+0.6	−0.02	−0.3	−0.05
102	−1.4	+0.03	+0.1	+0.06	+0.4	−0.04	−0.5	−0.04
108	−1.1	+0.06	+0.3	+0.02	+0.1	−0.06	−0.8	−0.02
114	−0.7	+0.07	+0.5	+0.01	−0.3	−0.05	−0.8	+0.02
120	−0.3	+0.04	+0.4	−0.02	−0.5	−0.04	−0.5	+0.05
126	−0.2	+0.01	+0.1	−0.05	−0.8	−0.02	−0.2	+0.06
132	−0.2	−0.02	−0.2	−0.05	−0.8	+0.01	+0.2	+0.06
138	−0.4	−0.05	−0.5	−0.03	−0.7	+0.03	+0.5	+0.05
144	−0.8	−0.06	−0.6	0.00	−0.4	+0.06	+0.8	+0.02
150	−1.1	−0.06	−0.5	+0.02	0.0	+0.07	+0.8	−0.01
156	−1.5	−0.05	−0.4	+0.05	+0.4	+0.05	+0.7	−0.02
162	−1.7	−0.02	+0.1	+0.08	+0.6	+0.03	+0.5	−0.04
168	−1.7	+0.01	+0.5	+0.07	+0.8	+0.02	+0.2	−0.05
174	−1.6	+0.02	+0.9	+0.07	+0.8	−0.02	−0.1	−0.05
180	−1.3	+0.06	+1.3	+0.05	+0.5	−0.04	−0.4	−0.04
186	−0.9	+0.07	+1.5	+0.01	+0.3	−0.02	−0.6	−0.02
192	−0.5	+0.06	+1.4	−0.02	+0.1	−0.04	−0.6	+0.01
198	−0.2	+0.03	+1.3	−0.02	−0.2	−0.03	−0.5	+0.02
204	−0.1	+0.02	+1.1	−0.04	−0.3	−0.02	−0.5	+0.02
210	0.0	+0.01	+0.8	−0.03	−0.4	−0.02	−0.2	+0.04
216	0.0	−0.01	+0.7	−0.02	−0.5	0.00	0.0	+0.02
222	−0.1	−0.02	+0.5	−0.02	−0.4	+0.02	+0.1	+0.01
228	−0.2	−0.02	+0.5	+0.01	−0.3	+0.02	+0.1	+0.01
234	−0.3	−0.02	+0.6	+0.02	−0.2	+0.01	+0.2	+0.01
240	−0.4	0.00	+0.7	+0.02	−0.2	+0.01	+0.2	0.00
246	−0.3	+0.02	+0.9	+0.02	−0.1	+0.01	+0.2	0.00
252	−0.2	+0.03	+1.0	+0.02	−0.1	0.00	+0.2	+0.01
258	+0.1	+0.05	+1.1	+0.01	−0.1	+0.01	+0.3	+0.02
264	+0.4	+0.05	+1.1	−0.01	0.0	+0.02	+0.4	+0.01
270	+0.7	+0.04	+1.0	−0.02	+0.1	+0.02	+0.4	−0.01
276	+0.9	+0.03	+0.8	−0.04	+0.3	+0.02	+0.3	−0.02
282	+1.1	+0.03	+0.5	−0.06	+0.5	+0.02	+0.2	−0.01
288	+1.3	+0.02	+0.1	−0.08	+0.5	+0.02	+0.2	−0.03
294	+1.4	+0.01	−0.5	−0.09	+0.6	0.00	−0.2	−0.05
300	+1.4	−0.02	−1.0	−0.08	+0.5	−0.02	−0.4	−0.03
306	+1.1	−0.06	−1.4	−0.08	+0.3	−0.04	−0.6	−0.03
312	+0.7	−0.08	−2.0	−0.09	0.0	−0.04	−0.8	−0.02
318	+0.1	−0.12	−2.5	−0.06	−0.2	−0.04	−0.8	+0.02
324	−0.8	−0.15	−2.7	−0.02	−0.5	−0.05	−0.6	+0.04
330	−1.7	−0.15	−2.7	+0.02	−0.8	−0.02	−0.3	+0.06
336	−2.6	−0.15	−2.3	+0.08	−0.8	0.00	+0.1	+0.06
342	−3.5	−0.13	−1.7	+0.14	−0.8	+0.02	+0.5	+0.05
348	−4.2	−0.08	−0.7	+0.18	−0.5	+0.05	+0.7	+0.02
354	−4.5	−0.01	+0.5	+0.22	−0.2	+0.06	+0.8	+0.01
360	−4.3	+0.08	+1.9	+0.22	+0.2	+0.07	+0.8	−0.02

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (161) Athor—Continued.

TABLE IV.—$u/\cos i$.

PERIODIC TERMS. Unit of a and b = 0°.001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	+1.7	0.00	+6.4	−0.13	−8.4	0.00	+5.3	+0.28	+4.7	−0.26
6	+1.7	0.00	+5.6	−0.12	−8.3	+0.02	+6.7	+0.19	+2.8	−0.33
12	+1.7	−0.02	+5.0	−0.11	−8.1	+0.06	+7.6	+0.07	+0.7	−0.36
18	+1.5	−0.03	+4.3	−0.09	−7.6	+0.08	+7.5	−0.07	−1.5	−0.38
24	+1.3	−0.04	+3.9	−0.08	−7.2	+0.09	+6.8	−0.17	−3.8	−0.37
30	+1.0	−0.07	+3.5	−0.04	−6.5	+0.12	+5.5	−0.28	−5.8	−0.28
36	+0.5	−0.08	+3.4	−0.01	−5.8	+0.11	+3.5	−0.35	−7.1	−0.18
42	0.0	−0.10	+3.4	+0.01	−5.2	+0.10	+1.3	−0.38	−8.0	−0.08
48	−0.7	−0.11	+3.5	+0.03	−4.6	+0.11	−1.1	−0.40	−8.0	+0.06
54	−1.3	−0.10	+3.8	+0.06	−3.9	+0.09	−3.5	−0.37	−7.3	+0.18
60	−1.9	−0.09	+4.2	+0.08	−3.5	+0.06	−5.5	−0.29	−5.8	+0.29
66	−2.4	−0.08	+4.7	+0.08	−3.2	+0.05	−7.0	−0.20	−3.8	+0.36
72	−2.9	−0.08	+5.1	+0.08	−2.9	+0.03	−7.9	−0.07	−1.5	+0.40
78	−3.3	−0.06	+5.7	+0.08	−2.8	+0.01	−7.8	+0.07	+1.0	+0.42
84	−3.6	−0.02	+6.1	+0.08	−2.8	−0.02	−7.1	+0.18	+3.6	+0.39
90	−3.6	0.00	+6.6	+0.08	−3.0	−0.02	−5.7	+0.29	+5.7	+0.31
96	−3.6	+0.02	+7.0	+0.04	−3.1	−0.02	−3.6	+0.37	+7.3	+0.21
102	−3.3	+0.06	+7.2	+0.04	−3.3	−0.04	−1.3	+0.42	+8.2	+0.09
108	−2.9	+0.08	+7.5	+0.03	−3.6	−0.05	+1.4	+0.43	+8.4	−0.04
114	−2.4	+0.08	+7.6	+0.02	−3.9	−0.04	+3.9	+0.39	+7.7	−0.17
120	−1.9	+0.09	+7.7	+0.02	−4.1	−0.02	+6.1	+0.33	+6.4	−0.28
126	−1.3	+0.10	+7.8	+0.02	−4.2	−0.03	+7.9	+0.23	+4.3	−0.37
132	−0.7	+0.11	+7.9	+0.01	−4.5	−0.03	+8.9	+0.10	+2.0	−0.41
138	0.0	+0.10	+7.9	+0.01	−4.6	−0.02	+9.1	−0.03	−0.6	−0.42
144	+0.5	+0.08	+8.0	+0.01	−4.8	−0.02	+8.5	−0.15	−3.1	−0.40
150	+1.0	+0.07	+8.0	+0.01	−4.9	−0.03	+7.3	−0.27	−5.4	−0.33
156	+1.3	+0.04	+8.1	+0.02	−5.2	−0.04	+5.3	−0.36	−7.1	−0.23
162	+1.5	+0.03	+8.2	+0.01	−5.4	−0.04	+3.0	−0.41	−8.2	−0.12
168	+1.7	+0.02	+8.2	0.00	−5.6	−0.05	+0.4	−0.42	−8.6	+0.01
174	+1.7	0.00	+8.2	0.00	−6.0	−0.05	−2.0	−0.39	−8.1	+0.14
180	+1.7	0.00	+8.2	−0.02	−6.2	−0.06	−4.3	−0.34	−6.9	+0.26
186	+1.7	−0.02	+8.0	−0.03	−6.7	−0.06	−6.1	−0.24	−5.0	+0.35
192	+1.5	−0.03	+7.8	−0.04	−6.9	−0.04	−7.2	−0.12	−2.7	+0.39
198	+1.3	−0.03	+7.5	−0.06	−7.2	−0.04	−7.5	+0.02	−0.3	+0.41
204	+1.1	−0.02	+7.1	−0.07	−7.4	−0.04	−7.0	+0.13	+2.2	+0.39
210	+1.0	−0.02	+6.7	−0.08	−7.7	−0.03	−5.9	+0.24	+4.4	+0.32
216	+0.9	0.00	+6.2	−0.09	−7.8	+0.01	−4.1	+0.33	+6.1	+0.23
222	+1.0	+0.01	+5.6	−0.09	−7.6	+0.03	−1.9	+0.38	+7.2	+0.12
228	+1.0	+0.01	+5.1	−0.08	−7.4	+0.04	+0.5	+0.40	+7.6	−0.01
234	+1.1	0 00	+4.6	−0.08	−7.1	+0.06	+2.9	+0.38	+7.1	−0.14
240	+1.0	+0.01	+4.2	−0.06	−6.7	+0.09	+5.1	+0.32	+6.0	−0.24
246	+1.2	+0.02	+3.9	−0.02	−6.0	+0.10	+6.8	+0.23	+4.2	−0.32
252	+1.3	+0.01	+3.9	0.00	−5.5	+0.10	+7.9	+0.12	+2.1	−0.37
258	+1.3	+0.01	+3.9	+0.02	−4.8	+0.11	+8.2	−0.02	−0.2	−0.39
264	+1.4	+0.01	+4.1	+0.04	−4.2	+0.10	+7.7	−0.12	−2.6	−0.38
270	+1.4	0.00	+4.4	+0.08	−3.6	+0.09	+6.7	−0.22	−4.7	−0.31
276	+1.4	−0.01	+5.0	+0.10	−3.1	+0.06	+5.0	−0.32	−6.3	−0.22
282	+1.3	−0.01	+5.6	+0.11	−2.9	+0.02	+2.9	−0.37	−7.4	−0.12
288	+1.3	−0.01	+6.3	+0.12	−2.8	+0.02	+0.6	−0.38	−7.8	+0.01
294	+1.2	−0.02	+7.0	+0.12	−2.7	−0.01	−1.7	−0.36	−7.3	+0.13
300	+1.1	−0.01	+7.7	+0.10	−2.9	−0.06	−3.7	−0.30	−6.2	+0.23
306	+1.1	−0.02	+8.2	+0.08	−3.4	−0.08	−5.3	−0.22	−4.5	+0.32
312	+0.9	−0.01	+8.7	+0.08	−3.9	−0.10	−6.3	−0.10	−2.4	+0.36
318	+1.0	0.00	+9.1	+0.04	−4.6	−0.12	−6.5	+0.03	−0.2	+0.38
324	+0.9	0.00	+9.2	+0.01	−5.4	−0.12	−5.9	+0.13	+2.1	+0.35
330	+1.0	+0.02	+9.2	−0.02	−6.1	−0.12	−4.9	+0.23	+4.0	+0.28
336	+1.1	+0.02	+8.9	−0.07	−6.8	−0.11	−3.1	+0.32	+5.5	+0.20
342	+1.3	+0.03	+8.4	−0.09	−7.4	−0.08	−1.0	+0.36	+6.4	+0.09
348	+1.5	+0.03	+7.8	−0.10	−7.8	−0.08	+1.2	+0.37	+6.6	0.04
354	+1.7	+0.02	+7.2	−0.12	−8.3	−0.05	+3.4	+0.34	+5.9	−0.16
360	+1.7	0.00	+6.4	−0.13	−8.4	0.00	+5.3	+0.28	+4.7	−0.26

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (161) Athor—Continued.

TABLE IV.—$u/\cos i$—Continued.

PERIODIC TERMS. Unit of a and b=0°.001.

i	3			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°
°				
0	+0. 2		+0. 2	
6	+0. 3		+0. 1	
12	+0. 2		−0. 1	
18	+0. 2		−0. 1	
24	+0. 1		−0. 2	
30	−0. 2		−0. 2	
36	−0. 2		−0. 2	
42	−0. 3		−0. 1	
48	−0. 3		+0. 1	
54	−0. 2		+0. 2	
60	−0. 2		+0. 4	
66	−0. 1		+0. 4	
72	0. 0		+0. 5	
78	+0. 2		+0. 3	
84	+0. 3		+0. 3	
90	+0. 4		+0. 2	
96	+0. 5		+0. 1	
102	+0. 5		0. 0	
108	+0. 3		−0. 2	
114	+0. 3		−0. 2	
120	+0. 2		−0. 4	
126	+0. 2		−0. 4	
132	0. 0		−0. 4	
138	0. 0		−0. 2	
144	0. 0		−0. 2	
150	−0. 2		−0. 2	
156	−0. 1		−0. 2	
162	−0. 1		−0. 2	
168	−0. 1		−0. 2	
174	−0. 1		−0. 3	
180	−0. 2		−0. 2	
186	−0. 3		−0. 1	
192	−0. 4		−0. 1	
198	−0. 4		−0. 1	
204	−0. 5		0. 0	
210	−0. 6		+0. 2	
216	−0. 4		+0. 4	
222	−0. 3		+0. 5	
228	−0. 3		+0. 7	
234	0. 0		+0. 8	
240	+0. 2		+0. 8	
246	+0. 5		+0. 6	
252	+0. 6		+0. 5	
258	+0. 8		+0. 3	
264	+0. 9		+0. 1	
270	+0. 8		−0. 2	
276	+0. 7		−0. 5	
282	+0. 5		−0. 6	
288	+0. 3		−0. 8	
294	+0. 1		−0. 8	
300	−0. 2		−0. 8	
306	−0. 4		−0. 6	
312	−0. 6		−0. 4	
318	−0. 6		−0. 2	
324	−0. 6		0. 0	
330	−0. 6		+0. 2	
336	−0. 3		+0. 4	
342	−0. 1		+0. 4	
348	−0. 1		+0. 4	
354	+0. 1		+0. 3	
360	+0. 2		+0. 2	

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form of $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (161) Athor—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY $T=(t-t_0)$ IN JULIAN YEARS.

g	$n\delta z$ Unit of $c=0^\circ.001$		$\delta \log r$ Unit of $c=0.00001$		$u/\cos i$ Unit of $c=0^\circ.001$	
	c	Diff. for 1°	c	Diff. for 1°	c	Diff. for 1°
°						
0	−2.35	+0.003	−0.09	−0.018	+0.69	+0.032
6	−2.32	+0.009	−0.20	−0.018	+0.88	+0.029
12	−2.24	+0.014	−0.30	−0.016	+1.04	+0.025
18	−2.15	+0.018	−0.39	−0.015	+1.18	+0.022
24	−2.03	+0.021	−0.48	−0.014	+1.31	+0.020
30	−1.90	+0.025	−0.56	−0.013	+1.42	+0.017
36	−1.73	+0.030	−0.64	−0.012	+1.51	+0.012
42	−1.54	+0.032	−0.70	−0.010	+1.56	+0.008
48	−1.34	+0.034	−0.76	−0.008	+1.60	+0.005
54	−1.13	+0.037	−0.80	−0.008	+1.62	+0.002
60	−0.90	+0.039	−0.85	−0.006	+1.62	−0.002
66	−0.66	+0.040	−0.87	−0.002	+1.59	−0.007
72	−0.42	+0.039	−0.88	−0.001	+1.54	−0.009
78	−0.19	+0.040	−0.88	0.000	+1.48	−0.012
84	+0.06	+0.041	−0.88	+0.002	+1.40	−0.016
90	+0.30	+0.040	−0.86	+0.003	+1.29	−0.018
96	+0.54	+0.038	−0.84	+0.005	+1.18	−0.019
102	+0.76	+0.036	−0.80	+0.007	+1.06	−0.021
108	+0.97	+0.034	−0.76	+0.008	+0.93	−0.022
114	+1.17	+0.032	−0.71	+0.008	+0.79	−0.024
120	+1.36	+0.030	−0.66	+0.010	+0.64	−0.025
126	+1.53	+0.027	−0.59	+0.011	+0.49	−0.025
132	+1.68	+0.024	−0.53	+0.011	+0.34	−0.027
138	+1.82	+0.021	−0.46	+0.012	+0.17	−0.027
144	+1.93	+0.018	−0.39	+0.012	+0.02	−0.026
150	+2.03	+0.014	−0.31	+0.013	−0.14	−0.028
156	+2.10	+0.011	−0.23	+0.012	−0.31	−0.028
162	+2.16	+0.008	−0.17	+0.012	−0.48	−0.026
168	+2.20	+0.003	−0.09	+0.013	−0.62	−0.025
174	+2.20	−0.001	−0.01	+0.014	−0.78	−0.024
180	+2.19	−0.003	+0.08	+0.013	−0.91	−0.023
186	+2.16	−0.008	+0.15	+0.012	−1.06	−0.022
192	+2.10	−0.011	+0.22	+0.012	−1.18	−0.020
198	+2.03	−0.014	+0.30	+0.012	−1.30	−0.019
204	+1.93	−0.018	+0.37	+0.012	−1.41	−0.018
210	+1.82	−0.020	+0.44	+0.012	−1.52	−0.017
216	+1.69	−0.023	+0.51	+0.011	−1.61	−0.013
222	+1.54	−0.028	+0.57	+0.010	−1.68	−0.012
228	+1.36	−0.029	+0.63	+0.009	−1.74	−0.010
234	+1.19	−0.032	+0.68	+0.009	−1.80	−0.008
240	+0.98	−0.034	+0.73	+0.008	−1.84	−0.004
246	+0.78	−0.035	+0.77	+0.006	−1.85	0.000
252	+0.56	−0.038	+0.80	+0.005	−1.84	+0.001
258	+0.33	−0.038	+0.83	+0.004	−1.84	+0.003
264	+0.10	−0.039	+0.85	+0.002	−1.80	+0.008
270	−0.14	−0.040	+0.85	+0.001	−1.75	+0.010
276	−0.38	−0.040	+0.86	0.000	−1.68	+0.012
282	−0.62	−0.039	+0.85	−0.003	−1.60	+0.016
288	−0.85	−0.038	+0.82	−0.005	−1.49	+0.019
294	−1.07	−0.036	+0.79	−0.006	−1.37	+0.022
300	−1.28	−0.035	+0.75	−0.008	−1.22	+0.025
306	−1.49	−0.033	+0.70	−0.009	−1.07	+0.027
312	−1.68	−0.029	+0.64	−0.011	−0.90	+0.030
318	−1.84	−0.026	+0.57	−0.012	−0.71	+0.032
324	−1.99	−0.022	+0.49	−0.014	−0.52	+0.032
330	−2.11	−0.019	+0.40	−0.015	−0.32	+0.034
336	−2.22	−0.016	+0.31	−0.016	−0.11	+0.035
342	−2.30	−0.010	+0.21	−0.017	+0.10	+0.034
348	−2.34	−0.005	+0.11	−0.017	+0.30	+0.033
354	−2.36	−0.001	+0.01	−0.017	+0.50	+0.032
360	−2.35	+0.003	−0.09	−0.018	+0.69	+0.032

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form of $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (161) Athor—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	A'	B'	C'	log sin a	log sin b	log sin c
	°	°	°			
1876.0	39.8897	311.6661	305.3692	9.99947	9.92836	9.72625
7	9035	6811	3796	47	36	625
8	9173	6962	3900	46	37	624
9	9311	7112	4005	46	37	623
1880	39.9450	311.7262	305.4109	9.99946	9.92837	9.72623
1	9588	7413	4213	46	38	622
2	9726	7563	4317	46	38	621
3	39.9864	7714	4421	46	38	621
4	40.0002	7864	4525	46	39	620
1885	40.0141	311.8015	305.4630	9.99946	9.92839	9.72619
6	0279	8166	4734	46	39	619
7	0417	8316	4838	46	40	618
8	0555	8467	4942	46	40	618
9	0693	8617	5046	46	40	617
1890	40.0832	311.8768	305.5150	9.99946	9.92841	9.72616
1	0970	8919	5255	46	41	616
2	1108	9070	5359	46	41	615
3	1246	9220	5463	45	42	614
4	1384	9371	5567	45	42	614
1895	40.1523	311.9522	305.5671	9.99945	9.92842	9.72613
6	1661	9672	5775	45	43	613
7	1799	9823	5880	45	43	612
8	1937	311.9974	5984	45	43	611
9	2075	312.0124	6088	45	44	611
1900	40.2214	312.0275	305.6192	9.99945	9.92844	9.72610
1	2352	0426	6296	45	44	609
2	2490	0576	6400	45	45	609
3	2628	0727	6504	45	45	608
4	2767	0878	6609	45	45	607
1905	40.2905	312.1028	305.6713	9.99944	9.92846	9.72607
6	3043	1179	6817	44	46	606
7	3181	1330	6921	44	47	606
8	3319	1480	7025	44	47	605
9	3458	1631	7130	44	47	604
1910	40.3596	312.1782	305.7234	9.99944	9.92848	9.72604
1	3734	1932	7338	44	48	603
2	3872	2083	7442	44	48	602
3	4011	2234	7546	44	49	602
4	4149	2384	7650	44	49	601
1915	40.4287	312.2535	305.7755	9.99943	9.92850	9.72600
6	4425	2686	7859	43	50	9.72600
7	4563	2836	7963	43	50	9.72599
8	4702	2987	8067	43	51	599
9	4841	3138	8171	43	51	598
1920	40.4979	312.3288	8276	9.99943	9.92851	9.72597
1	5117	3439	8380	43	52	597
2	5256	3590	8484	43	52	596
3	5394	3740	8588	43	52	595
4	5532	3891	8692	43	53	595
1925	40.5670	312.4042	305.8797	9.99942	9.92853	9.72594
6	5809	4192	8901	42	54	594
7	5947	4343	9005	42	54	593
8	6085	4494	9109	42	54	592
9	6223	4645	9213	42	55	592
1930	40.6362	312.4795	305.9318	9.99942	9.92855	9.72591

Year	log cos a	log cos b	log cos c
1876.0	8.696	9.724 n	9.928
1930.0	8.712	9.724 n	9.928

TABLES OF (174) PHAEDRA.

MEAN ELEMENTS.

Epoch, 1893, Nov. 16.0, M. T. Berlin=1893.876, M. T. Berlin.

	°	′	″	°	
g_0=	201	5	28	=201°.0912	
ω=	286	3	40	=286.0611	Mean equinox and ecliptic 1900.0.
☊=	328	42	26	=328.7073	
i=	12	7	3	= 12.1175	
ϕ=	8	18	11	= 8.3030	
n=	733.″4324			= 0.20373123	

The elements are based on oppositions extending from 1877 to 1901 and on the perturbations of the first order by *Jupiter*, as given on page 302.

AUXILIARY QUANTITIES.

$\log a=0.45643$ $\log 57.2958e=0.91772$ $\log\sqrt{\frac{1-e}{1+e}}=9.93684$

$\log e=9.15959$ $\log p=0.44728$

TABLE I.—MEAN ANOMALY (g).

Jan. 0.0 of common years; Jan. 1.0 of leap years

Year	g	Year	g
	°		°
1877	25.29186	1905	308.64741
8	99.65375	6	23.00931
9	174.01565	7	97.37121
B 1880	248.58128	B 8	171.93684
1	322.94318	9	246.29874
2	37.30508	1910	320.66064
3	111.66698	1	35.02254
B 4	186.23261	B 2	109.58817
5	260.59451	3	183.95007
6	334.95641	4	258.31197
7	49.31831	5	332.67387
B 8	123.88394	B 6	47.23950
9	198.24584	7	121.60139
1890	272.60774	8	195.96329
1	346.96964	9	270.32519
B 2	61.53527	B 1920	344.89082
3	135.89716	1	59.25272
4	210.25906	2	133.61462
5	284.62096	3	207.97652
B 6	359.18659	B 4	282.54215
7	73.54849	5	356.90405
8	147.91039	6	71.26595
9	222.27229	7	145.62785
1900	296.63419	B 8	220.19348
1	10.99609	9	294.55538
2	85.35799	1930	8.91727
3	159.71989		
B 4	234.28552		
1905	308.64741		

NOTE.—When g is used as an argument of the perturbations add to the g of this table $\Delta\pi=\pi-\pi_0=+0°.1151$. For explanation see page 203.

Table for beginning of month

Month	g
	°
Jan. 0.0 1.0	0.00000
Feb. 0.0 1.0	6.31567
Mar. 0.0	12.02014
Apr. 0.0	18.33581
May 0.0	24.44775
June 0.0	30.76342
July 0.0	36.87535
Aug. 0.0	43.19102
Sept. 0.0	49.50669
Oct. 0.0	55.61863
Nov. 0.0	61.93429
Dec. 0.0	68.04623

Change for n days[a]

n	g	n	g
	°		°
1	0.20373	16	3.25970
2	0.40746	17	3.46343
3	0.61119	18	3.66716
4	0.81492	19	3.87089
5	1.01866	20	4.07462
6	1.22239	21	4.27836
7	1.42612	22	4.48209
8	1.62985	23	4.68582
9	1.83358	24	4.88955
10	2.03731	25	5.09328
11	2.24104	26	5.29701
12	2.44477	27	5.50074
13	2.64851	28	5.70447
14	2.85224	29	5.90821
15	3.05597	30	6.11194

[a] For dates during January and February of leap years, subtract one day before entering this table.

Tables of (174) Phaedra—Continued.

PERTURBATIONS.

Arg. $ig-ig'$		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	0				−7		−7
0	0				+0.01 nt		−0.78 nt
+1	0				+4		
+1		−0.14 nt	−8.61 nt	−4.30 nt	+0.07 nt	+11.22 nt	+3.58 nt
+2		−2	−2	−1	+1	−1	+1
+2			−0.30 nt	−0.30 nt		+0.80 nt	+0.26 nt
+3	0		−0.02 nt	−0.03 nt		+0.09 nt	+0.03 nt
−1	+1	−4	−4	+2	−3	+3	−6
0		+20	+22		+2	+17	−16
+1		+122	+198	+63	−37	−17	+12
+2		+5		+1	−4	−10	+3
+3	+1		+1	+1		−1	
−1	+2		−2	+2		+3	
0		+4	−48	+21	+2	+30	+5
+1		−637	+1132	+157	+87	−25	−2
+2		−358	+549	+306	+199	−21	−15
+3		−17	+24	+25	+18	−1	+1
+4	+2	−1	+2	+3	+2		
0	+3	−4			−2	−4	−4
+1		−165	+72	−13	−33	−7	−14
+2		+465	−124	−50	−198	+11	+37
+3		+59			−44	+1	+5
+4	+3	+5	+1		−6	+1	−1
+1	+4	−19	−8	+3	−8	+1	−6
+2		+155	+76	+22	−41	−3	+7
+3		+68	+71	+42	−41	−9	+10
+4			−5	−3			
+5	+4		−1	−1			
+1	+5	+10	+14	−7	+5	−8	+3
+2		+654	+1442	−54	+21	−19	
+3		−29	−519	−263	+14	+85	−4
+4		+4	−33	−28	−2	+9	+1
+5	+5	−1	−1	−2	+1	+1	
+2	+6		+2				
+3		+18	−33	−11	−7	+3	+3
+4		+15	−10	−6	−8	+2	+2
+5	+6	−4			+2		−1
+3	+7	−7					−2
+4		+30	+6	+3	−16		+7
+5		−2	−3	−2	+1	+1	−1
+6	+7		+1	+1			

Tables of (174) Phaedra—Continued.

TABLE II.—$n\delta z$.

PERIODIC TERMS. Unit of a and b=0°001.

i	0		1			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°
°						
0	−7.3	−0.09	−189.8	+13.04	+388.2	+8.04
6	−7.6	+0.01	−105.5	+14.82	+428.1	+5.02
12	−7.2	+0.10	−13.4	+15.74	+448.5	+1.69
18	−6.4	+0.15	+81.8	+15.86	+448.4	−1.78
24	−5.4	+0.19	+175.2	+15.17	+427.2	−5.17
30	−4.1	+0.23	+262.4	+13.76	+386.4	−8.32
36	−2.6	+0.28	+339.0	+11.58	+327.4	−11.12
42	−0.8	+0.28	+401.2	+8.90	+252.9	−13.38
48	+0.8	+0.27	+445.8	+5.81	+166.9	−15.13
54	+2.4	+0.26	+470.9	+2.44	+72.8	−16.05
60	+3.9	+0.23	+475.1	−1.09	−24.2	−16.19
66	+5.2	+0.19	+457.8	−4.58	−119.9	−15.55
72	+6.2	+0.12	+420.2	−7.80	−209.2	−14.09
78	+6.8	+0.06	+364.2	−10.59	−287.5	−11.82
84	+6.9	0.00	+293.1	−12.89	−351.0	−9.11
90	+6.8	−0.06	+211.0	−14.37	−396.8	−6.00
96	+6.2	−0.15	+122.2	−15.08	−423.0	−2.65
102	+5.0	−0 21	+31.8	−14.90	−428.6	+0.68
108	+3.7	−0.25	−55.0	−13.85	−414.9	+3.73
114	+2.0	−0.32	−134.4	−12.32	−383.8	+6.41
120	−0.1	−0.37	−202.8	−10.30	−338.0	+8.54
126	−2.4	−0.42	−258.0	−7.95	−281.3	+10.05
132	−5.1	−0.43	−298.2	−5.48	−217.4	+10.96
138	−7.6	−0.42	−323.8	−3.07	−149.8	+11.33
144	−10.2	−0.42	−335.0	−0.80	−81.4	+11.25
150	−12.6	−0.40	−333.4	+1.28	−14.8	+10.77
156	−15.0	−0.35	−319.7	+3.17	+47.8	+9.97
162	−16.8	−0.27	−295.4	+4.78	+104.8	+8.98
168	−18.2	−0.19	−262.4	+6.17	+155.5	+7.80
174	−19.1	−0.11	−221.4	+7.40	+198.4	+6.44
180	−19.5	+0.01	−173.6	+8.40	+232.8	+4.92
186	−19.0	+0.12	−120.6	+9.13	+257.4	+3.22
192	−18.0	+0.22	−64.0	+9.58	+271.5	+1.38
198	−16.4	+0.33	−5.6	+9.67	+274.0	−0.56
204	−14.0	+0.42	+52.0	+9.37	+264.8	−2.53
210	−11.3	+0.52	+106.8	+8.63	+243.6	−4.46
216	−7.8	+0.59	+155.6	+7.47	+211.3	−6.13
222	−4.2	+0.63	+196.4	+5.98	+170.0	−7.53
228	−0.2	+0.65	+227.4	+4.22	+120.9	−8.62
234	+3.6	+0.64	+247.1	+2.28	+66.5	−9.28
240	+7.5	+0.62	+254.8	+0.31	+9.6	−9.47
246	+11.0	+0.56	+250.8	−1.62	−47.1	−9.27
252	+14.2	+0.48	+235.4	−3.43	−101.6	−8.76
258	+16.8	+0.38	+209.6	−5.09	−152.2	−7.90
264	+18.7	+0.27	+174.3	−6.57	−196.4	−6.80
270	+20.0	+0.14	+130.8	−7.82	−233.8	−5.50
276	+20.4	+0.02	+80.3	−8.90	−262.4	−4.00
282	+20.2	−0.11	+24.0	−9.76	−281.8	−2.29
288	+19.1	−0.22	−36.8	−10.33	−289.9	−0.33
294	+17.6	−0.30	−100.0	−10.55	−285.8	+1.79
300	+15.5	−0.38	−163.4	−10.38	−268.4	+4.07
306	+13.0	−0.45	−224.6	−9.73	−237.0	+6.38
312	+10.1	−0.50	−280.2	−8.47	−191.8	+8.65
318	+7.0	−0.49	−326.2	−6.63	−133.2	+10.72
324	+4.2	−0.48	−359.8	−4.28	−63.2	+12.38
330	+1.2	−0.47	−377.6	−1.46	+15.1	+13.62
336	−1.4	−0.40	−377.3	+1.65	+98.8	+14.04
342	−3.6	−0.32	−357.8	+4.86	+182.4	+13.72
348	−5.2	−0.24	−319.0	+7.98	+261.8	+12.56
354	−6.5	−0.18	−262.0	+10.77	+331.6	+10.53
360	−7.3	−0.09	−189.8	+13.04	+388.2	+8.04

[$n\delta z$, $\delta \log r$, and $u \cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (174) Phaedra—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit of a and b=0°.001.

i	2				3			
g'	a_2	Diff. for 1°	b_2	Diff. for 1°	a_3	Diff. for 1°	b_3	Diff. for 1°
°								
0	+267.9	+42.19	+565.7	−23.00	+25.2	−12.16	−131.5	−1.58
3	+384.3	+35.30	+480.6	−32.79	−41.7	−12.00	−130.8	+1.78
6	+477.4	+26.04	+371.0	−40.23	−46.8	−10.92	−120.8	+4.90
9	+539.0	+15.10	+241.6	−45.30	−77.2	−9.10	−101.4	+7.62
12	+568.0	+3.50	+102.2	−47.24	−101.4	−6.60	−75.1	+9.70
15	+560.0	−8.22	−39.0	−46.41	−116.8	−3.70	−43.2	+11.05
18	+518.7	−19.32	−173.2	−42.43	−123.5	−0.53	−8.8	+11.50
21	+444.1	−29.46	−291.0	−35.93	−120.0	+2.62	+25.8	+11.16
24	+344.0	−37.27	−386.4	−26.94	−107.8	+5.52	+58.2	+9.94
27	+222.8	−42.80	−451.1	−16.27	−86.9	+8.00	+85.4	+8.00
30	+90.2	−45.22	−484.0	−4.78	−59.8	+9.85	+106.2	+5.47
33	−45.6	−44.78	−479.8	+6.93	−27.8	+11.00	+118.2	+2.53
36	−175.4	−41.13	−442.4	+18.10	+6.2	+11.23	+121.4	−0.57
39	−289.8	−34.97	−371.2	+28.41	+39.6	+10.63	+114.8	−3.60
42	−382.8	−26.28	−273.9	+36.44	+70.0	+9.18	+99.8	−6.36
45	−445.8	−15.75	−154.9	+42.16	+94.7	+7.10	+76.6	−8.67
48	−477.3	−4.35	−23.9	+44.80	+112.6	+4.48	+47.8	−10.26
51	−471.9	+7.37	+111.1	+44.69	+121.6	+1.53	+15.0	−11.15
54	−433.1	+18.60	+241.2	+41.38	+121.8	−1.58	−19.1	−11.13
57	−360.3	+29.01	+356.8	+35.52	+112.1	−4.60	−51.8	−10.33
60	−260.9	+37.30	+451.8	+26.99	+94.2	−7.28	−81.1	−8.74
63	−138.8	+43.36	+517.0	+16.55	+68.4	−9.43	−104.2	−6.50
66	−3.7	+46.35	+551.1	+5.23	+37.6	−10.87	−120.1	−3.73
69	+136.5	+46.59	+548.4	−6.48	+3.2	−11.57	−126.6	−0.62
72	+272.8	+43.65	+512.2	−17.82	−31.8	−11.35	−123.8	+2.58
75	+395.8	+38.15	+441.5	−28.43	−64.9	−10.33	−111.1	+5.62
78	+499.2	+30.02	+343.4	−37.00	−93.8	−8.50	−90.1	+8.22
81	+574.2	+19.96	+221.7	−43.43	−115.9	−6.07	−61.8	+10.28
84	+619.0	+8.94	+85.6	−46.94	−130.2	−3.12	−28.4	+11.65
87	+627.8	−2.62	−57.2	−47.76	−134.6	+0.13	+8.1	+12.20
90	+603.3	−13.90	−198.0	−45.46	−129.4	+3.40	+44.8	+11.85
93	+544.4	−24.54	−327.4	−40.59	−114.2	+6.48	+79.2	+10.65
96	+457.8	−33.22	−439.1	−33.16	−90.5	+9.17	+108.7	+8.60
99	+347.2	−39.86	−524.6	−24.00	−59.2	+11.25	+130.8	+5.95
102	+221.3	−43.73	−581.8	−13.36	−23.0	+12.56	+144.4	+2.78
105	+87.4	−45.06	−604.8	−2.43	+16.1	+13.03	+147.5	−0.58
108	−46.2	−43.40	−596.4	+8.27	+55.2	+12.52	+140.9	−3.97
111	−170.5	−39.25	−555.2	+18.42	+91.2	+11.16	+123.7	−7.15
114	−279.3	−32.60	−487.5	+26.72	+122.2	+9.02	+98.0	−9.90
117	−364.4	−24.10	−396.8	+33 15	+145.3	+6.23	+64.3	−12.08
120	−423.9	−14.62	−291.2	+36.94	+159.6	+2.95	+25.5	−13.35
123	−452.1	−4.65	−177.6	+38.34	+163.0	−0.57	−15.8	−13.73
126	−451.8	+5.08	−64.0	+36.81	+156.2	−4.08	−56.9	−13.23
129	−421.6	+14.26	+40.9	+32.99	+138.5	−7.37	−95.2	−11.92
132	−367.8	+21.68	+131.7	+26.85	+112.0	−10.18	−128.4	−9.68
135	−293.4	+27.29	+200.4	+18.95	+77.4	−12.38	−153.3	−6.80
138	−206.5	+30.36	+245.4	+10.20	+37.7	−13.73	−169.2	−3.48
141	−113.6	+31.07	+261.6	+1.07	−5.0	−14.25	−174.2	+0.03
144	−22.7	+29.00	+251.8	−7.73	−47.8	−13.78	−169.0	+3.58
147	+58.2	+24.77	+215.2	−15.90	−87.7	−12.46	−152.7	+6.93
150	+123.9	+18.40	+158.0	−22.27	−122.6	−10.35	−127.4	+9.85
153	+167.2	+10.48	+83.5	−26.78	−149.8	−7.60	−93.6	+12.12
156	+186.8	+1.77	−0.2	−28.72	−168.2	−4.30	−54.7	+13.53
159	+177.8	−7.18	−86.5	−28.37	−175.6	−0.76	−12.4	+14.18
162	+143.7	−15.63	−167.8	−25.26	−172.8	+2.75	+30.4	+13.88
165	+84.0	−23.34	−235.9	−20.03	−159.1	+6.07	+70.9	+12.72
168	+5.1	−29.07	−286.0	−12.70	−136.4	+8.95	+106.7	+10.72
171	−88.4	−32.80	−310.8	−3.93	−105.4	+11.28	+135.2	+8.13
174	−188.9	−33.90	−309.6	+5.47	−68.7	+12.83	+155.5	+5.03
177	−289.4	−32.66	−278.0	+15.02	−28.4	+13.58	+165.4	+1.67
180	−382.1	−28.54	−219.5	+23.98	+12.8	+13.43	+165.5	−1.72

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig+\Sigma_i b_i \cos ig+cT$.]

Tables of (174) Phaedra—Continued.

PERIODIC TERMS.

TABLE II.—$n\delta z$—Continued.

Unit of a and b = 0°.001.

i	2				3			
g'	a_2	Diff. for 1°	b_2	Diff. for 1°	a_3	Diff. for 1°	b_3	Diff. for 1°
°								
180	−382.1	−28.54	−219.5	+23.98	+ 12.8	+13.43	+165.5	− 1.72
183	−458.4	−22.21	−134.1	+32.10	+ 52.2	+12.50	+155.1	− 4.98
186	−513.4	−13.82	− 28.8	+38.04	+ 87.8	+10.75	+135.6	− 7.90
189	−540.0	− 4.00	+ 92.0	+41.87	+116.7	+ 8.37	+107.7	−10.25
192	−537.4	+ 6.50	+219.8	+42.95	+138.0	+ 5.52	+ 74.1	−11.87
195	−501.0	+17.15	+347.1	+41.46	+149.8	+ 2.37	+ 36.5	−12.75
198	−434.5	+27.18	+465.7	+36.98	+152.2	− 0.93	− 2.4	−12.80
201	−337.9	+36.31	+566.7	+30.28	+144.2	− 4.13	− 40.3	−12.10
204	−218.6	+43.20	+645.2	+21.34	+127.4	− 6.97	− 75.0	−10.57
207	− 81.0	+47.86	+693.3	+10.80	+102.4	− 9.33	−103.7	− 8.38
210	+ 65.8	+49.66	+710.0	− 0.50	+ 71.4	−11.10	−125.3	− 5.70
213	+214.3	+48.86	+690.3	−12.00	+ 35.8	−12.17	−137.9	− 2.68
216	+356.0	+44.99	+638.0	−22.88	− 1.6	−12.37	−141.4	+ 0.48
219	+481.8	+38.74	+553.0	−32.93	− 38.4	−11.80	−135.0	+ 3.60
222	+586.2	+30.12	+442.3	−40.87	− 72.4	−10.45	−119.8	+ 6.47
225	+660.9	+19.75	+310.0	−46.63	−101.1	− 8.47	− 96.2	+ 8.93
228	+704.7	+ 8.55	+165.3	−49.51	−123.2	− 5.92	− 66.2	+10.80
231	+712.2	− 2.97	+ 15.6	−49.77	−136.6	− 2.97	− 31.4	+12.00
234	+686.9	−14.03	−130.4	−46.94	−141.0	+ 0.22	+ 5.8	+12.40
237	+628.0	−24.40	−263.6	−41.68	−135.3	+ 3.38	+ 43.0	+12.02
240	+542.3	−32.72	−378.2	−34.04	−120.7	+ 6.35	+ 77.9	+10.78
243	+433.7	−39.02	−466.2	−24.63	− 97.2	+ 8.98	+107.7	+ 8.87
246	+310.8	−42.55	−526.0	−14.30	− 66.8	+11.03	+131.1	+ 6.37
249	+181.0	−43.51	−552.0	− 3.57	− 31.0	+12.40	+145.9	+ 3.42
252	+ 52.6	−41.50	−547.4	+ 6.80	+ 7.6	+12.95	+151.6	+ 0.13
255	− 65.6	−37.18	−511.2	+16.52	+ 46.7	+12.70	+146.7	− 3.20
258	−168.2	−30.52	−449.9	+24.40	+ 83.8	+11.58	+132.4	− 6.35
261	−247.1	−22.10	−366.8	+30.35	+116.2	+ 9.73	+108.6	− 9.17
264	−300.8	−12.85	−270.4	+33.59	+142.2	+ 7.17	+ 77.4	−11.43
267	−324.2	− 3.25	−167.7	+34.44	+159.2	+ 4.10	+ 40.0	−13.03
270	−320.3	+ 6.03	− 66.4	+32.51	+166.8	+ 0.70	− 0.8	−13.78
273	−288.0	+14.73	+ 25.1	+28.38	+163.4	− 2.78	− 42.7	−13.65
276	−233.6	+21.52	+101.7	+22.02	+150.1	− 6.13	− 82.7	−12.55
279	−160.8	+26.44	+155.7	+14.02	+126.6	− 9.18	−118.0	−10.72
282	− 77.5	+28.73	+185.8	+ 5.32	+ 95.0	−11.70	−147.0	− 8.17
285	+ 9.2	+28.68	+187.6	− 3.63	+ 56.4	−13.45	−167.0	− 5.05
288	+ 92.0	+25.96	+161.0	−12.13	+ 14.3	−14.32	−177.3	− 1.53
291	+162.8	+21.11	+114.8	−19.91	− 29.5	−14.35	−176.2	+ 2.12
294	+216.7	+14.23	+ 46.3	−25.72	− 71.8	−13.38	−164.6	+ 5.70
297	+246.8	+ 5.85	− 37.5	−29.53	−109.8	−11.60	−142.0	+ 8.92
300	+251.8	− 3.15	−128.4	−30.78	−141.4	− 8.98	−111.1	+11.50
303	+227.9	−12.20	−219.8	−29.67	−163.7	− 5.80	− 73.0	+13.40
306	+178.6	−20.70	−303.8	−25.79	−176.2	− 2.23	− 30.7	+14.36
309	+103.7	−28.35	−372.4	−19.85	−177.1	+ 1.48	+ 13.2	+14.45
312	+ 10.4	−33.81	−420.9	−11.63	−167.4	+ 5.07	+ 56.0	+13.55
315	− 97.0	−37.19	−442.2	− 2.52	−146.7	+ 8.32	+ 94.5	+11.80
318	−210.1	−37.82	−436.0	+ 7.35	−117.5	+10.97	+126.8	+ 9.23
321	−321.4	−35.95	−398.1	+17.23	− 80.9	+12.88	+149.9	+ 6.10
324	−423.1	−31.27	−332.6	+26.42	− 40.2	+13.87	+163.4	+ 2.58
327	−506.8	−24.44	−239.6	+34.64	+ 2.3	+13.97	+165.4	− 1.07
330	−567.7	−15.27	−126.8	+40.50	+ 43.6	+13.05	+157.0	− 4.57
333	−598.4	− 5.18	+ 1.1	+44.12	+ 80.6	+11.30	+138.0	− 7.75
336	−598.8	+ 5.67	+135.2	+44.90	+111.1	+ 8.78	+110.5	−10.30
339	−564.4	+16.55	+267.8	+43.01	+133.3	+ 5.73	+ 76.2	−12.12
342	−499.5	+26.85	+390.4	+38.11	+145.8	+ 2.32	+ 37.8	−13.05
345	−404.6	+35.70	+494.2	+30.98	+147.2	− 1.17	− 2.1	−13.05
348	−287.3	+42.42	+574.2	+21.66	+138.8	− 4.50	− 40.5	−12.05
351	−152.4	+46.82	+622.8	+10.83	+120.2	− 7.48	− 74.1	−10.28
354	− 9.3	+48.15	+639.2	− 0.70	+ 93.9	− 9.82	−102.2	− 7.82
357	+133.6	+46.69	+618.6	−12.25	+ 61.3	−11.45	−121.3	− 4.88
360	+267.9	+42.19	+565.7	−23.00	+ 25.2	−12.16	−131.5	− 1.58

[$n\delta z$, $\delta \log r$, and $u \cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (174) Phaedra—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS. Unit of a and b=0°.001.

i	4				5			
g'	a_4	Diff. for 1°	b_4	Diff. for 1°	a_5	Diff. for 1°	b_5	Diff. for 1°
°								
0	+14.6	−0.93	−10.9	−1.60	−2.0	−0.12	−1.2	+0.18
6	+5.8	−1.72	−18.4	−0.70	−2.3	+0.03	+0.1	+0.22
12	−6.0	−2.00	−19.3	+0.48	−1.6	+0.16	+1.5	+0.17
18	−16.8	−1.31	−12.6	+1.58	−0.4	+0.22	+2.1	+0.02
24	−21.7	−0.13	−0.3	+2.24	+1.0	+0.19	+1.8	−0.11
30	−18.4	+1.18	+12.6	+1.89	+1.9	+0.08	+0.8	−0.20
36	−7.5	+2.20	+21.3	+0.78	+2.0	−0.08	−0.6	−0.19
42	+6.4	+2.26	+21.9	−0.59	+1.0	−0.18	−1.5	−0.11
48	+18.0	+1.36	+14.2	−1.91	−0.2	−0.20	−1.9	+0.02
54	+22.7	+0.06	+0.8	−2.37	−1.4	−0.13	−1.3	+0.16
60	+18.7	−1.24	−12.4	−1.76	−1.8	−0.01	0.0	+0.20
66	+7.8	−2.15	−20.3	−0.66	−1.5	+0.12	+1.1	+0.15
72	−5.4	−2.06	−20.3	+0.63	−0.3	+0.19	+1.8	+0.04
78	−15.5	−1.12	−12.7	+1.70	+0.8	+0.18	+1.6	−0.10
84	−18.9	+0.03	−1.4	+1.96	+1.8	+0.08	+0.6	−0.18
90	−15.1	+1.07	+9.4	+1.38	+1.8	−0.07	−0.6	−0.18
96	−6.1	+1.66	+15.1	+0.42	+1.0	−0.17	−1.6	−0.12
102	+3.4	+1.34	+14.5	−0.52	−0.2	−0.18	−2.0	+0.02
108	+10.0	+0.69	+8.8	−1.10	−1.2	−0.13	−1.3	+0.15
114	+11.7	−0.10	+1.3	−1.12	−1.8	−0.03	−0.2	+0.18
120	+8.9	−0.66	−4.7	−0.71	−1.6	+0.09	+0.9	+0.14
126	+3.9	−0.78	−7.2	−0.12	−0.7	+0.17	+1.5	+0.05
132	−0.6	−0.52	−6.2	+0.31	+0.4	+0.16	+1.5	−0.05
138	−2.5	−0.12	−3.5	+0.41	+1.2	+0.08	+0.9	−0.13
144	−2.0	+0.15	−1.3	+0.22	+1.4	−0.02	−0.1	−0.14
150	−0.7	+0.15	−0.8	−0.06	+1.0	−0.09	−0.8	−0.08
156	−0.2	−0.06	−2.0	−0.22	+0.3	−0.12	−1.1	0.00
162	−1.4	−0.34	−3.4	−0.09	−0.5	−0.10	−0.8	+0.07
168	−4.3	−0.43	−3.1	+0.22	−0.9	−0.02	−0.3	+0.09
174	−6.6	−0.21	−0.7	+0.55	−0.7	+0.06	+0.3	+0.08
180	−6.8	+0.22	+3.5	+0.69	−0.2	+0.08	+0.6	+0.02
186	−4.0	+0.67	+7.6	+0.47	+0.3	+0.07	+0.6	−0.04
192	+1.2	+0.88	+9.1	+0.07	+0.6	+0.01	+0.1	−0.08
198	+6.6	+0.68	+6.8	−0.63	+0.4	−0.03	−0.3	−0.06
204	+9.3	+0.13	+1.5	−0.95	+0.2	−0.06	−0.6	−0.01
210	+8.2	−0.50	−4.6	−0.87	−0.3	−0.07	−0.4	+0.03
216	+3.3	−0.97	−8.9	−0.36	−0.6	−0.02	−0.2	+0.04
222	−3.4	−0.98	−8.9	+0.34	−0.6	+0.03	+0.1	+0.06
228	−8.4	−0.54	−4.8	+0.91	−0.2	+0.05	+0.5	+0.03
234	−9.9	+0.14	+2.0	+1.08	0.0	+0.03	+0.5	−0.01
240	−6.7	+0.79	+8.2	+0.74	+0.2	+0.02	+0.4	−0.03
246	−0.4	+1.09	+10.9	+0.09	+0.3	+0.01	+0.1	−0.03
252	+6.4	+0.92	+9.3	−0.58	+0.3	−0.01	0.0	−0.01
258	+10.7	+0.38	+3.9	−0.99	+0.2	−0.01	0.0	0.00
264	+10.9	−0.28	−2.6	−0.96	+0.2	+0.02	0.0	0.00
270	+7.3	−0.75	−7.6	−0.58	+0.4	+0.03	0.0	−0.02
276	+1.9	−0.82	−9.5	−0.02	+0.6	0.00	−0.2	−0.03
282	−2.6	−0.58	−7.9	+0.40	+0.4	−0.05	−0.4	−0.06
288	−5.0	−0.19	−4.6	+0.52	0.0	−0.08	−0.9	−0.05
294	−4.9	+0.13	−1.7	+0.34	−0.6	−0.10	−1.0	+0.03
300	−3.4	+0.18	−0.5	+0.08	−1.2	−0.08	−0.5	+0.09
306	−2.8	−0.03	−0.8	−0.06	−1.5	0.00	+0.1	+0.13
312	−3.8	−0.26	−1.2	+0.04	−1.2	+0.09	+1.1	+0.13
318	−5.9	−0.32	−0.3	+0.34	−0.4	+0.17	+1.7	+0.05
324	−7.6	−0.05	+2.9	+0.68	+0.8	+0.18	+1.7	−0.04
330	−6.5	+0.49	+7.8	+0.78	+1.8	+0.11	+1.2	−0.15
336	−1.7	+1.02	+12.2	+0.42	+2.1	−0.01	−0.1	−0.22
342	+5.8	+1.23	+12.8	−0.32	+1.7	−0.12	−1.4	−0.17
348	+13.1	+0.93	+8.3	−1.11	+0.7	−0.22	−2.1	−0.06
354	+17.0	+0.12	−0.5	−1.60	−0.9	−0.22	−2.1	+0.08
360	+14.6	−0.93	−10.9	−1.60	−2.0	−0.12	−1.2	+0.18

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig+\Sigma_i b_i \cos ig+cT$.]

Tables of (174) Phaedra—Continued.

TABLE III.—∂ log r.

PERIODIC TERMS.

Unit of *a* and *b* = 0.00001.

i	0		1				2			
g′	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	−1.0	−0.16	+41.9	+0.12	+ 3.2	−1.18	+ 47.4	−0.91	− 4.5	−1.06
6	−2.0	−0.15	+42.1	−0.04	− 3.9	−1.17	+ 42.1	−0.81	− 9.5	−0.72
12	−2.8	−0.13	+41.4	−0.22	−10.8	−1.18	+ 37.7	−0.62	− 13.2	−0.56
18	−3.6	−0.12	+39.5	−0.39	−18.0	−1.12	+ 34.6	−0.51	− 16.2	−0.52
24	−4.2	−0.09	+36.7	−0.57	−24.3	−1.02	+ 31.6	−0.47	− 19.4	−0.55
30	−4.7	−0.07	+32.7	−0.74	−30.3	−0.94	+ 29.0	−0.48	− 22.8	−0.57
36	−5.0	−0.04	+27.8	−0.88	−35.6	−0.79	+ 25.8	−0.60	− 26.2	−0.54
42	−5.2	−0.02	+22.1	−1.00	−39.8	−0.62	+ 21.8	−0.68	− 29.3	−0.47
48	−5.2	+0.01	+15.8	−1.10	−43.0	−0.42	+ 17.6	−0.70	− 31.8	−0.35
54	−5.1	+0.03	+ 8.9	−1.15	−44.9	−0.23	+ 13.4	−0.68	− 33.5	−0.28
60	−4.8	+0.06	+ 2.0	−1.16	−45.8	−0.05	+ 9.5	−0.61	− 35.2	−0.25
66	−4.4	+0.08	− 5.0	−1.14	−45.5	+0.13	+ 6.1	−0.54	− 36.5	−0.28
72	−3.9	+0.09	−11.7	−1.12	−44.2	+0.31	+ 3.0	−0.61	− 38.5	−0.43
78	−3.3	+0.11	−18.5	−1.09	−41.8	+0.48	− 1.2	−0.80	− 41.7	−0.60
84	−2.6	+0.12	−24.8	−1.05	−38.4	+0.63	− 6.6	−1.14	− 45.7	−0.68
90	−1.9	+0.12	−31.1	−1.00	−34.2	+0.80	− 14.9	−1.65	− 49.9	−0.58
96	−1.1	+0.12	−36.8	−0.91	−28.8	+1.01	− 26.4	−2.16	− 52.6	−0.20
102	−0.4	+0.12	−42.0	−0.76	−22.1	+1.22	− 40.8	−2.58	− 52.3	+0.47
108	+0.3	+0.12	−45.9	−0.56	−14.2	+1.41	− 57.3	−2.76	− 47.0	+1.37
114	+1.0	+0.10	−48.7	−0.31	− 5.2	+1.57	− 74.0	−2.56	− 35.9	+2.42
120	+1.5	+0.08	−49.6	+0.04	+ 4.6	+1.66	− 88.1	−1.92	− 18.0	+3.44
126	+1.9	+0.07	−48.2	+0.42	+14.7	+1.66	− 97.0	−0.86	+ 5.5	+4.22
132	+2.3	+0.04	−44.5	+0.80	+24.5	+1.54	− 98.4	+0.54	+ 32.7	+4.61
138	+2.4	+0.01	−38.6	+1.17	+33.2	+1.32	− 90.5	+2.06	+ 60.8	+4.48
144	+2.4	−0.01	−30.5	+1.48	+40.4	+1.00	− 73.7	+3.45	+ 86.4	+3.78
150	+2.3	−0.04	−20.8	+1.68	+45.2	+0.59	− 49.1	+4.56	+106.1	+2.59
156	+1.9	−0.08	−10.5	+1.73	+47.5	+0.16	− 18.9	+5.20	+117.5	+1.09
162	+1.4	−0.10	0.0	+1.68	+47.1	−0.30	+ 13.3	+5.26	+119.2	−0.55
168	+0.7	−0.12	+ 9.7	+1.50	+43.9	−0.70	+ 44.3	+4.79	+110.9	−2.07
174	−0.1	−0.14	+18.0	+1.24	+38.7	−1.00	+ 70.8	+3.86	+ 94.4	−3.26
180	−1.0	−0.16	+24.6	+0.92	+31.8	−1.23	+ 90.6	+2.67	+ 71.8	−4.05
186	−2.0	−0.17	+29.1	+0.58	+23.9	−1.34	+102.8	+1.42	+ 45.8	−4.35
192	−3.0	−0.16	+31.5	+0.23	+15.7	−1.37	+107.6	+0.24	+ 19.6	−4.26
198	−3.9	−0.14	+31.9	−0.06	+ 7.5	−1.32	+105.7	−0.73	− 5.3	−3.91
204	−4.7	−0.13	+30.8	−0.32	− 0.2	−1.22	+ 98.8	−1.42	− 27.3	−3.38
210	−5.5	−0.11	+28.0	−0.55	− 7.1	−1.09	+ 88.7	−1.87	− 45.9	−2.87
216	−6.0	−0.08	+24.2	−0.73	−13.3	−0.94	+ 76.4	−2.20	− 61.7	−2.42
222	−6.4	−0.05	+19.2	−0.91	−18.4	−0.74	+ 62.3	−2.47	− 75.0	−2.03
228	−6.6	−0.02	+13.3	−1.04	−22.2	−0.56	+ 46.8	−2.78	− 86.1	−1.71
234	−6.6	+0.03	+ 6.7	−1.16	−25.1	−0.32	+ 29.0	−3.18	− 95.5	−1.32
240	−6.2	+0.08	− 0.6	−1.24	−26.1	−0.03	+ 8.6	−3.60	−101.9	−0.73
246	−5.6	+0.11	− 8.2	−1.27	−25.5	+0.25	− 14.2	−3.97	−104.3	+0.02
252	−4.9	+0.13	−15.8	−1.22	−23.1	+0.58	− 39.1	−4.15	−101.6	+1.03
258	−4.0	+0.16	−22.9	−1.08	−18.6	+0.90	− 64.0	−4.01	− 91.9	+2.22
264	−3.0	+0.18	−28.7	−0.82	−12.3	+1.20	− 87.2	−3.45	− 75.0	+3.40
270	−1.9	+0.19	−32.7	−0.51	− 4.2	+1.42	−105.4	−2.94	− 51.1	+4.42
276	−0.7	+0.19	−34.8	−0.13	+ 4.8	+1.53	−116.4	−1.08	− 21.9	+5.10
282	+0.4	+0.18	−34.3	+0.30	+14.2	+1.55	−118.4	+0.49	+ 10.2	+5.26
288	+1.4	+0.15	−31.2	+0.71	+23.4	+1.42	−110.5	+2.08	+ 41.2	+4.88
294	+2.2	+0.12	−25.8	+1.06	+31.3	+1.17	− 93.4	+3.43	+ 68.7	+3.98
300	+2.9	+0.10	−18.5	+1.32	+37.4	+0.84	− 69.3	+4.38	+ 89.0	+2.64
306	+3.4	+0.06	− 9.9	+1.48	+41.4	+0.48	− 40.9	+4.80	+100.4	+1.12
312	+3.6	+0.02	− 0.7	+1.52	+43.1	+0.10	− 11.7	+4.62	+102.5	−0.39
318	+3.6	−0.01	+ 8.3	+1.45	+42.6	−0.27	+ 14.6	+3.98	+ 95.7	−1.68
324	+3.5	−0.05	+16.7	+1.31	+39.9	−0.58	+ 36.1	+3.02	+ 82.3	−2.57
330	+3.0	−0.09	+24.0	+1.11	+35.7	−0.82	+ 50.9	+1.88	+ 64.9	−3.01
336	+2.4	−0.11	+30.0	+0.89	+30.1	−0.98	+ 58.7	+0.81	+ 46.2	−3.01
342	+1.7	−0.13	+34.7	+0.70	+23.9	−1.08	+ 60.6	−0.04	+ 28.8	−2.66
348	+0.8	−0.15	+38.4	+0.49	+17.1	−1.14	+ 58.2	−0.62	+ 14.3	−2.13
354	−0.1	−0.15	+40.6	+0.29	+10.2	−1.16	+ 53.0	−0 90	+ 3.2	−1.57
360	−1.0	−0.16	+41.9	+0.12	+ 3.2	−1.18	+ 47.4	−0.91	− 4.5	−1.06

[$n\delta z$, $\partial \log r$, and $u \cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (174) Phaedra—Continued.

TABLE III.—∂ log *r*—Continued.

PERIODIC TERMS. Unit of *a* and *b* = 0.00001.

i	3				4				5			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°	a_5	Diff. for 1°	b_5	Diff. for 1°
°												
0	−52.8	−0.38	− 3.5	+4.76	− 6.5	−0.64	− 6.4	+0.57	−0.9	+0.09	+0.9	+0.08
6	−47.5	+2.00	+24.4	+4.28	− 9.4	−0.22	− 1.7	+0.88	−0.3	+0.12	+1.2	+0.02
12	−28.8	+3.97	+45.6	+2.63	− 9.1	+0.34	+ 4.2	+0.88	+0.6	+0.11	+1.1	−0.05
18	− 2.0	+4.73	+54.6	+0.26	− 5.3	+0.82	+ 8.9	+0.55	+1.0	+0.04	+0.6	−0.11
24	+25.5	+4.18	+48.7	−2.07	+ 0.8	+1.02	+10.8	−0.02	+1.1	−0.02	−0.2	−0.11
30	+46.0	+2.40	+29.8	−3.94	+ 7.0	+0.83	+ 8.6	−0.65	+0.8	−0.08	−0.7	−0.06
36	+54.3	+0.18	+ 3.6	−4.61	+10.8	+0.32	+ 3.0	−1.03	+0.1	−0.11	−0.9	−0.01
42	+48.2	−2.02	−23.0	−3.99	+10.8	−0.33	− 3.8	−1.02	−0.5	−0.08	−0.8	+0.05
48	+30.0	−3.80	−42.2	−2.19	+ 6.8	−0.88	− 9.3	−0.63	−0.8	−0.02	−0.3	+0.08
54	+ 4.8	−4.32	−49.3	−0.05	+ 0.3	−1.08	−11.4	+0.01	−0.7	+0.05	+0.2	+0.07
60	−19.4	−3.60	−42.8	+2.15	− 6.1	−0.87	− 9.2	+0.62	−0.2	+0.08	+0.5	+0.03
66	−36.4	−1.82	−24.8	+3.63	−10.1	−0.33	− 4.0	+0.97	+0.2	+0.06	+0.6	−0.02
72	−41.2	+0.31	− 1.4	+3.97	−10.1	+0.30	+ 2.4	+0.96	+0.5	+0.02	+0.2	−0.07
78	−32.7	+2.39	+20.5	+3.11	− 6.5	+0.76	+ 7.5	+0.58	+0.5	−0.02	−0.2	−0.06
84	−14.1	+3.63	+34.1	+1.22	− 1.0	+0.90	+ 9.4	+0.02	+0.3	−0.06	−0.5	−0.02
90	+ 8.7	+3.79	+35.2	−0.90	+ 4.3	+0.72	+ 7.7	−0.48	−0.2	−0.08	−0.5	+0.02
96	+29.0	+2.69	+23.3	−2.91	+ 7.6	+0.29	+ 3.6	−0.74	−0.6	−0.04	−0.3	+0.05
102	+39.3	+0.65	+ 2.0	−4.00	+ 7.8	−0.18	− 1.2	−0.70	−0.7	+0.01	+0.1	+0.07
108	+36.8	−1.52	−22.4	−3.91	+ 5.5	−0.51	− 4.8	−0.43	−0.5	+0.06	+0.5	+0.06
114	+21.1	−3.57	−42.6	−2.62	+ 1.7	−0.59	− 6.4	−0.08	0.0	+0.08	+0.8	0.00
120	− 4.2	−4.62	−52.0	−0.38	− 1.6	−0.45	− 5.8	+0.22	+0.5	+0.06	+0.5	−0.05
126	−32.0	−4.42	−47.1	+1.98	− 3.7	−0.22	− 3.8	+0.37	+0.7	+0.01	+0.2	−0.07
132	−54.9	−2.97	−28.3	+4.16	− 4.3	−0.02	− 1.4	+0.33	+0.6	−0.03	−0.3	−0.07
138	−66.0	−0.58	+ 0.8	+5.27	− 4.0	+0.08	+ 0.2	+0.22	+0.3	−0.07	−0.6	−0.02
144	−61.8	+1.98	+32.4	+5.08	− 3.3	+0.09	+ 1.1	+0.12	−0.2	−0.07	−0.6	+0.02
150	−42.3	+4.34	+59.3	+3.65	− 2.9	+0.07	+ 1.7	+0.12	−0.5	−0.03	−0.3	+0.06
156	−11.7	+5.66	+74.3	+1.16	− 2.5	+0.08	+ 2.5	+0.15	−0.6	+0.01	+0.1	+0.06
162	+23.1	+5.68	+73.2	−1.53	− 1.9	+0.17	+ 3.5	+0.17	−0.4	+0.05	+0.4	+0.04
168	+53.8	+4.34	+55.9	−4.06	− 0.5	+0.30	+ 4.5	+0.12	0.0	+0.06	+0.6	0.00
174	+73.1	+1.90	+26.2	−5.63	+ 1.7	+0.38	+ 5.0	−0.04	+0.3	+0.04	+0.4	−0.05
180	+76.6	−0.83	− 9.1	−5.88	+ 4.1	+0.34	+ 4.0	−0.28	+0.5	+0.02	0.0	−0.06
186	+63.1	−3.51	−41.7	−4.75	+ 5.8	+0.15	+ 1.6	−0.47	+0.5	−0.03	−0.3	−0.04
192	+36.2	−5.22	−64.1	−2.48	+ 5.9	−0.14	− 1.6	−0.50	+0.1	−0.06	−0.5	−0.02
198	+ 2.8	−5.70	−71.4	+0.18	+ 4.1	−0.42	− 4.4	−0.35	−0.2	−0.05	−0.5	+0.02
204	−29.7	−4.86	−62.0	+2.83	+ 0.8	−0.56	− 5.8	−0.03	−0.5	−0.02	−0.2	+0.06
210	−53.4	−2.76	−38.9	+4.69	− 2.6	−0.47	− 4.8	+0.32	−0.5	+0.01	+0.2	+0.06
216	−62.8	−0.23	− 8.0	+5.20	− 4.8	−0.18	− 2.0	+0.52	−0.4	+0.04	+0.5	+0.03
222	−56.2	+2.26	+23.0	+4.70	− 4.7	+0.20	+ 1.5	+0.52	0.0	+0.06	+0.6	0.00
228	−35.7	+4.27	+46.2	+2.77	− 2.4	+0.48	+ 4.3	+0.29	+0.3	+0.04	+0.5	−0.03
234	− 7.1	+5.05	+56.2	+0.38	+ 1.1	+0.58	+ 5.0	−0.08	+0.5	+0.02	+0.2	−0.04
240	+22.4	+4.51	+50.8	−2.05	+ 4.5	+0.42	+ 3.3	−0.41	+0.5	−0.01	0.0	−0.04
246	+44.9	+2.81	+31.6	−4.07	+ 6.1	+0.08	+ 0.1	−0.58	+0.4	−0.02	−0.3	−0.03
252	+54.8	+0.38	+ 4.0	−4.92	+ 5.4	−0.29	− 3.6	−0.53	+0.2	−0.02	−0.4	−0.02
258	+49.5	−2.02	−24.9	−4.45	+ 2.6	−0.54	− 6.3	−0.27	+0.2	−0.03	−0.5	0.00
264	+30.5	−4.06	−47.1	−2.81	− 1.1	−0.58	− 6.8	+0.08	−0.2	−0.03	−0.4	+0.02
270	+ 2.8	−4.93	−57.2	−0.39	− 4.3	−0.42	− 5.3	+0.36	−0.2	−0.02	−0.4	+0.01
276	−26.2	−4.50	−51.8	+2.02	− 6.1	−0.15	− 2.5	+0.48	−0.5	−0.02	−0.3	+0.02
282	−48.9	−2.89	−33.0	+4.05	− 6.1	+0.11	+ 0.5	+0.43	−0.5	−0.01	−0.1	+0.04
288	−59.4	−0.48	− 5.1	+4.99	− 4.8	+0.25	+ 2.7	+0.28	−0.6	−0.01	+0.2	+0.04
294	−54.7	−1.97	+24.4	+4.60	− 3.1	+0.27	+ 3.9	+0.12	−0.6	+0.03	+0.4	+0.05
300	−35.8	+4.04	+47.8	+2.99	− 1.6	+0.22	+ 4.2	+0.02	−0.2	+0.07	+0.8	+0.04
306	− 8.3	+4.94	+58.8	+0.57	− 0.5	+0.19	+ 4.2	+0.01	+0.2	+0.08	+0.9	0.00
312	+21.1	+4.60	+54.6	−1.86	+ 0.7	+0.21	+ 4.3	0.00	+0.8	+0.08	+0.8	−0.06
318	+44.5	+3.00	+36.5	−3.91	+ 2.0	+0.26	+ 4.2	−0.05	+1.1	+0.02	+0.2	−0.11
324	+55.6	+0.60	+ 9.6	−4.87	+ 3.8	+0.32	+ 3.7	−0.18	+1.1	−0.02	−0.5	−0.11
330	+51.7	−1.82	−19.5	−4.52	+ 5.8	+0.24	+ 2.0	−0.39	+0.8	−0.09	−1.1	−0.07
336	+33.8	−3.89	−42.3	−2.90	+ 6.7	+0.02	− 1.0	−0.56	0.0	−0.12	−1.3	−0.01
342	+ 7.1	−4.79	−52.8	−0.51	+ 6.0	−0.31	− 4.7	−0.55	−0.7	−0.10	−1.2	+0.06
348	−21.2	−4.37	−48.4	+1.88	+ 3.0	−0.64	− 7.6	−0.32	−1.2	−0.06	−0.6	+0.12
354	−43.0	−2.75	−30.2	+3.92	− 1.7	−0.79	− 8.5	+0.10	−1.4	+0.02	+0.2	+0.12
360	−52.7	−0.38	− 3.5	+4.76	− 6.5	−0.64	− 6.4	+0.57	−0.9	+0.09	+0.9	+0.08

[$n\delta z$, ∂ log r, and u/cos i are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (174) Phaedra—Continued.

TABLE IV.—u cos i.

PERIODIC TERMS.

Unit of *a* and *b*=0°.001.

i	0		1				2			
g′	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	−6.2	−0.32	−17.2	−0.17	−3.7	+0.57	−12.2	+0.55	+9.6	+0.61
6	−8.1	−0.29	−17.7	+0.02	0.0	+0.61	−8.1	+0.76	+12.6	+0.34
12	−9.7	−0.26	−16.9	+0.21	+3.6	+0.56	−3.1	+0.84	+13.7	0.00
18	−11.2	−0.23	−15.2	+0.34	+6.7	+0.49	+2.0	+0.76	+12.6	−0.36
24	−12.5	−0.20	−12.8	+0.45	+9.5	+0.39	+6.0	+0.52	+9.4	−0.66
30	−13.6	−0.16	−9.8	+0.52	+11.4	+0.28	+8.2	+0.18	+4.8	−0.81
36	−14.4	−0.12	−6.6	+0.54	+12.8	+0.18	+8.2	−0.21	−0.3	−0.78
42	−15.0	−0.08	−3.3	+0.56	+13.6	+0.08	+5.7	−0.57	−4.6	−0.61
48	−15.3	−0.02	+0.1	+0.54	+13.8	+0.02	+1.4	−0.78	−7.6	−0.28
54	−15.3	+0.02	+3.2	+0.52	+13.8	−0.03	−3.7	−0.83	−8.0	+0.13
60	−15.1	+0.07	+6.3	+0.51	+13.4	−0.12	−8.6	−0.72	−6.0	+0.51
66	−14.5	+0.12	+9.3	+0.50	+12.4	−0.20	−12.3	−0.43	−1.9	+0.80
72	−13.6	+0.18	+12.3	+0.45	+11.0	−0.30	−13.8	−0.05	+3.6	+0.94
78	−12.3	+0.22	+14.7	+0.37	+8.8	−0.39	−12.9	+0.36	+9.4	+0.89
84	−10.9	+0.26	+16.7	+0.26	+6.3	−0.48	−9.5	+0.71	+14.3	+0.68
90	−9.2	+0.32	+17.8	+0.08	+3.0	−0.54	−4.4	+0.92	+17.5	+0.35
96	−7.1	+0.34	+17.7	−0.10	−0.2	−0.53	+1.6	+0.98	+18.5	−0.02
102	−5.1	+0.35	+16.6	−0.27	−3.4	−0.48	+7.4	+0.87	+17.2	−0.38
108	−2.9	+0.38	+14.5	−0.40	−5.9	−0.36	+12.0	+0.62	+13.9	−0.65
114	−0.6	+0.38	+11.8	−0.49	−7.7	−0.21	+14.9	+0.33	+9.4	−0.78
120	+1.7	+0.35	+8.6	−0.55	−8.4	+0.01	+16.0	+0.05	+4.6	−0.77
126	+3.6	+0.32	+5.2	−0.49	−7.6	+0.17	+15.5	−0.18	+0.2	−0.65
132	+5.5	+0.28	+2.7	−0.36	−6.4	+0.27	+13.9	−0.32	−3.2	−0.48
138	+6.9	+0.21	+0.9	−0.22	−4.4	+0.35	+11.7	−0.36	−5.6	−0.32
144	+8.0	+0.15	0.0	−0.08	−2.2	+0.32	+9.6	−0.32	−7.0	−0.21
150	+8.7	+0.08	0.0	+0.06	−0.5	+0.25	+7.8	−0.27	−8.1	−0.14
156	+8.9	−0.01	+0.7	+0.12	+0.8	+0.12	+6.4	−0.23	−8.8	−0.14
162	+8.6	−0.09	+1.5	+0.14	+1.0	−0.01	+5.0	−0.25	−9.8	−0.18
168	+7.8	−0.16	+2.4	+0.10	+0.7	−0.08	+3.4	−0.31	−11.0	−0.20
174	+6.7	−0.22	+2.7	−0.02	0.0	−0.15	+1.3	−0.42	−12.2	−0.18
180	+5.2	−0.27	+2.1	−0.12	−1.1	−0.15	−1.6	−0.58	−13.2	−0.08
186	+3.5	−0.29	+1.3	−0.17	−1.8	−0.09	−5.7	−0.68	−13.2	+0.10
192	+1.7	−0.29	+0.1	−0.22	−2.2	+0.01	−9.7	−0.66	−12.0	+0.37
198	0.0	−0.28	−1.3	−0.18	−1.7	+0.11	−13.6	−0.56	−8.8	+0.63
204	−1.7	−0.27	−2.0	−0.09	−0.9	+0.16	−16.4	−0.32	−4.4	+0.83
210	−3.2	−0.21	−2.4	+0.02	+0.2	+0.21	−17.4	−0.01	+1.2	+0.98
216	−4.2	−0.15	−1.8	+0.14	+1.6	+0.17	−16.5	+0.36	+7.3	+0.95
222	−5.0	−0.09	−0.7	+0.21	+2.2	+0.07	−13.1	+0.71	+12.6	+0.76
228	−5.3	−0.01	+0.7	+0.22	+2.4	+0.05	−8.0	+0.93	+16.4	+0.45
234	−5.1	+0.07	+2.0	+0.23	+1.6	−0.17	−1.9	+1.02	+18.0	+0.08
240	−4.5	+0.13	+3.5	+0.14	+0.4	−0.23	+4.2	+0.98	+17.4	−0.29
246	−3.5	+0.19	+3.7	−0.02	−1.2	−0.30	+9.9	+0.80	+14.5	−0.62
252	−2.2	+0.23	+3.3	−0.15	−3.2	−0.28	+13.8	+0.48	+10.0	−0.81
258	−0.7	+0.26	+1.9	−0.25	−4.6	−0.19	+15.7	+0.16	+4.8	−0.88
264	+0.9	+0.28	+0.3	−0.29	−5.5	−0.07	+15.7	−0.16	−0.5	−0.82
270	+2.6	+0.27	−1.6	−0.30	−5.4	+0.06	+13.8	−0.39	−5.1	−0.65
276	+4.1	+0.24	−3.3	−0.22	−4.8	+0.15	+11.0	−0.50	−8.3	−0.42
282	+5.5	+0.20	−4.3	−0.08	−3.6	+0.21	+7.8	−0.52	−10.2	−0.22
288	+6.5	+0.14	−4.3	+0.05	−2.3	+0.19	+4.8	−0.46	−11.0	−0.07
294	+7.2	+0.08	−3.7	+0.11	−1.3	+0.11	+2.3	−0.37	−11.0	+0.02
300	+7.5	+0.02	−3.0	+0.14	−1.0	−0.02	+0.4	−0.30	−10.7	+0.05
306	+7.4	−0.05	−2.0	+0.16	−1.6	−0.17	−1.3	−0.28	−10.4	+0.02
312	+6.9	−0.11	−1.1	+0.06	−3.0	−0.28	−2.9	−0.28	−10.4	0.00
318	+6.1	−0.18	−1.3	−0.09	−5.0	−0.34	−4.7	−0.36	−10.4	+0.03
324	+4.8	−0.23	−2.2	−0.24	−7.1	−0.32	−7.2	−0.42	−10.0	+0.12
330	+3.3	−0.28	−4.2	−0.39	−8.9	−0.24	−9.8	−0.43	−9.0	+0.28
336	+1.5	−0.31	−6.9	−0.48	−10.0	−0.09	−12.4	−0.40	−6.6	+0.47
342	−0.4	−0.32	−9.9	−0.51	−10.0	+0.08	−14.6	−0.25	−3.4	+0.62
348	−2.4	−0.32	−13.0	−0.48	−9.0	+0.27	−15.4	−0.01	+0.8	+0.72
354	−4.3	−0.32	−15.7	−0.35	−6.8	+0.44	−14.7	+0.27	+5.3	+0.73
360	−6.2	−0.32	−17.2	−0.17	−3.7	+0.57	−12.2	+0.55	+9.6	+0.61

[$n\delta z$, $\delta \log r$. and $u \cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (174) Phaedra—Continued.

TABLE IV.—$u/\cos i$—Continued.

PERIODIC TERMS. Unit of a and $b=0^{\circ}.0001$.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	+22.0	+0.18	+ 3.6	−1.88	+3.4	+0.27	+2.3	−0.28
6	+19.9	−0.78	− 8.0	−1.68	+4.5	+0.06	0.0	−0.42
12	+12.7	−1.48	−16.6	−1.02	+4.1	−0.22	−2.7	−0.39
18	+ 2.2	−1.78	−20.3	−0.10	+1.9	−0.42	−4.7	−0.22
24	− 8.7	−1.55	−17.8	+0.82	−1.0	−0.49	−5.3	+0.06
30	−16.4	−0.88	−10.5	+1.47	−4.0	−0.38	−4.0	+0.28
36	−19.3	+0.02	− 0.2	+1.71	−5.5	−0.08	−1.0	+0.52
42	−16.1	+0.90	+10.0	+1.45	−5.0	+0.21	+2.2	+0.47
48	− 8.5	+1.51	+17.2	+0.77	−3.0	+0.43	+4.6	+0.26
54	+ 2.0	+1.72	+19.2	−0.14	+0.2	+0.50	+5.3	−0.04
60	+12.1	+1.40	+15.5	−1.02	+3.0	+0.37	+4.1	−0.32
66	+18.8	+0.68	+ 7.0	−1.62	+4.6	+0.10	+1.5	−0.46
72	+20.2	−0.27	− 3.9	−1.75	+4.2	−0.18	−1.4	−0.40
78	+15.6	−1.15	−14.0	−1.38	+2.5	−0.34	−3.3	−0.20
84	+ 6.4	−1.72	−20.5	−0.62	+0.1	−0.38	−3.8	+0.04
90	− 5.1	−1.83	−21.5	+0.33	−2.1	−0.25	−2.8	+0.25
96	−15.6	−1.44	−16.5	+1.26	−2.9	−0.04	−0.8	+0.32
102	−22.4	−0.63	− 6.4	+1.86	−2.6	+0.12	+1.0	+0.23
108	−23.2	+0.43	+ 5.8	+1.95	−1.4	+0.23	+2.0	+0.09
114	−17.2	+1.38	+17.0	+1.50	+0.2	+0.22	+2.1	−0.05
120	− 6.7	+1.93	+23.8	+0.61	+1.2	+0.11	+1.4	−0.14
126	+ 6.0	+2.02	+24.3	−0.46	+1.5	−0.01	+0.4	−0.14
132	+17.6	+1.55	+18.2	−1.42	+1.1	−0.07	−0.3	−0.08
138	+24.6	+0.63	+ 7.2	−2.00	+0.7	−0.06	−0.5	−0.02
144	+25.2	−0.45	− 5.8	−2.07	+0.4	−0.03	−0.5	+0.01
150	+19.2	−1.43	−17.6	−1.59	+0.3	+0.02	−0.4	0.00
156	+ 8.0	−2.02	−24.9	−0.67	+0.6	+0.02	−0.5	−0.06
162	− 5.1	−2.09	−25.6	+0.42	+0.5	−0.05	−1.1	−0.09
168	−17.1	−1.62	−19.9	+1.38	0.0	−0.13	−1.6	−0.06
174	−24.6	−0.72	− 9.1	+1.99	−1.1	−0.18	−1.8	+0.04
180	−25.8	+0.36	+ 4.0	+2.08	−2.2	−0.15	−1.1	+0.17
186	−20.3	+1.31	+15.9	+1.63	−2.9	−0.04	+0.2	+0.25
192	−10.1	+1.91	+23.6	+0.80	−2.7	+0.15	+1.9	+0.26
198	+ 2.6	+2.05	+25.5	−0.23	−1.1	+0.29	+3.3	+0.15
204	+14.5	+1.67	+20.8	−1.19	+0.8	+0.32	+3.7	−0.04
210	+22.6	+0.87	+11.2	−1.85	+2.8	+0.26	+2.8	−0.24
216	+24.9	−0.14	− 1.4	−2.04	+3.9	+0.07	+0.8	−0.35
222	+20.9	−1.10	−13.3	−1.68	+3.6	−0.14	−1.4	−0.33
228	+11.7	−1.76	−21.6	−0.94	+2.2	−0.30	−3.2	−0.19
234	− 0.2	−2.00	−24.6	+0.04	0.0	−0.33	−3.7	+0.02
240	−12.3	−1.75	−21.1	+1.02	−1.8	−0.25	−2.9	+0.20
246	−21.2	−1.02	−12.4	+1.72	−3.0	−0.08	−1.3	+0.29
252	−24.6	−0.03	− 0.5	+2.02	−2.8	+0.11	+0.6	+0.27
258	−21.6	+0.95	+11.8	+1.80	−1.7	+0.21	+1.9	+0.13
264	−13.2	+1.72	+21.1	+1.11	−0.3	+0.22	+2.2	−0.02
270	− 1.0	+2.07	+25.1	+0.11	+0.9	+0.13	+1.6	−0.13
276	+11.6	+1.87	+22.4	−0.92	+1.3	+0.02	+0.6	−0.15
282	+21.4	+1.17	+14.1	−1.72	+1.2	−0.06	−0.2	−0.10
288	+25.6	+0.17	+ 1.8	−2.11	+0.6	−0.10	−0.6	−0.02
294	+23.4	−0.89	−11.2	−1.92	0.0	−0.05	−0.5	+0.03
300	+14.9	−1.72	−21.2	−1.22	0.0	+0.01	−0.2	+0.02
306	+ 2.8	−2.10	−25.9	−0.22	+0.1	+0.03	−0.2	−0.02
312	−10.3	−1.95	−23.8	+0.86	+0.4	0.00	−0.5	−0.06
318	−20.6	−1.25	−15.6	+1.68	+0.1	−0.08	−0.9	−0.05
324	−25.3	−0.23	− 3.6	+2.07	−0.6	−0.13	−1.1	+0.01
330	−23.4	+0.80	+ 9.2	+1.89	−1.5	−0.13	−0.8	+0.12
336	−15.7	+1.61	+19.1	+1.23	−2.2	−0.03	+0.3	+0.22
342	− 4.1	+2.00	+24.0	+0.25	−1.9	+0.12	+1.9	+0.22
348	+ 8.3	+1.82	+22.1	−0.79	−0.8	+0.27	+3.0	+0.12
354	+17.8	+1.14	+14.5	−1.54	+1.3	+0.35	+3.4	−0.06
360	+22.0	+0.18	+ 3.6	−1.88	+3.4	+0.27	+2.3	−0.28

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (174) Phaedra—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY $T=(t-t_0)$ IN JULIAN YEARS.

g	$n\delta z$ Unit of $c=0^\circ.001$		$\delta \log r$ Unit of $c=0.00001$		$u/\cos i$ Unit of $c=0^\circ.001$	
	c	Diff. for 1°	c	Diff. for 1°	c	Diff. for 1°
°						
0	−3.22	−0.001	+0.02	−0.022	+1.11	+0.082
6	−3.21	+0.005	−0.12	−0.024	+1.59	+0.078
12	−3.16	+0.012	−0.26	−0.023	+2.04	+0.073
18	−3.06	+0.020	−0.40	−0.022	+2.47	+0.067
24	−2.92	+0.024	−0.53	−0.022	+2.84	+0.059
30	−2.77	+0.029	−0.66	−0.019	+3.18	+0.052
36	−2.57	+0.036	−0.76	−0.017	+3.46	+0.042
42	−2.34	+0.040	−0.86	−0.017	+3.69	+0.034
48	−2.09	+0.042	−0.96	−0.013	+3.87	+0.024
54	−1.83	+0.047	−1.02	−0.010	+3.98	+0.015
60	−1.53	+0.050	−1.08	−0.008	+4.05	+0.008
66	−1.23	+0.052	−1.12	−0.005	+4.07	−0.002
72	−0.91	+0.053	−1.14	−0.004	+4.03	−0.011
78	−0.59	+0.053	−1.17	−0.002	+3.94	−0.018
84	−0.27	+0.054	−1.17	+0.001	+3.81	−0.025
90	+0.06	+0.054	−1.16	+0.002	+3.64	−0.031
96	+0.38	+0.052	−1.14	+0.004	+3.44	−0.038
102	+0.68	+0.051	−1.11	+0.006	+3.18	−0.044
108	+0.99	+0.049	−1.07	+0.008	+2.91	−0.048
114	+1.27	+0.047	−1.02	+0.009	+2.61	−0.051
120	+1.55	+0.044	−0.96	+0.012	+2.30	−0.054
126	+1.80	+0.040	−0.88	+0.012	+1.96	−0.059
132	+2.03	+0.038	−0.81	+0.012	+1.59	−0.062
138	+2.25	+0.035	−0.73	+0.014	+1.22	−0.062
144	+2.45	+0.029	−0.64	+0.016	+0.84	−0.064
150	+2.60	+0.024	−0.54	+0.017	+0.46	−0.066
156	+2.74	+0.021	−0.44	+0.017	+0.05	−0.066
162	+2.85	+0.016	−0.34	+0.017	−0.33	−0.064
168	+2.93	+0.011	−0.24	+0.018	−0.72	−0.065
174	+2.98	+0.006	−0.12	+0.018	−1.11	−0.064
180	+3.00	+0.001	−0.02	+0.018	−1.49	−0.062
186	+2.99	−0.004	+0.09	+0.018	−1.85	−0.059
192	+2.95	−0.009	+0.20	+0.018	−2.20	−0.058
198	+2.88	−0.014	+0.31	+0.018	−2.55	−0.055
204	+2.78	−0.019	+0.41	+0.017	−2.86	−0.051
210	+2.65	−0.022	+0.51	+0.016	−3.16	−0.047
216	+2.51	−0.028	+0.60	+0.016	−3.42	−0.042
222	+2.32	−0.033	+0.70	+0.016	−3.67	−0.039
228	+2.11	−0.036	+0.79	+0.013	−3.89	−0.032
234	+1.89	−0.038	+0.86	+0.012	−4.06	−0.027
240	+1.65	−0.043	+0.94	+0.012	−4.21	−0.022
246	+1.37	−0.048	+1.00	+0.009	−4.33	−0.017
252	+1.08	−0.048	+1.05	+0.009	−4.41	−0.009
258	+0.79	−0.049	+1.11	+0.008	−4.44	−0.002
264	+0.49	−0.052	+1.14	+0.005	−4.43	+0.005
270	+0.16	−0.054	+1.17	+0.002	−4.38	+0.011
276	−0.16	−0.053	+1.17	0.000	−4.30	+0.020
282	−0.48	−0.054	+1.17	−0.001	−4.14	+0.029
288	−0.81	−0.054	+1.16	−0.002	−3.95	+0.036
294	−1.13	−0.052	+1.14	−0.004	−3.71	+0.042
300	−1.43	−0.051	+1.11	−0.008	−3.44	+0.049
306	−1.74	−0.048	+1.05	−0.011	−3.12	+0.059
312	−2.01	−0.044	+0.98	−0.013	−2.73	+0.067
318	−2.27	−0.042	+0.89	−0.016	−2.32	+0.071
324	−2.51	−0.038	+0.79	−0.018	−1.88	+0.075
330	−2.72	−0.031	+0.68	−0.019	−1.42	+0.081
336	−2.88	−0.026	+0.56	−0.021	−0.91	+0.084
342	−3.03	−0.021	+0.43	−0.022	−0.41	+0.084
348	−3.13	−0.014	+0.30	−0.023	+0.10	+0.085
354	−3.20	−0.008	+0.15	−0.023	+0.61	+0.084
360	−3.22	−0.001	+0.02	−0.022	+1.11	+0.082

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form of $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (174) Phaedra—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	A′	B′	C′	log sin *a*	log sin *b*	log sin *c*
	°	°	°			
1877.0	47.1139	250.8059	264.3497	9.99736	9.92070	9.75124
8	0995	8211	3593	36	69	25
9	0852	8363	3690	36	68	27
1880	47.0708	250.8515	264.3787	9.99736	9.92068	9.75128
1	0565	8668	3884	36	67	29
2	0422	8820	3981	37	66	30
3	0278	8972	4078	37	65	31
4	0135	9124	4174	37	64	33
1885	46.9991	250.9277	264.4271	9.99737	9.92063	9.75134
6	9848	9429	4368	37	62	35
7	9704	9581	4465	38	62	36
8	9561	9733	4562	38	61	38
9	9417	250.9886	4658	38	60	39
1890	46.9274	251.0038	264.4755	9.99738	9.92059	9.75140
1	9130	0190	4852	38	58	41
2	8987	0342	4949	39	57	42
3	8844	0495	5046	39	56	44
4	8700	0647	5142	39	56	45
1895	46.8557	251.0799	264.5239	9.99739	9.92055	9.75146
6	8412	0952	5336	39	54	47
7	8269	1104	5433	40	53	48
8	8125	1256	5530	40	52	50
9	7982	1408	5627	40	51	51
1900	46.7839	251.1561	264.5724	9.99740	9.92051	9.75152
1	7695	1713	5820	41	50	53
2	7552	1865	5917	41	49	54
3	7408	2018	6014	41	48	56
4	7265	2170	6111	41	47	57
1905	46.7122	251.2323	264.6208	9.99741	9.92046	9.75158
6	6978	2475	6304	42	46	59
7	6835	2628	6401	42	45	60
8	6691	2780	6498	42	44	61
9	6548	2932	6595	42	43	63
1910	46.6404	251.3084	264.6692	9.99742	9.92042	9.75164
1	6261	3237	6788	43	41	65
2	6118	3390	6885	43	41	66
3	5974	3542	6982	43	40	67
4	5831	3695	7079	43	39	69
1915	46.5687	251.3847	264.7175	9.99743	9.92038	9.75170
6	5544	3999	7272	44	37	71
7	5401	4152	7369	44	36	72
8	5257	4304	7466	44	35	73
9	5114	4457	7563	44	35	74
1920	46.4970	251.4609	264.7659	9.99744	9.92034	9.75176
1	4827	4762	7756	45	33	77
2	4684	4914	7853	45	32	78
3	4540	5066	7950	45	31	79
4	4397	5219	8047	45	30	80
1925	46.4253	251.5371	264.8143	9.99745	9.92030	9.75182
6	4110	5524	8240	46	29	83
7	3967	5676	8337	46	28	84
8	3823	5829	8434	46	27	85
9	3680	5981	8529	46	26	86
1930	46.3536	251.6133	264.8627	9.99746	9.92025	9.75188

Year	log cos *a*	log cos *b*	log cos *c*
1877.0	9.043 *n*	9.743 *n*	9.917
1930.0	9.033 *n*	9.744 *n*	9.917

TABLES OF (179) KLYTAEMNESTRA.

MEAN ELEMENTS.

Epoch, 1893, Sept. 17.0, M. T. Berlin=1893.712, M. T. Berlin.

$$\begin{array}{rrrrl} & {}^\circ & {}' & {}'' & \\ g_0= & 89 & 22 & 45= & 89^\circ\!.3792 \\ \omega= & 100 & 51 & 48= & 100.8632 \\ \Omega= & 253 & 17 & 5= & 253.2848 \\ i= & 7 & 47 & 18= & 7.7882 \\ \varphi= & 6 & 26 & 14= & 6.4371 \\ n= & \multicolumn{3}{r}{692''.2030=} & 0.19227861 \end{array} \left.\begin{array}{l} \\ \\ \\ \\ \end{array}\right\} \text{Mean equinox and ecliptic 1900.0.}$$

The elements are based on oppositions extending from 1877 to 1899 and on the perturbations of the first order by *Jupiter*, as given on page 314.

AUXILIARY QUANTITIES.

$\log a=0.47318$ $\log 57.2957\, e=0.80777$ $\log\sqrt{\frac{1-e}{1+e}}=9.95110$

$\log e=9.04965$ $\log p=0.46769$

TABLE I.—MEAN ANOMALY (g).

Jan. 0.0 of common years; Jan. 1.0 of leap years

Year	*g*	Year	*g*
	°		°
1877	355. 71052	1905	161. 95159
8	65. 89222	6	232. 13328
9	136. 07391	7	302. 81498
B 1880	206. 44788	B 8	12. 68895
1	276. 62957	9	82. 87064
2	346. 81127	1910	153. 05233
3	56. 99296	1	223. 23403
B 4	127. 36693	B 2	293. 60800
5	197. 54862	3	3. 78969
6	267. 73032	4	73. 97138
7	337. 91201	5	144. 15307
B 8	48. 28598	B 6	214. 52705
9	118. 46767	7	284. 70874
1890	188. 64937	8	354. 89043
1	258. 83106	9	65. 07212
B 2	329. 20503	B 1920	135. 44610
3	39. 38672	1	205. 62779
4	109. 56841	2	275. 80948
5	179. 75011	3	345. 99117
B 6	250. 12408	B 4	56. 36514
7	320. 30577	5	126. 54684
8	30. 48746	6	196. 72853
9	100. 66916	7	266. 91022
1900	170. 85085	B 8	337. 28419
1	241. 03254	9	47. 46589
2	311. 21423	1930	117. 64758
3	21. 39593		
B 4	91. 76990		
1905	161. 95159		

NOTE.—When g is used as an argument of the perturbations add to the g of this table $\Delta\pi=\pi-\pi_0=-0^\circ\!.4719$. For explanation see page 203.

Table for beginning of month

Month	*g*
	°
Jan. 0.0 1.0	0. 00000
Feb. 0.0 1.0	5. 96064
Mar. 0.0	11. 34444
Apr. 0. 0	17. 30507
May 0.0	23. 07343
June 0.0	29. 03407
July 0.0	34. 80243
Aug. 0.0	40. 76306
Sept. 0.0	46. 72370
Oct. 0.0	52. 49206
Nov. 0.0	58. 45270
Dec. 0.0	64. 22105

Change for n days[a]

n	*g*	*n*	*g*
1	0. 19228	16	3. 07646
2	0. 38456	17	3. 26874
3	0. 57684	18	3. 46101
4	0. 76911	19	3. 65329
5	0. 96139	20	3. 84557
6	1. 15367	21	4. 03785
7	1. 34595	22	4. 23013
8	1. 53823	23	4. 42241
9	1. 73051	24	4. 61469
10	1. 92279	25	4. 80696
11	2. 11506	26	4. 99924
12	2. 30734	27	5. 19152
13	2. 49962	28	5. 38380
14	2. 69190	29	5. 57608
15	2. 88418	30	5. 76836

[a] For days during January and February of leap years subtract one day before entering this table.

Tables of (179) Klytaemnestra—Continued.

PERTURBATIONS.

Arg. $ig-i'g'$		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	0				− 8		+ 3
0	0				− 0.02nt		+ 0.20nt
+1	0				+ 3		
+1		+ 0.75nt	− 7.06nt	− 3.53nt	− 0.37nt	− 9.05nt	− 1.19nt
+2		− 1					
+2		+ 0.02nt	− 0.20nt	− 0.20nt	− 0.02nt	− 0.52nt	− 0.07nt
+3	0		− 0.01nt	− 0.01nt		− 0.04nt	− 0.01nt
−1	+1	+ 5	− 3	+ 2	+ 3	− 2	− 2
0			+ 14	− 2	+ 3	− 8	−13
+1		− 285	+ 93	+ 28	+ 87	+ 6	+ 9
+2		− 10	+ 4	+ 3	+ 7	+ 1	+ 7
+3	+1	− 2			+ 1		
0	+2	− 24	+ 24	− 12	− 12	+16	+ 8
+1		+1354	−1107	−117	−147	−12	−11
+2		+ 925	− 678	−371	−508	−14	−15
+3		+ 32	− 23	− 23	− 32		+ 1
+4	+2	+ 2	− 2	− 3	− 4		
+1	+3	+ 18	− 1		+ 3	+ 7	+ 1
+2		+ 13	− 138	− 56	− 9	−20	− 8
+3		+ 46	− 65	− 45	− 32	− 4	
+4	+3	+ 3	− 3	− 4	− 3		
+2	+4	+ 26	− 16	+ 2	− 4		
+3		+ 13	+ 46	+ 25	− 9	+10	
+4		+ 6	− 15	− 11	− 5	− 1	
+5	+4	+ 1	− 2	− 2	− 1		
+3	+5	+ 4	− 4	− 2	− 2		
+4		+ 4	+ 7	+ 4	− 3	+ 1	
+5			− 4	− 4			
+6	+5		− 1	− 1			
+4	+6	+ 1	+ 1				
+5		+ 2	+ 2	+ 1	− 1	+ 1	
+6	+6	− 1	− 2	− 1			
+3	+7	− 293	+ 78		− 4		
+4		+ 10	− 2	− 1	− 4		
+5			+ 1				
+6		+ 1			− 1		
+7	+7		− 1	− 1	+ 1		

Tables of (179) Klytaemnestra—Continued.

TABLE II.—nδz.

PERIODIC TERMS.

Unit of a and b=0°001.

i	0		1.				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	+10.6	+0.23	+308.9	−10.44	−289.8	−12.24	+268.5	− 8.90	−233.0	− 9.68
6	+11.8	+0.16	+238.0	−12.92	−356.5	− 9.72	+208.6	−10.75	−284.4	− 7.30
12	+12.6	+0.10	+153.9	−14.90	−406.4	− 6.72	+139.5	−12.10	−320.6	− 4.62
18	+13.0	+0.02	+ 60.4	−16.10	−437.0	− 3.35	+ 64.9	−12.60	−339.8	− 1.75
24	+13.0	−0.04	− 38.0	−16.60	−446.6	+ 0.18	− 10.6	−12.36	−341.6	+ 1.07
30	+12.5	−0.12	−137.0	−16.30	−434.8	+ 3.73	− 83.4	−11.57	−327.0	+ 3.73
36	+11.6	−0.19	−231.8	−15.20	−401.8	+ 7.18	−149.4	−10.19	−296.8	+ 6.10
42	+10.2	−0.26	−318.0	−13.31	−348.7	+10.34	−205.7	− 8.42	−253.8	+ 7.93
48	+ 8.5	−0.30	−391.5	−10.89	−277.7	+13.04	−250.4	− 6.36	−201.6	+ 9.25
54	+ 6.6	−0.34	−448.7	− 7.97	−192.2	+15.30	−282.0	− 4.15	−142.8	+10.12
60	+ 4.4	−0.38	−487.2	− 4.64	− 95.5	+16.80	−300.2	− 1.90	− 80.2	+10.45
66	+ 2.1	−0.38	−504.4	− 1.03	+ 7.8	+17.50	−304.8	+ 0.25	− 17.4	+10.28
72	− 0.2	−0.39	−499.6	+ 2.63	+113.4	+17.50	−297.2	+ 2.20	+ 43.2	+ 9.76
78	− 2.6	−0.38	−472.8	+ 6.23	+216.4	+16.70	−278.4	+ 3.90	+ 99.7	+ 8.90
84	− 4.7	−0.34	−424.8	+ 9.60	+312.6	+15.20	−250.4	+ 5.35	+150.0	+ 7.79
90	− 6.7	−0.30	−357.6	+12.57	+397.5	+12.88	−214.2	+ 6.57	+193.2	+ 6.53
96	− 8.3	−0.24	−274.0	+15.02	+467.2	+10.11	−171.6	+ 7.50	+228.4	+ 5.16
102	− 9.6	−0.18	−177.4	+17.00	+518.8	+ 6.88	−124.2	+ 8.20	+255.1	+ 3.71
108	−10.5	−0.12	− 71.8	+18.10	+549.7	+ 3.32	− 73.2	+ 8.65	+272.9	+ 2.22
114	−11.0	−0.05	+ 38.4	+18.50	+558.6	− 0.38	− 20.4	+ 8.90	+281.7	+ 0.68
120	−11.1	+0.02	+148.5	+18.10	+545.1	− 4.07	+ 33.6	+ 8.92	+281.0	− 0.96
126	−10.7	+0.10	+254.1	+16.90	+509.8	− 7.63	+ 86.6	+ 8.66	+270.2	− 2.57
132	− 9.9	+0.16	+350.2	+14.95	+453.5	−10.90	+137.5	+ 8.17	+250.2	− 4.14
138	− 8.8	+0.20	+433.5	+12.50	+379.0	−13.66	+184.6	+ 7.39	+220.5	− 5.67
144	− 7.5	+0.25	+500.2	+ 9.52	+289.6	−15.90	+226.2	+ 6.32	+182.1	− 7.07
150	− 5.8	+0.28	+547.7	+ 6.13	+188.2	−17.60	+260.4	+ 4.92	+135.6	− 8.32
156	− 4.1	+0.30	+573.8	+ 2.52	+ 79.4	−18.50	+285.2	+ 3.23	+ 82.2	− 9.33
162	− 2.2	+0.31	+577.9	− 1.19	− 31.9	−18.60	+299.2	+ 1.32	+ 23.6	− 9.98
168	− 0.4	+0.28	+559.5	− 4.83	−141.8	−17.90	+301.0	− 0.73	− 37.6	−10.22
174	+ 1.2	+0.27	+519.9	− 8.27	−245.6	−16.60	+290.4	− 2.86	− 99.0	−10.03
180	+ 2.8	+0.23	+460.3	−11.36	−339.3	−14.44	+266.7	− 4.95	−158.0	− 9.38
186	+ 4.0	+0.18	+383.5	−13.95	−418.9	−11.82	+231.0	− 6.89	−211.6	− 8.27
192	+ 5.0	+0.13	+292.9	−15.94	−481.2	− 8.78	+184.0	− 8.61	−257.3	− 6.73
198	+ 5.6	+0.07	+192.2	−17.43	−524.2	− 5.40	+127.7	− 9.94	−292.4	− 4.81
204	+ 5.8	+0.01	+ 85.2	−18.10	−546.0	− 1.82	+ 64.7	−10.84	−315.0	− 2.64
210	+ 5.7	−0.05	− 23.2	−18.00	−546.0	+ 1.80	− 2.4	−11.26	−324.1	− 0.30
216	+ 5.2	−0.11	−129.0	−17.12	−524.4	+ 5.31	− 70.4	−11.15	−318.6	+ 2.11
222	+ 4.4	−0.16	−227.2	−15.46	−482.3	+ 8.58	−136.2	−10.55	−298.8	+ 4.44
228	+ 3.3	−0.20	−314.6	−13.34	−421.4	+11.44	−197.0	− 9.43	−265.3	+ 6.60
234	+ 2.0	−0.24	−387.3	−10.65	−345.0	+13.77	−249.4	− 7.88	−219.6	+ 8.49
240	+ 0.4	−0.26	−442.4	− 7.56	−256.1	+15.70	−291.6	− 5.98	−163.4	+10.04
246	− 1.1	−0.25	−478.0	− 4.18	−158.4	+16.70	−321.2	− 3.77	− 99.1	+11.15
252	− 2.6	−0.26	−492.6	− 0.65	− 56.6	+17.10	−336.8	− 1.35	− 29.6	+11.77
258	− 4.2	−0.24	−485.8	+ 2.85	+ 45.2	+16.70	−337.4	+ 1.16	+ 42.1	+11.88
264	− 5.5	−0.21	−458.4	+ 6.20	+142.8	+15.60	−322.9	+ 3.67	+113.0	+11.47
270	− 6.7	−0.17	−411.4	+ 9.23	+231.7	+13.78	−293.4	+ 6.08	+179.8	+10.54
276	− 7.5	−0.11	−347.6	+11.83	+308.2	+11.44	−250.0	+ 8.26	+239.5	+ 9.12
282	− 8.0	−0.05	−269.4	+14.00	+369.0	+ 8.61	−194.3	+10.12	+289.2	+ 7.22
288	− 8.1	+0.02	−180.6	+15.40	+411.5	+ 5.40	−128.6	+11.54	+326.1	+ 4.92
294	− 7.8	+0.08	− 85.4	+16.10	+433.8	+ 2.02	− 55.8	+12.48	+348.2	+ 2.32
300	− 7.1	+0.14	+ 11.7	+16.10	+435.7	− 1.43	+ 21.2	+12.82	+354.0	− 0.48
306	− 6.1	+0.20	+106.7	+15.40	+416.6	− 4.85	+ 98.0	+12.50	+342.4	− 3.33
312	− 4.7	+0.26	+195.0	+13.82	+377.5	− 8.05	+171.2	+11.56	+314.0	− 6.06
318	− 3.0	+0.30	+272.6	+11.73	+320.0	−10.81	+236.8	+10.00	+269.7	− 8.54
324	− 1.1	+0.33	+335.8	+ 9.11	+247.8	−13.05	+291.2	+ 7.87	+211.5	−10.62
330	+ 1.0	+0.35	+381.9	+ 6.05	+163.4	−14.80	+331.2	+ 5.27	+142.2	−12.30
336	+ 3.1	+0.35	+408.4	+ 2.70	+ 71.0	−15.80	+354.4	+ 2.37	+ 65.1	−13.24
342	+ 5.2	+0.34	+414.3	− 0.78	− 24.9	−16.00	+359.6	− 0.68	− 15.2	−13.43
348	+ 7.2	+0.32	+399.1	− 4.25	−120.0	−15.50	+346.2	− 3.68	− 94.6	−12.88
354	+ 9.0	+0.28	+363.3	− 7.52	−209.6	−14.30	+315.4	− 6.48	−168.3	−11.53
360	+10.6	+0.23	+308.9	−10.44	−289.8	−12.24	+268.5	− 8.90	−233.0	− 9.68

[$n\delta z$, $\delta \log r$, and $u \cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig - cT$.]

Tables of (179) Klytaemnestra—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit of a and b=0″.001.

i	3				4			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°
°								
0	−22.5	+1.09	+ 0.2	+4.11	+6.7	−0.23	−4.0	−0.54
6	− 4.8	+3.88	+21.5	+1.85	+4.2	−0.50	−6.9	−0.35
12	+24.0	+4.29	+22.4	−1.80	+0.7	−0.62	−8.2	−0.06
18	+46.7	+2.02	− 0.1	−4.90	−3.3	−0.56	−7.6	+0.25
24	+48.2	−1.93	−36.4	−5.66	−6.0	−0.34	−5.2	+0.48
30	+23.5	−5.59	−68.0	−3.45	−7.4	−0.06	−1.8	+0.57
36	−18.9	−7.02	−77.8	+0.72	−6.7	+0.22	+1.6	+0.46
42	−60.8	−5.39	−59.3	+4.92	−4.8	+0.35	+3.7	+0.26
48	−83.6	−1.44	−18.8	+7.22	−2.5	+0.37	+4.8	+0.08
54	−78.1	+3.04	+27.4	+6.53	−0.4	+0.30	+4.7	−0.07
60	−47.1	+6.01	+59.6	+3.18	+1.1	+0.22	+4.0	−0.12
66	− 6.0	+6.09	+65.6	−1.08	+2.2	+0.15	+3.2	−0.13
72	+26.0	+3.53	+46.6	−4.20	+2.9	+0.11	+2.4	−0.16
78	+36.4	−0.22	+15.2	−4.75	+3.5	+0.10	+1.3	−0.21
84	+23.4	−3.16	−10.4	−2.68	+4.1	+0.04	−0.1	−0.28
90	− 1.5	−3.72	−17.0	+0.68	+4.1	−0.09	−2.0	−0.33
96	−21.3	−1.74	− 2.2	+3.42	+3.0	−0.28	−4.1	−0.29
102	−22.4	+1.64	+24.0	+3.90	+0.8	−0.43	−5.5	−0.13
108	− 1.6	+4.48	+44.6	+1.73	−2.2	−0.48	−5.7	+0.12
114	+31.4	+5.09	+44.8	−1.98	−5.0	−0.38	−4.0	+0.38
120	+59.5	+2.90	+20.8	−5.32	−6.8	−0.16	−1.1	+0.57
126	+66.2	−1.19	−19.0	−6.45	−6.9	+0.19	+2.8	+0.61
132	+45.2	−5.22	−56.6	−4.60	−4.5	+0.50	+6.2	+0.42
138	+ 3.6	−7.15	−74.2	−0.48	−0.9	+0.65	+7.8	+0.08
144	−40.6	−6.01	−62.4	+4.03	+3.3	+0.59	+7.2	−0.28
150	−68.5	−2.30	−25.8	+6.82	+6.2	+0.35	+4.5	−0.53
156	−68.2	+2.29	+19.5	+6.62	+7.5	+0.02	+0.8	−0.61
162	−41.0	+5.65	+53.6	+3.59	+6.5	−0.29	−2.8	−0.50
168	− 0.4	+6.25	+62.6	−0.70	+4.0	−0.46	−5.2	−0.25
174	+34.0	+4.01	+45.2	−4.15	+1.0	−0.46	−5.8	+0.02
180	+47.7	+0.23	+12.8	−5.19	−1.5	−0.33	−5.0	+0.21
186	+36.8	−3.06	−17.1	−3.52	−3.0	−0.17	−3.3	+0.30
192	+11.0	−4.18	−29.4	−0.20	−3.5	−0.02	−1.4	+0.26
198	−13.3	−2.68	−19.5	+2.85	−3.3	+0.06	−0.2	+0.18
204	−21.1	+0.52	+ 4.8	+3.88	−2.8	+0.08	+0.8	+0.13
210	− 7.1	+3.55	+27.0	+2.27	−2.4	+0.08	+1.4	+0.10
216	+21.5	+4.61	+32.0	−1.11	−1.9	+0.08	+2.0	+0.12
222	+48.2	+2.96	+13.7	−4.45	−1.4	+0.15	+2.9	+0.13
228	+57.0	−0.72	−21.4	−5.88	−0.1	+0.27	+3.6	+0.08
234	+39.6	−4.62	−56.8	−4.47	+1.8	+0.33	+3.9	−0.08
240	+ 1.5	−6.75	−75.0	−0.75	+3.9	+0.28	+2.6	−0.28
246	−41.4	−5.96	−65.8	+3.58	+5.1	+0.10	+0.6	−0.40
252	−70.0	−2.55	−32.0	+6.45	+5.1	−0.13	−2.2	−0.46
258	−72.0	+1.90	+11.6	+6.46	+3.5	−0.37	−4.9	−0.32
264	−47.2	+5.26	+45.5	+3.63	+0.7	−0.50	−6.1	−0.08
270	− 8.9	+5.91	+55.2	−0.58	−2.5	−0.48	−5.8	+0.20
276	+23.7	+3.69	+38.6	−4.05	−5.0	−0.29	−3.7	+0.41
282	+35.4	−0.19	+ 6.6	−5.13	−6.0	−0.02	−0.9	+0.47
288	+21.4	−3.71	−23.0	−3.32	−5.2	+0.22	+1.9	+0.38
294	− 9.1	−5.01	−33.2	+0.40	−3.4	+0.33	+3.6	+0.17
300	−38.7	−3.44	−18.2	+4.00	−1.2	+0.31	+3.9	−0.03
306	−50.4	+0.21	+14.8	+5.62	+0.3	+0.16	+3.2	−0.16
312	−36.2	+4.07	+49.2	+4.33	+0.7	0.00	+2.0	−0.15
318	− 1.6	+6.12	+66.8	+0.82	+0.3	−0.08	+1.4	−0.02
324	+37.2	+5.34	+59.0	−3.20	−0.3	−0.02	+1.8	+0.12
330	+62.5	+2.17	+28.4	−5.77	0.0	+0.13	+2.9	+0.17
336	+63.2	−1.84	−10.2	−5.60	+1.3	+0.29	+3.8	+0.08
342	+40.4	−4.63	−38.8	−2.87	+3.5	+0.38	+3.8	−0.12
348	+ 7.6	−4.86	−44.6	+0.92	+5.8	+0.29	+2.4	−0.35
354	−17.9	−2.51	−27.8	+3.73	+7.0	+0.08	−0.4	−0.53
360	−22.5	+1.09	+ 0.2	+4.11	+6.7	−0.23	−4.0	−0.54

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (179) Klytaemnestra—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit of a and b=0°.001.

i	5				6			
g'	a_5	Diff. for 1°	b_5	Diff. for 1°	a_6	Diff. for 1°	b_6	Diff. for 1°
°								
0	+0.9	−0.07	−1.0	−0.08	0.0	−0.08	−0.8	−0.01
6	+0.3	−0.11	−1.4	−0.04	−0.5	−0.08	−0.8	+0.03
12	−0.4	−0.12	−1.5	+0.02	−0.9	−0.03	−0.4	+0.08
18	−1.1	−0.09	−1.1	+0.08	−0.9	+0.02	+0.2	+0.09
24	−1.5	−0.05	−0.5	+0.12	−0.7	+0.06	+0.7	+0.07
30	−1.7	+0.02	+0.3	+0.15	−0.2	+0.09	+1.0	+0.02
36	−1.3	+0.10	+1.3	+0.12	+0.4	+0.09	+0.9	−0.04
42	−0.5	+0.14	+1.7	+0.04	+0.9	+0.05	+0.5	−0.08
48	+0.4	+0.15	+1.8	−0.04	+1.0	−0.02	−0.1	−0.10
54	+1.3	+0.12	+1.3	−0.11	+0.7	−0.07	−0.7	−0.08
60	+1.8	+0.04	+0.5	−0.16	+0.2	−0.09	−1.0	−0.02
66	+1.8	−0.05	−0.6	−0.16	−0.4	−0.08	−0.9	+0.05
72	+1.2	−0.12	−1.4	−0.10	−0.8	−0.04	−0.4	+0.08
78	+0.3	−0.16	−1.8	−0.02	−0.9	+0.02	+0.1	+0.08
84	−0.7	−0.15	−1.7	+0.07	−0.6	+0.08	+0.6	+0.06
90	−1.5	−0.08	−1.0	+0.14	0.0	+0.08	+0.8	+0.01
96	−1.7	+0.01	0.0	+0.16	+0.4	+0.06	+0.7	−0.05
102	−1.4	+0.08	+0.9	+0.12	+0.7	+0.02	+0.2	−0.08
108	−0.7	+0.14	+1.5	+0.05	+0.6	−0.02	−0.3	−0.07
114	+0.3	+0.15	+1.5	−0.03	+0.4	−0.07	−0.6	−0.02
120	+1.1	+0.10	+1.1	−0.10	−0.2	−0.08	−0.6	+0.02
126	+1.5	+0.02	+0.3	−0.15	−0.5	−0.03	−0.4	+0.05
132	+1.3	−0.06	−0.7	−0.12	−0.6	+0.02	0.0	+0.07
138	+0.8	−0.12	−1.2	−0.07	−0.3	+0.05	+0.4	+0.05
144	−0.1	−0.15	−1.5	+0.01	0.0	+0.06	+0.6	0.00
150	−1.0	−0.11	−1.1	+0.09	+0.4	+0.04	+0.4	−0.05
156	−1.4	−0.03	−0.4	+0.14	+0.5	+0.01	0.0	−0.06
162	−1.4	+0.04	+0.6	+0.13	+0.5	−0.03	−0.3	−0 04
168	−0.9	+0.11	+1.2	+0.08	+0.1	−0.07	−0.5	−0.02
174	−0.1	+0.15	+1.5	+0.02	−0.3	−0.06	−0.5	+0.02
180	+0.9	+0.13	+1.4	−0.08	−0.6	−0.02	−0.2	+0.06
186	+1.5	+0.06	+0.6	−0.14	−0.5	+0.02	+0.2	+0.07
192	+1.6	−0.01	−0.3	−0.14	−0.3	+0.05	+0.6	+0.03
198	+1.4	−0.09	−1.1	−0.12	+0.1	+0.07	+0.6	−0.01
204	+0.5	−0.16	−1.7	−0.04	+0.5	+0.06	+0.5	−0.05
210	−0.5	−0.15	−1.6	+0.05	+0.8	+0.01	0.0	−0.07
216	−1.3	−0.10	−1.1	+0.11	+0.6	−0.04	−0.3	−0.06
222	−1.7	−0.02	−0.3	+0.14	+0.3	−0.07	−0.7	−0.03
228	−1.6	+0.05	+0.6	+0.13	−0.2	−0.07	−0.7	+0.02
234	−1.1	+0.12	+1.3	+0.08	−0.5	−0.05	−0.5	+0.06
240	−0.2	+0.14	+1.6	+0.01	−0.8	−0.01	0.0	+0.07
246	+0.6	+0.12	+1.4	−0.06	−0.6	+0.03	+0.3	+0.05
252	+1.2	+0.08	+1.0	−0.10	−0.4	+0.06	+0.6	+0.03
258	+1.5	+0.01	+0.2	−0.12	+0.1	+0.07	+0.7	0.00
264	+1.3	−0.05	−0.5	−0.10	+0.4	+0.04	+0.6	−0.04
270	+0.9	−0.08	−1.0	−0.06	+0.6	+0.02	+0.2	−0.06
276	+0.3	−0.09	−1.2	−0.01	+0.6	−0.01	−0.1	−0.05
282	−0.2	−0.08	−1.1	+0.02	+0.5	−0.03	−0.4	−0.03
288	−0.7	−0.06	−0.9	+0.05	+0.2	−0.06	−0.5	−0.02
294	−0.9	−0.02	−0.5	+0.07	−0.2	−0.05	−0.6	+0.01
300	−0.9	0.00	−0.1	+0.07	−0.4	−0.02	−0.4	+0.03
306	−0.9	+0.02	+0.3	+0.05	−0.5	−0.02	−0.2	+0.05
312	−0.7	+0.04	+0.5	+0.04	−0.6	0.00	+0.2	+0.05
318	−0.4	+0.05	+0.8	+0.03	−0.5	+0.03	+0.4	+0.03
324	−0.1	+0.05	+0.9	+0.01	−0.2	+0.06	+0.6	+0.02
330	+0.2	+0.06	+0.9	−0.01	+0.2	+0.06	+0.6	0.00
336	+0.6	+0.07	+0.8	−0.02	+0.5	+0.04	+0.6	−0.04
342	+1.0	+0.04	+0.6	−0.07	+0.7	+0.02	+0.1	−0.08
348	+1.1	+0.01	0.0	−0.09	+0.7	−0.02	−0.3	−0.07
354	+1.1	−0.02	−0.5	−0.08	+0.5	−0.06	−0.7	−0.04
360	+0.9	−0.07	−1.0	−0.08	0.0	−0.08	−0.8	−0.01

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (179) Klytaemnestra—Continued.

TABLE III.—δ log r.

PERIODIC TERMS.

Unit of a and b=0.00001.

i	0		1				2			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	−3.6	+0.08	−19.6	−0.72	−10.9	+0.74	− 88.0	−3.78	−107.0	+3.24
6	−3.0	+0.11	−23.2	−0.52	− 5.8	+0.92	−108.5	−2.97	− 85.1	+3.98
12	−2.3	+0.13	−25.9	−0.32	+ 0.2	+1.02	−123.6	−2.01	− 59.3	+4.50
18	−1.4	+0.12	−27.1	−0.08	+ 6.5	+1.08	−132.6	−0.98	− 31.1	+4.78
24	−0.8	+0.12	−26.8	+0.17	+13.2	+1.10	−135.4	+0.08	− 2.0	+4.83
30	0.0	+0.12	−25.1	+0.42	+19.7	+1.08	−131.7	+1.12	+ 26.9	+4.65
36	+0.7	+0.12	−21.7	+0.68	+26.1	+0.98	−122.0	+2.06	+ 53.8	+4.24
42	+1.4	+0.10	−17.0	+0.88	+31.5	+0.83	−107.0	+2.88	+ 77.8	+3.65
48	+1.9	+0.07	−11.1	+1.08	+36.1	+0.65	− 87.3	+3.56	+ 97.6	+2.92
54	+2.2	+0.04	− 4.1	+1.22	+39.3	+0.40	− 64.3	+4.02	+112.9	+2.08
60	+2.4	+0.02	+ 3.6	+1.32	+40.9	+0.15	− 39.1	+4.30	+122.6	+1.16
66	+2.5	0.00	+11.8	+1.37	+41.1	−0.11	− 12.7	+4.38	+126.8	+0.24
72	+2.4	−0.02	+20.0	+1.36	+39.6	−0.38	+ 13.5	+4.27	+125.5	−0.64
78	+2.2	−0.06	+28.1	+1.29	+36.5	−0.66	+ 38.5	+3.98	+119.0	−1.48
84	+1.7	−0.08	+35.5	+1.16	+31.7	−0.93	+ 61.2	+3.54	+107.8	−2.21
90	+1.3	−0.08	+42.0	+0.98	+25.3	−1.17	+ 81.0	+3.00	+ 92.5	−2.82
96	+0.7	−0.12	+47.2	+0.76	+17.7	−1.35	+ 97.2	+2.35	+ 73.9	−3.31
102	−0.1	−0.13	+51.1	+0.50	+ 9.1	−1.50	+109.2	+1.62	+ 52.8	−3.66
108	−0.9	−0.13	+53.1	+0.20	− 0.3	−1.58	+116.7	+0.88	+ 30.0	−3.87
114	−1.7	−0.13	+53.5	−0.11	− 9.9	−1.62	+119.8	−0.15	+ 6.4	−3.93
120	−2.5	−0.13	+51.8	−0.42	−19.7	−1.60	+118.5	−0.60	− 17.2	−3.87
126	−3.3	−0.12	+48.4	−0.70	−29.1	−1.52	+112.6	−1.32	− 40.0	−3.67
132	−4.0	−0.11	+43.4	−0.99	−37.9	−1.35	+102.6	−1.97	− 61.2	−3.33
138	−4.6	−0.08	+36.5	−1.24	−45.3	−1.13	+ 89.0	−2.58	− 80.0	−2.91
144	−5.1	−0.07	+28.5	−1.45	−51.5	−0.88	+ 71.7	−3.11	− 96.1	−2.40
150	−5.4	−0.04	+19.1	−1.61	−55.9	−0.60	+ 51.7	−3.52	−108.8	−1.78
156	−5.6	−0.02	+ 9.2	−1.70	−58.7	−0.29	+ 29.4	−3.82	−117.5	−1.08
162	−5.6	+0.01	− 1.2	−1.72	−59.4	+0.04	+ 5.8	−4.00	−121.7	−0.32
168	−5.5	+0.03	−11.4	−1.67	−58.2	+0.37	− 18.6	−4.05	−121.4	+0.47
174	−5.2	+0.06	−21.2	−1.58	−55.0	+0.68	− 42.8	−3.92	−116.1	+1.28
180	−4.8	+0.08	−30.3	−1.42	−50.0	+0.97	− 65.7	−3.64	−106.0	+2.06
186	−4.3	+0.10	−38.2	−1.21	−43.4	+1.27	− 86.5	−3.21	− 91.4	+2.78
192	−3.6	+0.11	−44.8	−0.93	−35.3	+1.42	−104.2	−2.62	− 72.6	+3.42
198	−3.0	+0.11	−49.4	−0.64	−26.4	+1.58	−118.0	−1.88	− 50.3	+3.94
204	−2.3	+0.12	−52.5	−0.35	−16.5	+1.66	−126.8	−1.04	− 25.3	+4.31
210	−1.5	+0.12	−53.6	−0.02	− 6.5	+1.64	−130.5	−0.14	+ 1.4	+4.50
216	−0.8	+0.11	−52.8	+0.31	+ 3.2	+1.59	−128.4	+0.83	+ 28.7	+4.48
222	−0.2	+0.10	−49.9	+0.61	+12.6	+1.49	−120.5	+1.77	+ 55.2	+4.27
228	+0.4	+0.08	−45.5	+0.86	+21.1	+1.32	−107.2	+2.65	+ 79.9	+3.83
234	+0.8	+0.06	−39.6	+1.09	+28.5	+1.10	− 88.7	+3.45	+101.2	+3.21
240	+1.1	+0.04	−32.4	+1.25	+34.3	+0.83	− 65.8	+4.11	+118.4	+2.43
246	+1.3	+0.01	−24.6	+1.35	+38.5	+0.55	− 39.4	+4.58	+130.4	+1.52
252	+1.2	−0.02	−16.2	+1.38	+40.9	+0.27	− 10.9	+4.82	+136.6	+0.50
258	+1.1	−0.02	− 8.0	+1.38	+41.7	−0.02	+ 18.5	+4.85	+136.4	−0.56
264	+0.8	−0.06	+ 0.3	+1.31	+40.6	−0.32	+ 47.3	+4.65	+129.9	−1.60
270	+0.4	−0.08	+ 7.7	+1.18	+37.9	−0.55	+ 74.3	+4.23	+117.2	−2.58
276	−0.1	−0.09	+14.4	+0.99	+34.0	−0.78	+ 98.1	+3.58	+ 98.9	−3.45
282	−0.7	−0.11	+19.6	+0.76	+28.6	−0.95	+117.3	+2.75	+ 75.8	−4.17
288	−1.4	−0.11	+23.5	+0.52	+22.6	−1.08	+131.1	+1.80	+ 48.9	−4.68
294	−2.0	−0.10	+25.9	+0.28	+15.7	−1.14	+139.0	+0.74	+ 19.6	−4.98
300	−2.7	−0.11	+26.8	0.00	+ 8.9	−1.12	+140.0	−0.38	− 10.8	−5.04
306	−3.3	−0.10	+25.9	−0.28	+ 2.3	−1.06	+134.5	−1.46	− 40.9	−4.85
312	−3.9	−0.08	+23.5	−0.48	− 3.8	−0.98	+122.5	−2.49	− 69.0	−4.41
318	−4.3	−0.06	+20.1	−0.68	− 9.4	−0.82	+104.6	−3.38	− 93.8	−3.78
324	−4.6	−0.04	+15.3	−0.87	−13.7	−0.62	+ 81.9	−4.13	−114.3	−2.95
330	−4.8	−0.02	+ 9.7	−0.98	−16.9	−0.41	+ 55.0	−4.68	−129.2	−1.96
336	−4.9	+0.01	+ 3.6	−1.02	−18.6	−0.14	+ 25.8	−4.98	−137.8	−0.88
342	−4.7	+0.03	− 2.6	−1.03	−18.6	+0.08	− 4.7	−5.05	−139.8	+0.24
348	−4.5	+0.06	− 8.8	−1.00	−17.6	+0.32	− 34.8	−4.88	−134.9	+1.32
354	−4.0	+0.08	−14.6	−0.90	−14.7	+0.56	− 63.1	−4.43	−124.0	+2.32
360	−3.6	+0.08	−19.6	−0.72	−10.9	+0.74	− 88.0	−3.78	−107.0	+3.24

[$n\delta z$, δ log r, and u/cos i are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (179) Klytaemnestra—Continued.

TABLE III.—$\delta \log r$—Continued.

PERIODIC TERMS.

Unit of a and b=0.00001.

i	3				4				5			
g'	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°	a_5	Diff. for 1°	b_5	Diff. for 1°
°												
0	−9.2	−0.83	−16.4	+0.32	−3.1	−0.30	−4.1	+0.18	−1.0	−0.02	−0.5	+0.08
6	−14.1	−0.72	−13.6	+0.62	−4.7	−0.19	−2.6	+0.30	−1.1	−0.01	+0.2	+0.09
12	−17.9	−0.50	−9.0	+0.84	−5.4	−0.02	−0.4	+0.38	−1.1	+0.04	+0.6	+0.07
18	−20.1	−0.19	−3.5	+0.94	−4.9	+0.15	+2.0	+0.33	−0.6	+0.09	+1.0	+0.06
24	−20.2	+0.13	+2.4	+0.97	−3.6	+0.27	+3.6	+0.21	0.0	+0.10	+1.3	+0.01
30	−18.5	+0.38	+8.1	+0.88	−1.7	+0.32	+4.5	+0.06	+0.6	+0.08	+1.1	−0.05
36	−15.6	+0.60	+12.8	+0.70	+0.3	+0.28	+4.3	−0.09	+1.0	+0.06	+0.7	−0.08
42	−11.3	+0.78	+16.5	+0.49	+1.7	+0.18	+3.4	−0.18	+1.3	+0.02	+0.2	−0.10
48	−6.2	+0.88	+18.7	+0.27	+2.4	+0.08	+2.1	−0.19	+1.2	−0.04	−0.5	−0.10
54	−0.8	+0.91	+19.7	+0.03	+2.7	+0.02	+1.1	−0.18	+0.8	−0.08	−1.0	−0.06
60	+4.7	+0.89	+19.1	−0.24	+2.6	−0.05	0.0	−0.14	+0.2	−0.11	−1.2	−0.01
66	+9.9	+0.82	+16.8	−0.52	+2.1	−0.08	−0.6	−0.11	−0.5	−0.09	−1.1	+0.03
72	+14.5	+0.63	+12.9	−0.75	+1.7	−0.08	−1.3	−0.10	−0.9	−0.06	−0.8	+0.08
78	+17.5	+0.34	+7.8	−0.93	+1.2	−0.12	−1.8	−0.08	−1.2	−0.02	−0.2	+0.11
84	+18.6	+0.01	+1.7	−1.02	+0.3	−0.17	−2.2	−0.03	−1.1	+0.05	+0.5	+0.08
90	+17.6	−0.35	−4.4	−0.94	−0.8	−0.18	−2.2	+0.04	−0.6	+0.08	+0.8	+0.05
96	+14.4	−0.67	−9.6	−0.72	−1.8	−0.16	−1.7	+0.14	−0.1	+0.09	+1.1	+0.01
102	+9.6	−0.86	−13.0	−0.40	−2.7	−0.08	−0.5	+0.23	+0.5	+0.08	+0.9	−0.05
108	+4.1	−0.91	−14.4	−0.05	−2.8	+0.06	+1.1	+0.26	+0.8	+0.03	+0.5	−0.08
114	−1.3	−0.81	−13.6	+0.28	−2.0	+0.20	+2.6	+0.21	+0.9	0.00	−0.1	−0.08
120	−5.6	−0.58	−11.1	+0.52	−0.4	+0.30	+3.6	+0.08	+0.8	−0.05	−0.5	−0.06
126	−8.3	−0.30	−7.3	+0.68	+1.6	+0.31	+3.5	−0.10	+0.3	−0.08	−0.8	−0.02
132	−9.3	−0.05	−3.0	+0.68	+3.3	+0.23	+2.4	−0.27	−0.2	−0.08	−0.8	+0.02
138	−8.9	+0.18	+0.9	+0.59	+4.4	+0.05	+0.3	−0.35	−0.6	−0.04	−0.5	+0.07
144	−7.0	+0.39	+4.1	+0.46	+3.9	−0.14	−1.8	−0.32	−0.7	0.00	0.0	+0.08
150	−4.2	+0.49	+6.4	+0.29	+2.7	−0.28	−3.5	−0.20	−0.6	+0.03	+0.5	+0.06
156	−1.1	+0.58	+7.6	+0.08	+0.5	−0.33	−4.2	−0.02	−0.3	+0.07	+0.7	+0.02
162	+2.7	+0.60	+7.4	−0.14	−1.3	−0.26	−3.7	+0.14	+0.2	+0.08	+0.7	−0.02
168	+6.1	+0.51	+5.9	−0.36	−2.6	−0.15	−2.5	+0.24	+0.6	+0.05	+0.5	−0.06
174	+8.8	+0.35	+3.1	−0.56	−3.1	−0.01	−0.8	+0.25	+0.8	+0.01	0.0	−0.08
180	+10.3	+0.10	−0.8	−0.71	−2.7	+0.08	+0.5	+0.18	+0.7	−0.03	−0.5	−0.07
186	+10.0	−0.20	−5.4	−0.74	−2.0	+0.16	+1.4	+0.09	+0.4	−0.08	−0.8	−0.03
192	+7.9	−0.50	−9.7	−0.63	−0.8	+0.15	+1.6	0.00	−0.2	−0.08	−0.9	+0.01
198	+4.0	−0.74	−13.0	−0.40	−0.2	+0.08	+1.4	−0.04	−0.6	−0.06	−0.7	+0.06
204	−1.0	−0.88	−14.5	−0.08	+0.2	+0.04	+1.1	−0.05	−0.9	−0.02	−0.2	+0.08
210	−6.5	−0.84	−13.9	+0.29	+0.3	+0.03	+0.8	−0.02	−0.9	+0.02	+0.2	+0.08
216	−11.1	−0.65	−11.0	+0.59	+0.6	+0.04	+0.8	−0.02	−0.7	+0.06	+0.7	+0.08
222	−14.3	−0.39	−6.8	+0.76	+0.8	+0.04	+0.5	−0.05	−0.2	+0.08	+1.1	+0.02
228	−15.8	−0.08	−1.9	+0.82	+1.1	+0.04	+0.2	−0.08	+0.3	+0.08	+1.0	−0.03
234	−15.4	+0.18	+3.0	+0.75	+1.3	−0.02	−0.6	−0.13	+0.8	+0.07	+0.7	−0.06
240	−13.6	+0.38	+7.1	+0.62	+0.9	−0.11	−1.4	−0.12	+1.1	+0.02	+0.3	−0.08
246	−10.8	+0.49	+10.4	+0.46	0.0	−0.17	−2.0	+0.05	+1.1	−0.02	−0.2	−0.09
252	−7.7	+0.55	+12.6	+0.29	−1.1	−0.19	−2.0	+0.07	+0.8	−0.07	−0.8	−0.08
258	−4.2	+0.59	+13.9	+0.14	−2.3	−0.16	−1.2	+0.18	+0.3	−0.08	−1.1	−0.02
264	−0.6	+0.59	+14.3	0.00	−3.0	−0.05	+0.1	+0.23	−0.2	−0.08	−1.1	+0.02
270	+2.9	+0.57	+13.9	−0.13	−2.9	+0.10	+1.6	+0.23	−0.6	−0.07	−0.8	+0.05
276	+6.2	+0.52	+12.7	−0.25	−1.8	+0.20	+2.9	+0.16	−1.0	−0.04	−0.5	+0.07
282	+9.1	+0.43	+10.9	−0.38	−0.5	+0.23	+3.5	+0.03	−1.1	+0.02	0.0	+0.08
288	+11.4	+0.31	+8.2	−0.48	+1.0	+0.22	+3.3	−0.08	−0.8	+0.04	+0.5	+0.07
294	+12.8	+0.16	+5.1	−0.52	+2.2	+0.14	+2.4	−0.17	−0.6	+0.05	+0.8	+0.04
300	+13.3	+0.02	+2.0	−0.50	+2.7	+0.04	+1.3	−0.16	−0.2	+0.08	+1.0	+0.01
306	+13.1	−0.08	−0.9	−0.48	+2.7	−0.03	+0.5	−0.13	+0.3	+0.08	+0.9	−0.02
312	+12.4	−0.14	−3.6	−0.42	+2.3	−0.05	−0.3	−0.08	+0.7	+0.05	+0.8	−0.04
318	+11.4	−0.18	−5.9	−0.37	+2.1	−0.01	−0.5	−0.04	+0.9	+0.02	+0.4	−0.07
324	+10.3	−0.21	−8.0	−0.36	+2.2	+0.02	−0.8	−0.06	+1.0	0.00	0.0	−0.08
330	+8.9	−0.27	−10.2	−0.38	+2.3	+0.02	−1.2	−0.10	+0.9	−0.02	−0.5	−0.07
336	+7.1	−0.37	−12.6	−0.40	+2.4	−0.03	−2.0	−0.18	+0.6	−0.06	−0.8	−0.05
342	+4.5	−0.54	−15.0	−0.34	+1.9	−0.13	−3.3	−0.18	+0.2	−0.08	−1.1	−0.02
348	+0.6	−0.72	−16.7	−0.20	+0.8	−0.25	−4.2	−0.12	−0.3	−0.08	−1.1	+0.02
354	−4.1	−0.82	−17.4	+0.02	−1.1	−0.32	−4.7	+0.01	−0.8	−0.06	−0.9	+0.05
360	−9.2	−0.83	−16.4	+0.32	−3.1	−0.30	−4.1	+0.18	−1.0	−0.02	−0.5	+0.08

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (179) Klytaemnestra—Continued.

TABLE IV.—u/cos i.

PERIODIC TERMS. Unit of *a* and *b*=0°.001.

i	0		1			
g'	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°
°						
0	− 0.5	−0.12	+1.1	−0.04	−0.8	−0.01
6	− 1.2	−0.12	+0.8	−0.04	−0.8	+0.02
12	− 1.9	−0.12	+0.6	−0.06	−0.6	+0.02
18	− 2.7	−0.12	+0.1	−0.07	−0.5	+0.04
24	− 3.4	−0.10	−0.2	−0.04	−0.1	+0.08
30	− 3.9	−0.08	−0.4	−0.02	+0.5	+0.10
36	− 4.3	−0.06	−0.5	0.00	+1.1	+0.10
42	− 4.6	−0.03	−0.4	+0.02	+1.8	+0.12
48	− 4.7	+0.02	−0.2	+0.05	+2.5	+0.12
54	− 4.4	+0.05	+0.2	+0.08	+3.3	+0.12
60	− 4.1	+0.08	+0.9	+0.12	+4.0	+0.11
66	− 3.4	+0.12	+1.7	+0.16	+4.6	+0.06
72	− 2.8	+0.14	+2.8	+0.18	+4.7	0.00
78	− 1.7	+0.18	+3.9	+0.18	+4.6	−0.02
84	− 0.6	+0.20	+5.0	+0.18	+4.4	−0.07
90	+ 0.7	+0.22	+6.1	+0.17	+3.8	−0.13
96	+ 2.1	+0.22	+7.0	+0.12	+2.8	−0.18
102	+ 3.4	+0.22	+7.6	+0.08	+1.6	−0.22
108	+ 4.8	+0.22	+8.1	+0.05	+0.1	−0.26
114	+ 6.1	+0.20	+8.2	−0.02	−1.5	−0.27
120	+ 7.2	+0.18	+7.8	−0.10	−3.1	−0.28
126	+ 8.2	+0.15	+7.0	−0.17	−4.8	−0.25
132	+ 9.0	+0.12	+5.8	−0.22	−6.1	−0.21
138	+ 9.6	+0.08	+4.4	−0.26	−7.3	−0.18
144	+ 9.9	+0.03	+2.7	−0.30	−8.2	−0.12
150	+10.0	−0.01	+0.8	−0.33	−8.7	−0.05
156	+ 9.8	−0.05	−1.3	−0.33	−8.8	+0.02
162	+ 9.4	−0.08	−3.2	−0.30	−8.5	+0.10
168	+ 8.7	−0.13	−4.9	−0.28	−7.6	+0.15
174	+ 7.8	−0.17	−6.5	−0.23	−6.7	+0.20
180	+ 6.7	−0.20	−7.7	−0.18	−5.2	+0.26
186	+ 5.4	−0.22	−8.6	−0.11	−3.6	+0.24
192	+ 4.1	−0.22	−9.0	−0.04	−2.2	+0.26
198	+ 2.7	−0.22	−9.1	+0.02	−0.5	+0.26
204	+ 1.4	−0.22	−8.8	+0.08	+0.9	+0.23
210	+ 0.1	−0.21	−8.2	+0.12	+2.3	+0.20
216	− 1.1	−0.19	−7.3	+0.17	+3.3	+0.16
222	− 2.2	−0.17	−6.2	+0.18	+4.2	+0.12
228	− 3.1	−0.13	−5.2	+0.18	+4.7	+0.06
234	− 3.8	−0.10	−4.0	+0.19	+4.9	+0.01
240	− 4.3	−0.07	−2.9	+0.19	+4.8	−0.04
246	− 4.6	−0.02	−1.7	+0.16	+4.4	−0.06
252	− 4.6	+0.01	−1.0	+0.12	+4.1	−0.07
258	− 4.5	+0.04	−0.3	+0.10	+3.6	−0.09
264	− 4.1	+0.07	+0.2	+0.07	+3.0	−0.12
270	− 3.7	+0.08	+0.5	+0.03	+2.2	−0.10
276	− 3.1	+0.11	+0.6	+0.02	+1.8	−0.08
282	− 2.4	+0.12	+0.8	+0.02	+1.2	−0.08
288	− 1.6	+0.12	+0.9	0.00	+0.9	−0.04
294	− 0.9	+0.12	+0.8	−0.01	+0.7	−0.05
300	− 0.2	+0.11	+0.8	0.00	+0.3	−0.02
306	+ 0.4	+0.10	+0.8	+0.02	+0.4	−0.02
312	+ 1.0	+0.08	+1.0	+0.02	+0.1	−0.02
318	+ 1.4	+0.04	+1.0	+0.01	+0.1	−0.01
324	+ 1.5	+0.02	+1.1	+0.02	0.0	−0.02
330	+ 1.6	−0.01	+1.2	+0.02	−0.1	−0.02
336	+ 1.4	−0.03	+1.3	+0.02	−0.2	−0.02
342	+ 1.2	−0.06	+1.4	0.00	−0.3	−0.03
348	+ 0.7	−0.08	+1.3	−0.01	−0.6	−0.03
354	+ 0.2	−0.10	+1.3	−0.02	−0.7	−0.02
360	− 0.5	−0.12	+1.1	−0.04	−0.8	−0.01

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (179) Klytaemnestra—Continued.

TABLE IV.—$u/\cos i$—Continued.

PERIODIC TERMS. Unit of a and b=0°.001.

i	2				3			
g'	a_2	Diff. for 1°	b_2	Diff. for 1°	a_3	Diff. for 1°	b_3	Diff. for 1°
°								
0	−9.2	−0.22	−4.4	+0.42	+1.7	+0.01	+0.2	−0.12
6	−10.2	−0.10	−1.8	+0.46	+1.6	−0.06	−0.6	−0.12
12	−10.4	+0.03	+1.1	+0.47	+1.0	−0.12	−1.3	−0.08
18	−9.8	+0.17	+3.8	+0.43	+0.2	−0.13	−1.7	−0.02
24	−8.4	+0.28	+6.3	+0.38	−0.6	−0.12	−1.6	+0.05
30	−6.5	+0.36	+8.4	+0.29	−1.2	−0.10	−1.1	+0.10
36	−4.1	+0.42	+9.8	+0.17	−1.8	−0.06	−0.4	+0.12
42	−1.5	+0.43	+10.4	+0.05	−1.9	+0.02	+0.4	+0.15
48	+1.1	+0.42	+10.4	−0.08	−1.6	+0.08	+1.4	+0.13
54	+3.6	+0.39	+9.5	−0.18	−1.0	+0.13	+2.0	+0.08
60	+5.8	+0.31	+8.2	−0.25	0.0	+0.17	+2.3	+0.03
66	+7.3	+0.22	+6.5	−0.32	+1.0	+0.18	+2.4	−0.02
72	+8.4	+0.12	+4.4	−0.36	+2.1	+0.15	+2.0	−0.12
78	+8.8	+0.02	+2.2	−0.36	+2.8	+0.08	+1.0	−0.18
84	+8.6	−0.08	+0.1	−0.34	+3.2	+0.01	−0.2	−0.20
90	+7.9	−0.15	−1.9	−0.29	+2.9	−0.08	−1.4	−0.19
96	+6.8	−0.21	−3.4	−0.21	+2.3	−0.13	−2.5	−0.17
102	+5.4	−0.24	−4.4	−0.12	+1.3	−0.21	−3.4	−0.10
108	+3.9	−0.24	−4.9	−0.05	−0.2	−0.23	−3.7	−0.01
114	+2.5	−0.22	−5.0	+0.02	−1.5	−0.22	−3.5	+0.08
120	+1.2	−0.18	−4.7	+0.07	−2.8	−0.18	−2.7	+0.16
126	+0.3	−0.12	−4.2	+0.11	−3.7	−0.10	−1.6	+0.22
132	−0.3	−0.07	−3.4	+0.13	−4.0	−0.01	−0.1	+0.25
138	−0.5	−0.01	−2.6	+0.12	−3.8	+0.08	+1.4	+0.24
144	−0.4	+0.04	−1.9	+0.09	−3.1	+0.17	+2.8	+0.19
150	0.0	+0.08	−1.5	+0.05	−1.8	+0.23	+3.7	+0.11
156	+0.5	+0.08	−1.3	−0.01	−0.3	+0.25	+4.1	+0.02
162	+1.0	+0.08	−1.6	−0.06	+1.2	+0.24	+3.9	−0.08
168	+1.4	+0.04	−2.0	−0.10	+2.6	+0.19	+3.2	−0.17
174	+1.5	0.00	−2.8	−0.13	+3.5	+0.11	+1.9	−0.23
180	+1.4	−0.06	−3.6	−0.13	+3.9	+0.02	+0.4	−0.24
186	+0.8	−0.12	−4.4	−0.14	+3.8	−0.08	−1.0	−0.22
192	0.0	−0.17	−5.3	−0.12	+3.0	−0.17	−2.3	−0.19
198	−1.2	−0.23	−5.8	−0.05	+1.8	−0.22	−3.3	−0.11
204	−2.8	−0.26	−5.9	+0.02	+0.4	−0.23	−3.6	0.00
210	−4.3	−0.26	−5.6	+0.08	−1.0	−0.22	−3.6	+0.08
216	−5.9	−0.25	−4.8	+0.18	−2.2	−0.16	−2.6	+0.14
222	−7.3	−0.20	−3.4	+0.25	−2.9	−0.08	−1.6	+0.20
228	−8.3	−0.12	−1.8	+0.31	−3.2	−0.01	−0.2	+0.22
234	−8.8	−0.04	+0.3	+0.37	−3.0	+0.08	+1.0	+0.19
240	−8.8	+0.06	+2.6	+0.37	−2.2	+0.15	+2.1	+0.15
246	−8.1	+0.17	+4.7	+0.35	−1.2	+0.19	+2.8	+0.08
252	−6.8	+0.26	+6.8	+0.31	+0.1	+0.20	+3.0	−0.02
258	−5.0	+0.35	+8.4	+0.22	+1.2	+0.18	+2.6	−0.10
264	−2.6	+0.41	+9.5	+0.12	+2.2	+0.12	+1.8	−0.15
270	−0.1	+0.43	+9.9	+0.01	+2.7	+0.04	+0.8	−0.18
276	+2.6	+0.42	+9.6	−0.11	+2.7	−0.03	−0.3	−0.18
282	+5.0	+0.38	+8.6	−0.22	+2.3	−0.11	−1.4	−0.15
288	+7.1	+0.31	+6.9	−0.33	+1.4	−0.15	−2.1	−0.09
294	+8.7	+0.21	+4.6	−0.42	+0.5	−0.17	−2.5	−0.03
300	+9.6	+0.08	+1.9	−0.45	−0.6	−0.17	−2.5	+0.04
306	+9.7	−0.04	−0.8	−0.46	−1.5	−0.12	−2.0	+0.12
312	+9.1	−0.17	−3.6	−0.43	−2.0	−0.06	−1.1	+0.15
318	+7.7	−0.29	−6.0	−0.36	−2.2	−0.01	−0.2	+0.16
324	+5.6	−0.39	−7.9	−0.28	−2.1	+0.05	+0.8	+0.14
330	+3.0	−0.44	−9.3	−0.17	−1.6	+0.12	+1.5	+0.09
336	+0.3	−0.47	−9.9	−0.02	−0.7	+0.15	+1.9	+0.03
342	−2.6	−0.46	−9.6	+0.11	+0.2	+0.14	+1.9	−0.02
348	−5.2	−0.41	−8.6	+0.23	+1.0	+0.11	+1.6	−0.08
354	−7.5	−0.33	−6.8	+0.35	+1.5	+0.06	+0.9	−0.12
360	−9.2	−0.22	−4.4	+0.42	+1.7	+0.01	+0.2	−0.12

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i a_i \sin ig + \Sigma_i b_i \cos ig + cT$.]

Tables of (179) Klytaemnestra—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY T=(t−t$_0$) IN JULIAN YEARS.

g	$n\delta z$ Unit of c=0°.001		$\delta \log r$ Unit of c=0.00001		$u/\cos i$ Unit of c=0°.001	
	c	Diff. for 1°	c	Diff. for 1°	c	Diff. for 1°
°						
0	−2.48	+0.004	−0.11	−0.018	−0.36	−0.061
6	−2.44	+0.010	−0.21	−0.018	−0.73	−0.059
12	−2.36	+0.015	−0.32	−0.018	−1.06	−0.056
18	−2.26	+0.018	−0.42	−0.016	−1.40	−0.054
24	−2.14	+0.023	−0.51	−0.015	−1.72	−0.052
30	−1.98	+0.028	−0.60	−0.013	−2.02	−0.045
36	−1.80	+0.030	−0.67	−0.012	−2.26	−0.038
42	−1.62	+0.033	−0.74	−0.011	−2.48	−0.034
48	−1.40	+0.037	−0.80	−0.008	−2.67	−0.028
54	−1.18	+0.038	−0.84	−0.008	−2.82	−0.022
60	−0.94	+0.041	−0.89	−0.006	−2.94	−0.017
66	−0.69	+0.042	−0.92	−0.003	−3.02	−0.010
72	−0.44	+0.042	−0.93	−0.001	−3.06	−0.004
78	−0.18	+0.042	−0.93	0.000	−3.07	+0.002
84	+0.07	+0.042	−0.93	+0.002	−3.04	+0.008
90	+0.32	+0.042	−0.91	+0.003	−2.98	+0.013
96	+0.57	+0.040	−0.89	+0.006	−2.88	+0.018
102	+0.80	+0.038	−0.84	+0.008	−2.76	+0.022
108	+1.03	+0.038	−0.80	+0.008	−2.62	+0.027
114	+1.25	+0.034	−0.76	+0.008	−2.44	+0.032
120	+1.45	+0.032	−0.70	+0.010	−2.23	+0.035
126	+1.64	+0.029	−0.64	+0.011	−2.02	+0.038
132	+1.80	+0.025	−0.57	+0.012	−1.78	+0.043
138	+1.94	+0.022	−0.50	+0.012	−1.50	+0.043
144	+2.07	+0.019	−0.42	+0.014	−1.26	+0.043
150	+2.17	+0.015	−0.33	+0.014	−0.98	+0.047
156	+2.25	+0.012	−0.25	+0.013	−0.70	+0.047
162	+2.31	+0.008	−0.17	+0.013	−0.42	+0.048
168	+2.34	+0.003	−0.09	+0.014	−0.13	+0.048
174	+2.35	0.000	0.00	+0.014	+0.16	+0.049
180	+2.34	−0.004	+0.08	+0.014	+0.46	+0.049
186	+2.30	−0.008	+0.17	+0.013	+0.75	+0.048
192	+2.24	−0.012	+0.24	+0.013	+1.03	+0.046
198	+2.16	−0.015	+0.33	+0.013	+1.30	+0.044
204	+2.06	−0.020	+0.40	+0.013	+1.56	+0.043
210	+1.92	−0.023	+0.49	+0.012	+1.82	+0.040
216	+1.78	−0.025	+0.55	+0.011	+2.04	+0.036
222	+1.62	−0.028	+0.62	+0.011	+2.26	+0.034
228	+1.44	−0.032	+0.68	+0.010	+2.45	+0.032
234	+1.24	−0.035	+0.74	+0.009	+2.64	+0.028
240	+1.02	−0.038	+0.79	+0.008	+2.80	+0.023
246	+0.79	−0.038	+0.83	+0.006	+2.92	+0.018
252	+0.56	−0.039	+0.86	+0.005	+3.02	+0.016
258	+0.32	−0.041	+0.89	+0.003	+3.11	+0.012
264	+0.07	−0.042	+0.90	+0.002	+3.16	+0.004
270	−0.18	−0.042	+0.91	0.000	+3.16	−0.002
276	−0.43	−0.042	+0.90	−0.002	+3.14	−0.007
282	−0.68	−0.042	+0.89	−0.002	+3.08	−0.012
288	−0.93	−0.041	+0.86	−0.005	+3.00	−0.017
294	−1.17	−0.038	+0.83	−0.007	+2.88	−0.024
300	−1.39	−0.036	+0.78	−0.008	+2.71	−0.030
306	−1.60	−0.034	+0.73	−0.010	+2.52	−0.036
312	−1.80	−0.031	+0.66	−0.012	+2.28	−0.043
318	−1.97	−0.028	+0.59	−0.014	+2.00	−0.047
324	−2.13	−0.023	+0.49	−0.016	+1.72	−0.050
330	−2.25	−0.018	+0.41	−0.016	+1.40	−0.053
336	−2.35	−0.015	+0.31	−0.017	+1.08	−0.055
342	−2.43	−0.011	+0.21	−0.017	+0.74	−0.059
348	−2.48	−0.005	+0.11	−0.018	+0.37	−0.062
354	−2.49	0.000	0.00	−0.018	0.00	−0.060
360	−2.48	+0.004	−0.11	−0.018	−0.36	−0.061

[$n\delta z$, $\delta \log r$, and $u/\cos i$ are to be computed in the form $\Sigma_i\, a_i \sin ig + \Sigma_i\, b_i \cos ig + cT$.]

Tables of (179) Klytaemnestra—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	A'	B'	C'	log sin a	log sin b	log sin c
	°	°	°			
1877.0	83.6776	350.8069	12.1875	9.99632	9.97022	9.58051
8	.6917	.8205	.2012	32	022	054
9	.7058	.8341	.2149	31	021	058
1880	83.7198	350.8477	12.2286	9.99631	9.97021	9.58061
1	.7339	.8613	.2423	31	020	064
2	.7480	.8749	.2560	31	020	068
3	.7620	.8885	.2697	31	019	071
4	.7761	.9021	.2834	31	019	074
1885	83.7901	350.9157	12.2971	9.99631	9.97018	9.58078
6	.8042	.9292	.3109	31	018	081
7	.8183	.9428	.3246	31	017	085
8	.8324	.9564	.3383	31	017	088
9	.8465	.9700	.3520	31	016	092
1890	83.8605	350.9836	12.3657	9.99631	9.97016	9.58095
1	.8745	350.9972	.3794	31	015	099
2	.8886	351.0108	.3931	31	015	102
3	.9027	.0244	.4068	30	014	106
4	.9167	.0380	.4205	30	014	109
1895	83.9308	351.0516	12.4342	9.99630	9.97013	9.58113
6	.9448	.0651	.4480	30	013	116
7	.9589	.0787	.4617	30	012	119
8	.9730	.0923	.4754	30	012	123
9	83.9870	.1059	.4891	30	011	126
1900	84.0011	351.1195	12.5028	9.99630	9.97011	9.58130
1	.0152	.1331	.5165	30	010	133
2	.0292	.1467	.5302	30	010	137
3	.0433	.1603	.5439	30	009	140
4	.0574	.1739	.5576	30	009	144
1905	84.0714	351.1875	12.5713	9.99630	9.97008	9.58147
6	.0855	.2010	.5851	30	008	151
7	.0995	.2146	.5988	30	007	154
8	.1136	.2282	.6125	29	007	158
9	.1277	.2418	.6262	29	006	161
1910	84.1417	351.2554	12.6399	9.99629	9.97006	9.58165
1	.1558	.2690	.6536	29	005	168
2	.1699	.2826	.6673	29	005	171
3	.1839	.2962	.6810	29	004	175
4	.1980	.3098	.6947	29	004	178
1915	84.2120	351.3234	12.7084	9.99629	9.97003	9.58182
6	.2261	.3369	.7222	29	003	185
7	.2402	.3505	.7359	29	002	188
8	.2542	.3641	.7496	29	002	192
9	.2683	.3777	.7633	29	001	195
1920	84.2824	351.3913	12.7770	9.99629	9.97001	9.58199
1	.2964	.4049	.7907	29	000	203
2	.3105	.4185	.8044	29	9.97000	206
3	.3246	.4321	.8181	28	9.96999	210
4	.3386	.4457	.8318	28	999	213
1925	84.3527	351.4593	12.8455	9.99628	9.96998	9.58217
6	.3667	.4728	.8593	28	998	220
7	.3808	.4864	.8730	28	997	223
8	.3949	.5000	.8867	28	997	227
9	.4089	.5136	.9004	28	996	230
1930	84.4230	351.5272	12.9141	9.99628	9.96996	9.58234

Year	log cos a	log cos b	log cos c
1877.0	9.113 *n*	9.554 *n*	9.966
1930.0	9.115 *n*	9.556 *n*	9.966

TABLES

OF

(101) HELENA. (103) HERA. (119) ALTHAEA.

The perturbations are tabulated in the forms

$$n\partial z = (n\partial z)_1 + (n\partial z)_2 + \ .\ .\ .\ .\ .\ + (n\partial z)_t T - c_z$$

$$\partial \log r = (\partial \log r)_1 + (\partial \log r)_2 + \ .\ .\ .\ + (\partial \log r)_t T - c_r$$

$$\partial\beta = (\partial\beta)_1 + (\partial\beta)_2 + \ .\ .\ .\ + (\partial\beta)_t T - c_\beta .$$

TABLES OF (101) HELENA.

OSCULATING ELEMENTS.

Epoch and osculation, 1877, Dec. 10.0, M. T. Berlin=1877.942, M. T. Berlin.

$$
\begin{array}{lrrrl}
 & {}^{\circ} & {}' & {}'' & \\
g_0= & 99 & 46 & 33= & 99^{\circ}7757 \\
\omega= & 343 & 57 & 7= & 343.9519 \\
\Omega= & 343 & 39 & 43= & 343.6620 \\
i= & 10 & 9 & 51= & 10.1642 \\
= & 7 & 55 & 16= & 7.9210 \\
\end{array}
\left.\begin{array}{l} \\ \\ \\ \end{array}\right\}\text{Mean equinox and ecliptic 1880.0.}
$$

$n=854.''4377 = 0.23734381$

g_0 and n are mean elements.

The elements are based on oppositions extending from 1868 to 1899 and on the perturbations of the first order by *Jupiter*, as given on page 329.

AUXILIARY QUANTITIES.

$\log a=0.41222$ $\log 57.2958e=0.89740$ $\log \sqrt{\frac{1-e}{1+e}}=9.93977$

$\log e=9.13928$ $\log p =0.40389$

NUMERAL DESIGNATION OF THE ARGUMENTS FOR TABLES II-V.

$1= g-3g'$
$2= g$
$3= g-g'$
$4= g-2g'$
$5=2g-3g'$
$6= -g'$
$7=2g-g'$
$8= g-4g'$
$9= 2g-5g'$
$10= 3g-4g'$
$11= 3g-5g'$
$12= 4g-3g'$
$13= 3g-2g'$
$14=-g-g'$
$15= 4g-5g'$
$16= 4g-7g'$
$17= 5g-4g'$
$18= 5g-6g'$
$19= 5g-3g'$
$20=-g-2g'$
$21= g-5g'$

CONSTANTS TO BE SUBTRACTED FROM THE TABULATED PERTURBATIONS.

$c_z=0^{\circ}9227$ $c_r=0.00224$ $c_\beta=0.00263$

Derivation of c_z, c_r, c_β (See also page 208)

	Arg. 1–11	$n\delta z$ Unit=0°001	$\delta \log r$ Unit=0.00001	$\delta\beta$ Unit=0.00001	Arg. 11–21	$n\delta z$ Unit=0°001	$\delta \log r$ Unit=0.00001	$\delta\beta$ Unit=0.00001
Constants added to make all numbers positive.	1	307.97	11.4	17.9	sum	916.46	213.8	243.8
	2	231.97	87.5	87.7	12	0.78	0.7	0.9
	3	102.78	37.8	9.8	13	3.22	2.7	1.2
	4	106.58	16.4	18.9	14	1.03	0.5	4.4
	5	148.00	54.6	82.4	15	0.72	0.4	0.5
	6	5.67	0.9	16.5	16	0.17	0.1	
	7	2.39	1.6	4.4	17	0.14	0.1	
	8	0.44	0.1	1.0	18	0.22	0.1	
	9	3.47	0.3	0.2	19		0.1	
	10	4.36	2.1	2.2	20			1.1
	11	2.83	1.1	2.8	21			2.1
	Sum	916.46	213.8	243.8	Sum	922.7	218.5	254.0

$c_z=0^{\circ}9227$

$c_r=0.002185-$(constant part of $\delta \log r+$correction for difference between mean and osculating values of semi-major axis).
$=0.002185-(-112''.33+88''.49)\sin 1''$ Mod.
$=0.002185+0.000050.$
$=0.00224$

$c_\beta=0.002540-$(constant part of $\delta\beta$)
$=0.002540+0.000087$
$=0.00263$

Tables of (101) Helena—Continued.

TABLE I.—MEAN ANOMALY (g).

Jan. 0.0 of common years; Jan. 1.0 of leap years

Year	g	Year	g
	°		°
B 1868	317. 98033	1900	211. 81744
9	44. 61082	1	298. 44793
1870	131. 24131	2	25. 07842
1	217. 87180	3	111. 70891
B 2	304. 73964	B 4	198. 57674
3	31. 37013	5	285. 20723
4	118. 00062	6	11. 83772
5	204. 63111	7	98. 46821
B 6	291. 49894	B 8	185. 33605
7	18. 12943	9	271. 96654
8	104. 75992	1910	358. 59703
9	191. 39041	1	85. 22752
B 1880	278. 25825	B 2	172. 09536
1	4. 88874	3	258. 72585
2	91. 51923	4	345. 35634
3	178. 14972	5	71. 98683
B 4	265. 01756	B 6	158. 85466
5	351. 64805	7	245. 48515
6	78. 27854	8	332. 11564
7	164. 90903	9	58. 74613
B 8	251. 77686	B 1920	145. 61397
9	338. 40735	1	232. 24445
1890	65. 03784	2	318. 87495
1	151. 66833	3	45. 50544
B 2	238. 53612	B 4	132. 37327
3	325. 16666	5	219. 00376
4	51. 79715	6	305. 63426
5	138. 42764	7	32. 26475
B 6	225. 29547	B 8	119. 13258
7	311. 92596	9	205. 76307
8	38. 55646	1930	292. 39356
1899	125. 18695		

NOTE.—When g is used as an argument of the perturbations, add to the g of this table $\Delta\pi=\pi-\pi_0=+0^{\circ}.1071$. For explanation see page 203.

Table for beginning of month

Month	g
	°
Jan. 0.0 1.0	0. 00000
Feb. 0.0 1.0	7. 35766
Mar. 0.0	14. 00328
Apr. 0.0	21. 36094
May 0.0	28. 48126
June 0.0	35. 83892
July 0.0	42. 95923
Aug. 0.0	50. 31689
Sept. 0.0	57. 67455
Oct. 0.0	64. 79486
Nov. 0.0	72. 15252
Dec. 0.0	79. 27283

Change for n days[a]

n	g	n	g
	°		°
1	0. 23734	16	3. 79750
2	0. 47469	17	4. 03484
3	0. 71203	18	4. 27218
4	0. 94937	19	4. 50953
5	1. 18671	20	4. 74687
6	1. 42406	21	4. 98422
7	1. 66140	22	5. 22156
8	1. 89874	23	5. 45890
9	2. 13609	24	5. 69625
10	2. 37343	25	5. 93359
11	2. 61078	26	6. 17094
12	2. 84812	27	6. 40828
13	3. 08546	28	6. 64562
14	3. 32281	29	6. 88297
15	3. 56015	30	7. 12031

[a] For days during January and February of leap years subtract one day before entering this table.

Tables of (101) Helena—Continued.

PERTURBATIONS.

Arg. $ig-i'g'$		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	−0				−112.33		− 6.97
0	−0						+ 0.241nt
+1	0	+ 832.0	+ 76.4	+ 37.9	−412.5	+53.6	+44.4
+1		+ 0.608nt	− 7.382nt	− 3.691nt	− 0.304nt	+ 1.158nt	+ 3.000nt
+2		+ 1.2	− 0.0	0.0	− 1.1	− 0.4	+ 0.0
+2		+ 0.021nt	− 0.160nt	− 0.160nt	− 0.021nt	+ 0.079nt	+ 0.206nt
+3	0	+ 0.2	+ 0.0	− 0.1	+ 0.2		
−2	−1	− 0.2	+ 0.1		− 0.1	+ 0.1	− 0.1
−1		− 2.8	+ 2.4	− 1.6	− 1.8	+ 2.4	− 2.5
0		− 0.8	+ 17.3	− 1.3	+ 1.4	+ 7.2	− 4.1
+1		− 103.6	+114.9	+ 40.4	+ 36.3	− 5.4	+ 0.2
+2		− 4.2	+ 6.8	+ 5.1	+ 3.3	+ 1.6	− 3.2
+3	−1	− 0.1		+ 0.2	+ 0.2		− 0.2
−1	−2	+ 0.4	+ 0.6	− 0.2	+ 0.2	− 0.1	+ 0.9
0		+ 3.1	− 1.1	− 0.9	+ 1.3	− 1.8	+ 9.6
+1		− 48.3	−365.0	− 81.8	+ 9.9	+ 7.4	−13.0
+2		− 13.4	−257.2	−152.4	+ 7.9	− 0.8	− 2.0
+3			− 11.6	− 12.6	− 0.2	− 0.1	− 1.0
+4	−2	− 0.1	− 1.0	− 1.5	+ 0.1		− 0.1
0	−3	− 1.5	− 3.6	+ 1.9	− 0.9	+ 4.7	+ 1.4
+1		+1040.3	−462.3	+ 15.1	+ 50.8	+ 8.7	+10.9
+2		− 532.0	− 17.5	− 10.1	+258.5	−40.8	−51.9
+3		− 35.5	− 16.6	− 12.3	+ 30.2	− 2.5	− 3.7
+4		− 2.4	− 1.4	− 1.6	+ 3.2	− 0.5	− 0.5
+5	−3	− 0.3	− 0.2	− 0.2	+ 0.5		
+1	−4	+ 1.6	+ 0.1	− 0.4	+ 0.2	+ 0.3	+ 0.7
+2		+ 10.8	− 18.0	− 6.9	− 4.3	− 3.0	− 1.8
+3		+ 11.1	− 11.0	− 7.3	− 6.8	− 1.8	+ 0.1
+4		− 4.5	− 0.2	− 0.3	+ 3.5	+ 0.2	− 0.1
+5		− 0.6	− 0.1	− 0.1	+ 0.6	− 0.1	
+6	−4	− 0.1			+ 0.1		
+1	−5						− 1.7
+2		+ 6.1	+ 10.8	+ 1.3	− 0.5	+ 0.1	+ 0.3
+3		+ 3.8	+ 9.4	+ 5.2	− 2.1	− 0.1	+ 2.2
+4		+ 0.1	− 2.6	− 1.8		+ 0.4	− 0.1
+5		− 0.8	+ 0.9	+ 0.7	+ 0.8		
+6	−5	− 0.2	+ 0.1	+ 0.1	+ 0.2		
+2	−6	− 15.6	− 27.4	+ 1.0	− 1.8	− 0.3	− 0.1
+3		+ 8.3	− 0.5	− 0.2	− 4.0	+ 1.1	+ 0.3
+4		+ 1.5	+ 0.4	+ 0.2	− 1.0	+ 0.3	+ 0.2
+5		− 0.6	− 0.6	− 0.4	+ 0.4		− 0.1
+6			+ 0.4	− 0.3			
+7	−6		+ 0.1	+ 0.1			
+4	−7	− 0.4	+ 0.4	+ 0.2	+ 0.2	− 0.1	
+5		+ 0.3	− 0.2	− 0.1	− 0.2	+ 0.1	
+6		− 0.3			+ 0.2		
+7	−7	+ 0.1	+ 0.1	+ 0.1	− 0.1		
+5	−8		+ 0.1	+ 0.1			
+6			− 0.1	− 0.1			
+7	−8	− 0.1	+ 0.1	+ 0.1	+ 0.1		
+7	−9	− 0.1	− 0.1				
+8	−9		+ 0.1				

The constant part in $n\delta z$ is included in the element g_0.

The nontrigonometrical term multiplied by the time in $n\delta z$ is included in the element n.

The constant part of ν is included in the constant c_r.

The constant part of $u\cos i$ is included in the constant c_β.

All other terms are contained in Tables II–V.

Tables of (101) Helena—Continued.

TABLE II.—$n\partial z$.

Args. 1-5	$(n\partial z)_1$	Diff. for 1°	$(n\partial z)_2$	Diff. for 1°	$(n\partial z)_3$	Diff. for 1°	$(n\partial z)_4$	Diff. for 1°	$(n\partial z)_5$	Diff. for 1°
°										
0	172.0	+17.59	253.1	+14.50	58.9	− 4.48	0.0	−0.10	143.3	−9.22
6	202.1	+18.56	277.2	+14.29	53.0	− 2.52	0.6	+0.70	127.9	−9.17
12	233.7	+19.36	300.7	+13.96	50.7	− 0.30	2.3	+1.42	112.7	−8.98
18	266.5	+19.91	323.6	+13.49	52.1	+ 2.01	5.3	+2.12	98.0	−8.70
24	299.9	+20.20	345.5	+12.79	57.3	+ 4.15	9.3	+2.72	83.8	−8.33
30	333.7	+20.30	366.2	+11.96	65.8	+ 5.94	14.3	+3.26	70.3	−7.88
36	367.4	+20.17	385.2	+10.96	77.0	+ 7.50	20.1	+3.70	57.6	−7.34
42	400.8	+19.81	402.7	+ 9.93	90.5	+ 8.46	26.6	+4.04	45.9	−6.67
48	433.3	+19.18	418.2	+ 8.71	104.8	+ 8.70	33.6	+4.46	35.3	−6.02
54	464.6	+18.27	431.6	+ 7.47	119.1	+ 8.29	41.4	+4.78	25.9	−5.26
60	494.1	+17.15	443.1	+ 6.10	132.3	+ 7.07	49.5	+5.03	17.9	−4.40
66	521.6	+15.84	451.9	+ 4.63	143.5	+ 5.94	58.1	+5.27	11.2	−3.54
72	546.8	+14.28	458.5	+ 3.22	151.9	+ 4.04	67.1	+5.46	6.0	−2.63
78	569.1	+12.52	462.6	+ 1.66	156.8	+ 1.81	76.4	+5.71	2.5	−1.70
84	588.4	+10.66	464.1	+ 0.14	157.8	− 0.53	86.1	+5.86	0.4	−0.73
90	604.5	+ 8.62	463.1	− 1.32	155.1	− 2.78	95.9	+5.92	0.1	+0.26
96	617.1	+ 6.48	459.6	− 2.87	148.6	− 4.96	105.8	+6.05	1.3	+1.24
102	626.1	+ 4.24	453.5	− 4.38	138.8	− 6.78	116.0	+6.08	4.2	+2.20
108	631.2	+ 1.93	445.1	− 5.80	126.2	− 8.29	126.0	+5.96	8.6	+3.12
114	632.3	− 0.33	434.2	− 7.14	111.4	− 9.36	135.8	+5.84	14.6	+4.03
120	630.1	− 2.62	421.3	− 8.48	95.2	− 9.95	145.5	+5.66	22.1	+4.90
126	623.8	− 4.88	406.1	− 9.70	78.4	−10.14	154.6	+5.37	30.9	+5.72
132	613.8	− 7.05	389.1	−10.71	61.7	− 9.82	163.3	+5.01	41.1	+6.42
138	600.3	− 9.12	370.5	−11.65	45.9	− 9.06	171.3	+4.58	52.3	+7.11
144	583.5	−11.03	350.3	−12.55	31.7	− 7.95	178.6	+4.08	64.7	+7.74
150	563.6	−12.80	328.8	−13.22	19.6	− 6.53	184.9	+3.54	78.0	+8.23
156	541.0	−14.36	306.3	−13.80	10.1	− 4.81	190.4	+3.03	92.1	+8.65
162	515.8	−15.75	282.9	−14.23	3.6	− 2.94	195.0	+2.46	106.8	+8.96
168	488 5	−16.97	259.0	−14.48	0.4	− 0.96	198.6	+1.87	121.9	+9.24
174	459.4	−17.93	234.8	−14.54	0.4	+ 1.04	201.2	+1.38	137.4	+9.33
180	428.8	−18.70	210.6	−14.48	3.8	+ 2.93	203.1	+0.76	153.0	+9.31
186	397.1	−19.24	186.6	−14.26	10.2	+ 4.73	203.9	+0.26	168.4	+9.24
192	364.8	−19.57	163.2	−13.87	19.4	+ 6.30	204.0	−0.25	183.7	+9.07
198	332.1	−19.65	140.4	−13.40	31.0	+ 7.58	203.1	−0.78	198.6	+8.76
204	299.4	−19.53	118.6	−12.71	44.6	+ 8.65	201.4	−1.22	212.9	+8.38
210	267.1	−19.20	98.1	−11.85	59.7	+ 9.40	199.0	−1.73	226.5	+7.92
216	235.5	−18.70	79.2	−10.92	75.7	+ 9.81	195.6	−2.23	239.2	+7.34
222	204.9	−18.00	61.8	− 9.89	92.2	+ 9.98	191.5	−2.73	250.9	+6.68
228	175.6	−17.14	46.2	− 8.71	108.8	+ 9.88	186.5	−3.28	261.4	+5.97
234	147.8	−16.12	32.8	− 7.49	125.0	+ 9.52	180.6	−3.80	270.8	+5.18
240	121.9	−14.95	21.3	− 6.13	140.4	+ 8.90	173.9	−4.34	278.7	+4.34
246	98.1	−13.71	12.4	− 4.67	154.6	+ 8.10	166.1	−4.88	285.2	+3.46
252	76.3	−12.28	5.8	− 3.20	167.3	+ 7.12	157.6	−5.38	290.2	+2.53
258	57.2	−10.76	1.7	− 1.74	178.2	+ 5.94	148.2	−5.92	293.6	+1.58
264	40.5	− 9.18	0.0	− 0.24	187.0	+ 4.57	137.9	−6.32	295.4	+0.60
270	26.6	− 7.51	0.9	+ 1.26	193.4	+ 3.08	127.1	−6.69	295.7	−0.33
276	15.5	− 5.76	4.2	+ 2.80	197.2	+ 1.55	115.6	−7.00	294.3	−1.31
282	7.3	− 4.01	10.2	+ 4.30	198.5	− 0.08	103.8	−7.22	291.3	−2.28
288	2.1	− 2.19	18.5	+ 5.71	197.0	− 1.68	91.6	−7.31	286.8	−3.19
294	0.1	− 0.33	29.1	+ 7.07	192.9	− 3.27	79.5	−7.22	280.7	−4.08
300	1.1	+ 1.53	42.1	+ 8.40	186.0	− 4.83	67.6	−7.04	273.2	−4.93
306	5.2	+ 3.41	57.1	+ 9.62	176.9	− 6.13	56.1	−6.74	264.3	−5.71
312	12.4	+ 5.25	74.1	+10.70	165.7	− 7.32	45.2	−6.32	254.2	−6.43
318	22.7	+ 7.07	92.7	+11.07	152.6	− 8.29	35.1	−5.73	242.9	−7.07
324	36.0	+ 8.88	112.9	+12.56	138.2	− 8.89	26.2	−5.04	230.6	−7.70
330	52.2	+10.58	134.5	+13.15	123.1	− 9.16	18.3	−4.30	217.3	−8.20
336	71.2	+12.25	157.0	+13.82	107.9	− 9.09	11.9	−3.50	203.4	−8.54
342	92.9	+13.75	180.5	+14.28	93.1	− 8.58	6.7	−2.65	188.9	−8.90
348	117.1	+15.23	204.5	+14.57	79.5	− 7.61	3.1	−1.74	173.8	−9.17
354	143 6	+16.49	228.9	+14.59	67.9	− 6.23	0.9	−0.92	158.6	−9.18
360	172.0	+17.59	253.1	+14.50	58.9	− 4.48	0.0	−0.10	143.3	−9.22

$[n\partial z=(n\partial z)_1+(n\partial z)_2+\ldots\ldots\ldots\ldots+(n\partial z)_t T-cz.]$

Tables of (101) Helena—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit=0°001.

Arg's. 6–18	$(n\delta z)_6$	$(n\delta z)_7$	$(n\delta z)_8$	$(n\delta z)_9$	$(n\delta z)_{10}$	$(n\delta z)_{11}$	$(n\delta z)_{12}$	$(n\delta z)_{13}$	$(n\delta z)_{14}$	$(n\delta z)_{15}$	$(n\delta z)_{16}$	$(n\delta z)_{17}$	$(n\delta z)_{18}$
°													
0	9.2	4.0	0.5	6.5	1.3	5.4	0.4	0.0	1.7	0.0	0.3	0.1	0.1
10	9.3	3.8	0.6	6.7	1.9	5.6	0.3	0.0	1.6	0.0	0.3	0.1	0.0
20	9.6	3.6	0.6	6.9	2.6	5.7	0.2	0.2	1.4	0.1	0.3	0.1	0.0
30	9.9	3.3	0.7	6.9	3.3	5.6	0.1	0.4	1.2	0.2	0.2	0.0	0.0
40	10.1	3.0	0.8	6.9	4.0	5.5	0.1	0.8	1.1	0.2	0.2	0.0	0.0
50	10.1	2.8	0.8	6.7	4.8	5.3	0.0	1.1	0.9	0.3	0.2	0.0	0.0
60	9.8	2.5	0.8	6.4	5.5	5.1	0.0	1.6	0.7	0.4	0.1	0.0	0.0
70	9.0	2.1	0.9	6.1	6.2	4.7	0.0	2.1	0.5	0.5	0.1	0.0	0.0
80	7.8	1.9	0.9	5.7	6.9	4.3	0.1	2.7	0.4	0.6	0.1	0.0	0.0
90	6.2	1.6	0.9	5.2	7.4	3.9	0.1	3.2	0.3	0.8	0.1	0.0	0.1
100	4.5	1.2	0.9	4.6	7.9	3.4	0.2	3.8	0.1	0.9	0.1	0.0	0.1
110	2.8	0.9	0.9	4.1	8.3	2.9	0.3	4.3	0.1	1.0	0.1	0.0	0.1
120	1.5	0.6	0.9	3.4	8.6	2.4	0.4	4.8	0.0	1.1	0.0	0.0	0.2
130	0.5	0.3	0.8	2.8	8.7	1.9	0.5	5.3	0.0	1.2	0.0	0.0	0.2
140	0.1	0.1	0.8	2.3	8.7	1.5	0.7	5.7	0.0	1.3	0.0	0.1	0.3
150	0.1	0.0	0.7	1.7	8.6	1.1	0.8	6.0	0.1	1.4	0.0	0.1	0.3
160	0.4	0.0	0.6	1.2	8.3	0.7	0.9	6.3	0.1	1.4	0.0	0.1	0.3
170	1.0	0.1	0.6	0.8	7.9	0.4	1.1	6.4	0.3	1.4	0.0	0.1	0.4
180	1.6	0.2	0.5	0.5	7.4	0.2	1.2	6.4	0.4	1.4	0.1	0.2	0.4
190	2.0	0.5	0.4	0.2	6.8	0.1	1.3	6.4	0.5	1.4	0.1	0.2	0.4
200	2.4	0.8	0.3	0.1	6.2	0.0	1.4	6.3	0.7	1.4	0.1	0.2	0.4
210	2.6	1.2	0.3	0.0	5.4	0.0	1.5	6.0	0.8	1.4	0.1	0.3	0.4
220	2.8	1.6	0.2	0.1	4.7	0.2	1.5	5.7	1.0	1.3	0.1	0.3	0.4
230	3.0	2.1	0.2	0.2	3.9	0.3	1.5	5.3	1.2	1.2	0.2	0.3	0.4
240	3.4	2.6	0.1	0.5	3.2	0.6	1.6	4.8	1.4	1.1	0.2	0.3	0.4
250	3.9	3.0	0.1	0.8	2.5	0.9	1.5	4.3	1.5	0.9	0.2	0.3	0.4
260	4.8	3.5	0.0	1.3	1.8	1.3	1.5	3.8	1.7	0.8	0.3	0.3	0.4
270	5.8	3.8	0.0	1.8	1.3	1.8	1.4	3.2	1.8	0.7	0.3	0.3	0.4
280	6.9	4.1	0.0	2.3	0.8	2.3	1.3	2.7	1.9	0.6	0.3	0.3	0.4
290	7.9	4.3	0.0	2.9	0.4	2.8	1.2	2.1	2.0	0.4	0.3	0.3	0.3
300	8.7	4.5	0.1	3.5	0.1	3.2	1.2	1.6	2.0	0.3	0.3	0.3	0.3
310	9.2	4.6	0.1	4.1	0.0	3.7	1.0	1.1	2.1	0.2	0.3	0.3	0.2
320	9.5	4.5	0.2	4.7	0.0	4.2	0.9	0.8	2.1	0.1	0.3	0.2	0.2
330	9.4	4.5	0.3	5.2	0.2	4.5	0.8	0.4	2.0	0.1	0.3	0.2	0.2
340	9.3	4.3	0.3	5.7	0.4	4.9	0.6	0.2	1.9	0.1	0.3	0.2	0.1
350	9.2	4.1	0.4	6.1	0.8	5.2	0.5	0.0	1.8	0.0	0.3	0.1	0.1
360	9.2	4.0	0.5	6.5	1.3	5.4	0.4	0.0	1.7	0.0	0.3	0.1	0.1

$[n\delta z=(n\delta z)_1+(n\delta z)_2+\ldots\ldots\ldots\ldots\ldots\ldots+(n\delta z)_t\ T-c_z.]$

Tables of (101) Helena—Continued.

TABLE III.—∂ log r.

PERIODIC TERMS. Unit=0.00001.

Arg's. 1, 2, 4, 5	$(\partial \log r)_1$	$(\partial \log r)_2$	Diff. for 1°	$(\partial \log r)_4$	$(\partial \log r)_5$	Diff. for 1°	Arg. 3	$(\partial \log r)_3$	Diff. for 1°	Arg. 3	$(\partial \log r)_3$	Diff. for 1°
°							°			°		
0	21.7	0.4	+0.13	16.8	108.8	−0.04	0	54.3	−1.09	192	13.7	−0.90
10	22.1	3.0	+0.41	13.4	107.5	−0.19	8	44.8	−1.22	200	7.4	−0.67
20	22.3	8.4	+0.65	10.4	104.8	−0.36	16	34.7	−1.26	208	3.0	−0.42
30	22.2	16.2	+0.88	7.8	100.5	−0.50	24	24.9	−1.13	216	0.5	−0.19
40	21.7	26.1	+1.07	5.7	94.8	−0.63	32	16.8	−0.86	224	0.0	+0.42
50	20.9	37.8	+1.26	4.0	87.9	−0.74	40	11.4	−0.46	232	1.3	+0.25
60	19.8	51.1	+1.39	2.5	80.0	−0.84	48	9.5	0.00	240	4.1	+0.44
70	18.4	65.4	+1.47	1.4	71.3	−0.90	56	11.3	+0.46	248	8.3	+0.61
80	16.8	80.4	+1.51	0.6	62.2	−0.94	64	16.8	+0.88	256	13.9	+0.76
90	14.9	95.6	+1.51	0.1	52.7	−0.94	72	25.0	+1.13	264	20.3	+0.84
100	12.9	110.5	+1.47	0.0	43.2	−0.92	80	34.8	+1.30	272	27.5	+0.92
110	10.8	124.7	+1.36	0.5	34.1	−0.88	88	45.5	+1.30	280	35.2	+0.99
120	8.8	137.7	+1.24	1.3	25.7	−0.80	96	55.6	+1.18	288	43.2	+0.99
130	6.8	149.3	+1.07	2.7	18.0	−0.71	104	64.2	+0.94	296	51.0	+0.94
140	4.9	158.8	+0.86	4.6	11.5	−0.59	112	70.5	+0.63	304	58.1	+0.82
150	3.3	166.2	+0.63	6.8	6.3	−0.44	120	74.1	+0.25	312	64.1	+0.65
160	2.0	171.3	+0.38	9.2	2.6	−0.29	128	74.5	−0.13	320	68.3	+0.42
170	1.0	173.9	+0.13	11.7	0.5	−0.13	136	72.1	−0.48	328	70.6	+0.13
180	0.3	173.8	−0.13	14.2	0.0	−0.04	144	66.8	−0.80	336	70.3	−0.19
190	0.0	171.1	−0.40	16.8	1.2	+0.21	152	59.4	−1.03	344	67.4	−0.52
200	0.1	165.9	−0.65	19.1	4.1	+0.36	160	50.4	−1.20	352	62.0	−0.82
210	0.5	158.3	−0.86	21.6	8.5	+0.52	168	40.5	−1.24	360	54.3	−1.09
220	1.3	148.6	−1.07	23.9	14.3	+0.65	176	30.7	−1.20			
230	2.3	137.0	−1.24	26.2	21.4	+0.76	184	21.6	−1.07			
240	3.6	123.9	−1.36	28.6	29.4	+0.84						
250	5.1	109.8	−1.47	30.9	38.2	+0.90						
260	6.8	94.8	−1.51	32.9	47.5	+0.94						
270	8.6	79.6	−1.51	34.5	57.0	+0.94						
280	10.4	64.7	−1.47	35.5	66.3	+0.92						
290	12.2	50.4	−1.39	35.6	75.3	+0.88						
300	14.0	37.3	−1.24	34.9	83.8	+0.80						
310	15.7	25.5	−1.07	33.2	91.2	+0.69						
320	17.3	15.7	−0.88	30.8	97.5	+0.57						
330	18.7	8.1	−0.65	27.7	102.6	+0.44						
340	19.9	2.9	−0.40	24.1	106.3	+0.29						
350	20.9	0.3	−0.13	20.4	108.3	+0.13						
360	21.7	0.4	+0.13	16.8	108.8	−0.04						

[$\partial \log r = (\partial \log r)_1 + (\partial \log r)_2 + \ldots\ldots\ldots\ldots + (\partial \log r)_t\ T - c_r$.]

Tables of (101) Helena—Continued.

TABLE III.—∂ log r—Continued.

PERIODIC TERMS. Unit=0.00001.

Arg's. 6–19	$(\partial \log r)_6$	$(\partial \log r)_7$	$(\partial \log r)_8$	$(\partial \log r)_9$	$(\partial \log r)_{10}$	$(\partial \log r)_{11}$	$(\partial \log r)_{12}$	$(\partial \log r)_{13}$	$(\partial \log r)_{14}$	$(\partial \log r)_{15}$	$(\partial \log r)_{16}$	$(\partial \log r)_{17}$	$(\partial \log r)_{18}$	$(\partial \log r)_{19}$
°														
0	1.3	2.3	0.1	0.2	0.7	0.8	1.4	2.6	0.1	0.4	0.1	0.3	0.2	0.2
15	1.4	2.4	0.1	0.3	0.3	1.1	1.3	1.9	0.1	0.3	0.1	0.3	0.2	0.2
30	1.4	2.4	0.1	0.3	0.1	1.3	1.1	1.3	0.0	0.2	0.1	0.2	0.2	0.2
45	1.2	2.5	0.1	0.4	0.0	1.6	0.9	0.8	0.0	0.1	0.2	0.2	0.1	0.1
60	0.7	2.6	0.0	0.5	0.1	1.9	0.8	0.3	0.0	0.0	0.1	0.2	0.1	0.1
75	0.3	2.7	0.0	0.5	0.3	2.1	0.6	0.1	0.1	0.0	0.1	0.1	0.1	0.1
90	0.0	2.7	0.0	0.6	0.5	2.3	0.4	0.0	0.2	0.0	0.1	0.1	0.0	0.0
105	0.1	2.6	0.0	0.6	1.0	2.4	0.2	0.1	0.3	0.0	0.1	0.1	0.0	0.0
120	0.4	2.4	0.0	0.6	1.5	2.3	0.1	0.4	0.4	0.0	0.1	0.0	0.0	0.0
135	0.9	2.2	0.0	0.6	2.0	2.3	0.0	0.8	0.5	0.1	0.1	0.0	0.0	0.0
150	1.3	1.8	0.0	0.5	2.5	2.1	0.0	1.4	0.6	0.2	0.1	0.0	0.0	0.0
165	1.3	1.3	0.0	0.5	3.0	1.9	0.0	2.0	0.8	0.3	0.1	0.0	0.0	0.0
180	1.1	0.9	0.1	0.4	3.5	1.6	0.1	2.7	0.9	0.4	0.0	0.0	0.0	0.0
195	0.7	0.5	0.1	0.3	3.8	1.3	0.2	3.4	0.9	0.5	0.0	0.0	0.1	0.0
210	0.4	0.2	0.1	0.3	4.0	1.0	0.3	4.0	1.0	0.5	0.0	0.0	0.1	0.0
225	0.3	0.0	0.1	0.1	4.1	0.7	0.5	4.5	1.0	0.6	0.0	0.1	0.1	0.1
240	0.5	0.0	0.1	0.1	4.1	0.5	0.7	5.0	1.0	0.7	0.0	0.1	0.1	0.1
255	0.9	0.2	0.1	0.1	3.9	0.3	0.9	5.2	0.9	0.7	0.0	0.1	0.2	0.1
270	1.3	0.5	0.1	0.0	3.6	0.1	1.1	5.3	0.8	0.7	0.0	0.1	0.2	0.2
285	1.5	0.8	0.1	0.0	3.2	0.0	1.2	5.2	0.7	0.7	0.1	0.2	0.2	0.2
300	1.5	1.2	0.2	0.0	2.7	0.0	1.4	4.9	0.6	0.7	0.1	0.2	0.2	0.2
315	1.4	1.6	0.1	0.0	2.1	0.1	1.5	4.5	0.5	0.6	0.1	0.2	0.3	0.2
330	1.3	1.9	0.1	0.1	1.6	0.2	1.5	3.9	0.4	0.5	0.1	0.3	0.3	0.2
345	1.2	2.1	0.1	0.1	1.1	0.5	1.5	3.3	0.3	0.4	0.1	0.3	0.3	0.2
360	1.3	2.3	0.1	0.2	0.7	0.8	1.4	2.6	0.1	0.4	0.1	0.3	0.2	0.2

[$\partial \log r = (\partial \log r)_1 + (\partial \log r)_2 + \ldots\ldots\ldots\ldots + (\log r)_t\ T - c_r$.]

Tables of (101) Helena—Continued.

TABLE IV.—$\partial\beta$.

PERIODIC TERMS. Unit=0.00001.

Arg's. 1-6	$(\partial\beta)_1$	$(\partial\beta)_2$	$(\partial\beta)_3$	$(\partial\beta)_4$	$(\partial\beta)_5$	$(\partial\beta)_6$
°						
0	31.6	143.2	2.9	0.9	17.5	25.0
10	33.2	153.7	0.4	2.1	9.8	27.9
20	34.3	162.6	0.1	4.1	4.3	28.4
30	34.9	168.8	1.5	6.5	0.9	26.6
40	35.0	172.8	3.8	9.4	0.0	22.4
50	34.7	174.3	6.5	12.6	1.9	17.2
60	33.8	173.1	8.9	16.3	5.8	12.0
70	32.6	169.5	10.3	20.4	12.0	8.3
80	30.9	163.2	10.0	24.7	20.5	6.5
90	28.8	154.8	8.8	29.1	30.9	7.8
100	26.3	144.3	6.5	33.2	42.8	11.6
110	23.8	132.2	4.0	37.0	56.1	17.5
120	20.8	118.4	1.6	39.8	70.1	24.5
130	17.8	103.8	0.5	41.5	84.4	31.2
140	14.8	88.7	0.8	42.0	98.7	36.5
150	11.8	73.6	2.5	41.1	112.8	39.3
160	9.0	58.9	5.4	39.0	126.0	39.2
170	6.4	44.9	8.6	35.8	137.5	36.5
180	4.3	32.2	11.8	32.4	147.5	31.8
190	2.4	21.4	13.9	28.8	155.6	26.2
200	1.1	12.3	14.6	25.4	161.3	19.9
210	0.3	5.8	14.5	22.5	164.4	14.5
220	0.0	1.5	13.3	20.4	165.3	10.4
230	0.4	0.0	12.0	18.7	163.4	7.1
240	1.3	1.5	11.1	17.3	159.1	5.0
250	2.8	5.4	11.5	16.2	152.6	3.5
260	4.6	11.9	13.3	14.9	143.8	2.4
270	7.0	20.5	15.9	13.3	133.1	1.5
280	9.6	31.3	18.8	11.4	121.0	0.5
290	12.5	43.7	21.3	9.1	107.5	0.0
300	15.7	57.6	22.4	6.8	93.7	0.6
310	18.8	72.4	22.0	4.4	79.3	2.1
320	21.8	87.7	19.5	2.4	65.1	5.3
330	24.8	102.5	15.8	1.0	51.5	9.8
340	27.3	117.0	11.1	0.1	38.6	15.2
350	29.7	130.9	6.6	0.3	27.3	20.6
360	31.6	143.2	2.9	0.9	17.5	25.0

$[\partial\beta=(\partial\beta)_1+(\partial\beta)_2+ \ldots\ldots\ldots\ldots\ldots\ldots +(\partial\beta)_t\ T-c_\beta.]$

Tables of (101) Helena—Continued.

TABLE IV.—$\delta\beta$—Continued.

PERIODIC TERMS.

Unit=0.00001.

Arg's. 7–15, 20, 21	$(\partial\beta)_7$	$(\partial\beta)_8$	$(\partial\beta)_9$	$(\partial\beta)_{10}$	$(\partial\beta)_{11}$	$(\partial\beta)_{12}$	$(\partial\beta)_{13}$	$(\partial\beta)_{14}$	$(\partial\beta)_{15}$	$(\partial\beta)_{20}$	$(\partial\beta)_{21}$
°											
0	0.4	1.9	0.8	2.4	5.5	0.2	0.0	1.2	0.4	2.2	0.0
15	1.0	2.0	0.8	3.0	5.5	0.1	0.0	2.1	0.5	2.2	0.0
30	2.0	1.9	0.8	3.5	5.0	0.1	0.0	3.2	0.6	2.0	0.2
45	3.0	1.9	0.8	4.0	4.5	0.0	0.2	4.2	0.8	1.9	0.6
60	4.1	1.8	0.6	4.4	4.0	0.0	0.5	5.5	0.8	1.6	1.0
75	5.4	1.6	0.6	4.5	3.4	0.1	0.8	6.5	0.9	1.2	1.5
90	6.4	1.4	0.5	4.5	2.6	0.2	1.1	7.4	1.0	1.0	2.1
105	7.4	1.1	0.4	4.5	1.9	0.5	1.5	8.0	1.0	0.8	2.8
120	8.2	1.0	0.4	4.1	1.1	0.8	1.8	8.5	1.0	0.4	3.2
135	8.8	0.6	0.2	3.8	0.6	1.0	2.0	8.8	1.0	0.1	3.6
150	8.8	0.4	0.0	3.2	0.2	1.1	2.2	8.5	0.9	0.0	4.0
165	8.8	0.2	0.0	2.8	0.0	1.4	2.5	8.1	0.8	0.0	4.2
180	8.4	0.1	0.0	2.1	0.0	1.5	2.5	7.5	0.6	0.0	4.2
195	7.8	0.0	0.0	1.5	0.0	1.6	2.5	6.6	0.5	0.0	4.2
210	6.8	0.1	0.0	1.0	0.5	1.6	2.5	5.5	0.4	0.2	4.0
225	5.8	0.1	0.0	0.5	1.0	1.8	2.2	4.4	0.2	0.4	3.6
240	4.8	0.2	0.1	0.1	1.5	1.8	2.0	3.2	0.2	0.6	3.2
255	3.5	0.4	0.1	0.0	2.1	1.6	1.8	2.2	0.1	1.0	2.8
270	2.4	0.6	0.2	0.0	2.9	1.5	1.4	1.1	0.0	1.2	2.1
285	1.4	0.9	0.4	0.0	3.6	1.4	1.0	0.8	0.0	1.5	1.5
300	0.5	1.0	0.5	0.4	4.2	1.0	0.8	0.2	0.0	1.9	1.0
315	0.0	1.4	0.5	0.8	4.9	0.8	0.5	0.0	0.0	2.1	0.6
330	0.0	1.6	0.8	1.1	5.2	0.6	0.2	0.2	0.1	2.2	0.2
345	0.0	1.8	0.8	1.8	5.5	0.4	0.0	0.6	0.2	2.2	0.0
360	0.4	1.9	0.8	2.4	5.5	0.2	0.0	1.2	0.4	2.2	0.0

$[\partial\beta=(\partial\beta)_1+(\partial\beta_2)+\ldots\ldots\ldots\ldots\ldots\ldots+(\partial\beta)_t\ T-c_\beta.]$

Tables of (101) Helena—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY T=(t—t$_0$) IN JULIAN YEARS.

Arg. 2.	$(n\partial z)_t$ Unit=0°.001.			Arg. 2.	$(\partial \log r)_t$ Unit=0.00001.			Arg. 2.	$(\partial\beta)_t$ Unit=0.00001.		
°		°		°		°		°		°	
0	−3.17	180	+3.06	0	−0.10	180	+0.10	0	+6.00	180	−5.25
10	−3.06	190	+2.94	15	−0.40	195	+0.36	15	+6.62	195	−5.62
20	−2.89	200	+2.78	30	−0.71	210	+0.63	30	+6.38	210	−5.62
30	−2.58	210	+2.53	45	−0.92	225	+0.84	45	+5.62	225	−5.38
40	−2.22	220	+2.22	60	−1.09	240	+1.01	60	+4.62	240	−4.88
50	−1.81	230	+1.81	75	−1.18	255	+1.13	75	+3.38	255	−3.88
60	−1.31	240	+1.36	90	−1.18	270	+1.18	90	+1.75	270	−2.50
70	−0.75	250	+0.86	105	−1.09	285	+1.13	105	+0.13	285	−1.12
80	−0.22	260	+0.33	120	−0.92	300	+1.01	120	−1.38	300	−0.62
90	+0.31	270	−0.19	135	−0.71	315	+0.80	135	−2.62	315	+2.38
100	+0.83	280	−0.72	150	−0.46	330	+0.55	150	−3.62	330	+3.88
110	+1.36	290	−1.25	165	−0.19	345	+0.23	165	−4.62	345	+5.12
120	+1.81	300	−1.75	180	+0.10	360	−0.10	180	−5.25	360	+6.00
130	+2.19	310	−2.19								
140	+2.56	320	−2.56								
150	+2.81	330	−2.86								
160	+2.94	340	−3.06								
170	+3.06	350	−3.17								
180	+3.06	360	−3.17								

The perturbations are to be computed in the form—

$$n\partial z=(n\partial z)_1+(n\partial z)_2+\ldots\ldots\ldots\ldots\ldots+(n\partial z)_t\ T-c_t.$$
$$\partial \log r=(\partial \log r)_1+(\partial \log r)_2+\ldots\ldots+(\partial \log r)_t\ T-c_r.$$
$$\partial\beta=(\partial\beta)_1+(\partial\beta)_2+\ldots\ldots\ldots\ldots\ldots\ldots+(\partial\beta)_t\ T-c_\beta.$$

Tables of (101) Helena—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	*A′*	*B′*	*C′*	log sin *a*	log sin *b*	log sin *c*
	°	°	°			
1868.0	57.6916	325.8120	332.0712	9.99945	9.92280	9.73980
9	.7054	.8272	.0813	45	79	81
1870	57.7191	325.8425	332.0914	9.99945	9.92279	9.73981
1	.7329	.8578	.1015	46	79	82
2	.7467	.8730	.1116	46	78	83
3	.7605	.8883	.1217	46	78	83
4	.7743	.9036	.1318	46	78	84
1875	57.7880	325.9188	332.1419	9.99946	9.92277	9.73984
6	.8018	.9341	.1520	46	77	85
7	.8156	.9494	.1621	46	76	85
8	.8294	.9646	.1722	46	76	86
9	.8431	.9799	.1823	46	75	87
1880	57.8569	325.9952	332.1924	9.99946	9.92275	9.73987
1	.8707	326.0104	.2025	46	75	88
2	.8845	.0257	.2126	47	74	88
3	.8983	.0410	.2227	47	74	89
4	.9120	.0562	.2328	47	74	89
1885	57.9258	326.0715	332.2429	9.99947	9.92273	9.73990
6	.9396	.0868	.2530	47	73	91
7	.9534	.1020	.2631	47	72	91
8	.9671	.1173	.2732	47	72	92
9	.9809	.1326	.2833	47	72	92
1890	57.9947	326.1478	332.2934	9.99947	9.92271	9.73993
1	58.0085	.1631	.3035	47	71	93
2	.0223	.1784	.3136	47	71	94
3	.0360	.1936	.3236	48	70	95
4	.0498	.2089	.3337	48	70	96
1895	58.0636	326.2242	332.3438	9.99948	9.92269	9.73996
6	.0774	.2394	.3539	48	69	96
7	.0911	.2547	.3640	48	69	97
8	.1049	.2699	.3741	48	68	97
9	.1187	.2852	.3842	48	68	98
1900	58.1324	326.3005	332.3943	9.99948	9.92268	9.73998
1	.1462	.3158	.4044	48	67	99
2	.1600	.3310	.4145	48	67	4000
3	.1738	.3463	.4246	48	66	00
4	.1876	.3616	.4347	48	66	01
1905	58.2013	326.3769	332.4448	9.99949	9.92266	9.74001
6	.2151	.3921	.4549	49	65	02
7	.2289	.4074	.4650	49	65	03
8	.2427	.4227	.4751	49	65	03
9	.2565	.4379	.4852	49	64	04
1910	58.2702	326.4532	332.4953	9.99949	9.92264	9.74004
1	.2840	.4685	.5054	49	63	05
2	.2978	.4838	.5155	49	63	05
3	.3116	.4990	.5256	49	63	06
4	.3254	.5143	.5357	49	62	07
1915	58.3391	326.5296	332.5458	9.99949	9.92262	9.74007
6	.3529	.5449	.5559	50	61	08
7	.3667	.5601	.5660	50	61	08
8	.3805	.5754	.5761	50	61	09
9	.3943	.5907	.5862	50	60	10
1920	58.4080	326.6060	332.5963	9.99950	9.92260	9.74010
1	.4218	.6212	.6064	50	59	10
2	.4356	.6365	.6165	50	59	11
3	.4494	.6518	.6266	50	59	12
4	.4632	.6670	.6367	50	58	12
1925	58.4769	326.6823	332.6468	9.99950	9.92258	9.74013
6	.4907	.6976	.6569	50	57	14
7	.5045	.7129	.6669	51	57	14
8	.5183	.7281	.6770	51	57	15
9	.5321	.7434	.6871	51	56	15
1930	58.5458	326.7587	332.6972	9.99951	9.92256	9.74016

Year	log cos *a*	log cos *b*	log cos *c*
1868.0	8.699 *n*	9.738 *n*	9.922
1930.0	8.678 *n*	9.739 *n*	9.922

TABLES OF (103) HERA.

OSCULATING ELEMENTS.

Epoch and osculation, 1895, Nov. 26.0, M. T. Berlin=1895.904, M. T. Berlin.

	°	′	″		
$g_0=$	76	9	2	$=76^\circ.1506$	
$\omega=$	185	15	25	$=185.2569$	Mean equinox and ecliptic 1895.0.
$\Omega=$	136	12	23	$=136.2063$	
$i=$	5	24	39	$=5.4107$	
$\varphi=$	4	34	6	$=4.5682$	

$n=798''.6939 \;=\; 0.22185943$

g_0 and n are mean elements.

The elements are based on oppositions extending from 1868 to 1902 and on the perturbations of the first order by *Jupiter*, as given on page 340.

AUXILIARY QUANTITIES.

$\log a=0.43175$ $\quad\log 57.2958e=0.65928$ $\quad\log\sqrt{\dfrac{1-e}{1+e}}=9.96534$

$\log e=8.90116$ $\quad\log p=0.42898$

NUMERICAL DESIGNATION OF THE ARGUMENTS FOR TABLES II–IV.

$1=g-g'$	$6=\;-g'$	$11=3g-5g'$
$2=g-2g'$	$7=2g-g'$	$12=4g-3g'$
$3=g$	$8=2g-5g'$	$13=4g-5g'$
$4=g-3g'$	$9=3g-2g'$	$14=5g-6g'$
$5=2g-3g'$	$10=3g-4g'$	$15=-g-g'$

CONSTANTS TO BE SUBTRACTED FROM THE TABULATED PERTURBATIONS.

$c_z=0^\circ.5356$ $\qquad c_r=0.001447$ $\qquad c_\beta=0.000653$

Derivation of c_z, c_r, c_β. (See also page 208.)

	Arg.	$n\partial z$ Unit=0°.001	$\partial \log r$ Unit=0.00001	$\partial\beta$ Unit=0.00001
Constants to be added to make all numbers positive.	1	147.94	57.5	3.2
	2	93.31	13.5	6.9
	3	168.53	63.3	14.2
	4	35.58	2.9	2.0
	5	63.36	22.3	20.4
	6	5.08	0.7	8.8
	7	1.75	1.1	2.9
	8	2.69		
	9	2.69	2.2	0.7
	10	5.36	2.6	2.2
	11	6.69	2.3	3.1
	12	0.42	0.4	
	13	1.72	0.9	0.7
	14	0.33	0.2	
	15	0.17		1.0
	Sum	535.6	169.9	66.0

$c_z=0^\circ.5356$

$c_r=0.001699-$(constant part of $\partial \log r$ + correction for difference between mean and osculating values of semimajor axis)

$=0.001699-(+133.6''-13.8'')\sin 1''$ Mod.

$=0.001699-0.000252$

$c_r=0.001447$

$c_\beta=0.000660-$(constant part of $\partial\beta$)

$=0.000660-0.000007$

$c_\beta=0.000653$

Tables of (103) Hera—Continued.

TABLE I.—MEAN ANOMALY (g).

Jan. 0.0 of common years; Jan. 1.0 of leap years

Year	*g*	Year	*g*
	°		°
B 1868	335. 18115	1899	327. 07362
9	56. 15984	1900	48. 05231
1870	137. 13853	1	129. 03100
1	218. 11722	2	210. 00969
B 2	299. 31778	3	290. 98839
3	20. 29643	B 4	12. 18894
4	101. 27516	5	93. 16763
5	182. 25385	6	174. 14632
B 6	263. 45440	7	255. 12501
7	344. 43310	B 8	336. 32556
8	65. 41179	9	57. 30426
9	146. 39048	1910	138. 28295
B 1880	227. 59103	1	219. 26164
1	308. 56972	B 2	300. 46219
2	29. 54842	3	21. 44088
3	110, 52711	4	102, 41958
B 4	191, 72766	5	183. 39827
5	272, 70635	B 6	264. 59882
6	353. 68504	7	345. 57751
7	74. 66374	8	66. 55620
B 8	155. 86429	9	147. 53490
9	236. 84298	B 1920	228. 73545
1890	317. 82167	1	309. 71414
1	38. 80036	2	30. 69283
B 2	120. 00091	3	111. 67152
3	200. 97961	B 4	192. 87208
4	281. 95830	5	273. 85077
5	2. 93699	6	354. 82946
B 6	84. 13754	7	75. 80815
7	165. 11623	B 8	157. 00870
8	246. 09493	9	237. 98739
1899	327. 07362	1930	318. 96609

NOTE.—When *g* is used as an argument of the perturbations, add to the *g* of this table $\Delta\pi=\pi-\pi_0=-0^{\circ}.2719$. For explanation see page 203.

Table for beginning of month

Month	*g*
	°
Jan. 0.0 1.0	0. 00000
Feb. 0.0 1.0	6. 87764
Mar. 0.0	13. 08970
Apr. 0.0	19. 96734
May 0.0	26. 62313
June 0.0	33. 50077
July 0.0	40. 15656
Aug. 0.0	47. 03420
Sept. 0.0	53. 91184
Oct. 0.0	60. 56762
Nov. 0.0	67. 44527
Dec. 0.0	74. 10105

Change for *n* days[a]

n	*g*	*n*	*g*
	°		°
1	0. 22186	16	3. 54975
2	0. 44372	17	3. 77161
3	0. 66558	18	3. 99347
4	0. 88744	19	4. 21533
5	1. 10930	20	4. 43719
6	1. 33115	21	4. 65905
7	1. 55301	22	4. 88091
8	1. 77487	23	5. 10277
9	1. 99673	24	5. 32463
10	2. 21859	25	5. 54648
11	2. 44045	26	5. 76834
12	2. 66231	27	5. 99020
13	2. 88417	28	6. 21206
14	3. 10603	29	6. 43392
15	3. 32789	30	6. 65578

[a] For days during January and February of leap years subtract one day before entering this table.

Tables of (103) Hera—Continued.

PERTURBATIONS.

Arg. $ig—i'g'$		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	0				+133.6		+0.5
0	0				− 0.107 t		+0.481 t
+1	0	+ 89.0	−588.7	−295.0	− 42.1	+10.8	−1.4
+1		+ 2.334 t	− 6.424 t	− 3.212 t	− 1.167 t	− 0.391 t	−4.634 t
+2		+ 1.9	− 11.9	− 11.9	− 1.8	+ 0.5	−0.1
+2		+ 0.046 t	− 0.127 t	− 0.127 t	− 0.046 t	− 0.016 t	−0.160 t
+3	0	− 0.4	+ 0.3	+ 0.4	+ 0.5		
−1	−1	− 0.1	+ 0.6	− 0.4		− 0.3	+0.8
0		+ 9.7	+ 14.9	− 1.3	+ 3.0	− 3.4	3.3
+1		−128.1	+163.4	+ 55.4	+ 43.4	+ 1.6	−0.3
+2	−1	− 2.7	+ 5.3	+ 4.0	+ 2.2	− 1.1	+1.8
0	−2	+ 0.2	+ 2.3	− 1.3	+ 0.3	− 1.6	−2.8
+1		−127.0	−294.6	− 58.2	+ 22.1	+ 1.0	+6.2
+2		− 84.0	−382.0	−221.1	+ 48.5	− 1.0	+1.0
+3		− 1.5	− 9.6	− 10.2	+ 1.8	+ 0.2	+0.5
+4	−2	− 0.1	− 0.4	− 0.7	+ 0.1		
0	−3	+ 0.7	− 0.6	+ 0.3	+ 0.3	− 0.4	+0.7
+1		+ 39.7	−123.5	+ 12.6	+ 5.8	− 1.1	−1.1
+2		−172.6	+149.2	+ 67.2	+ 80.5	+13.4	+7.9
+3		− 35.2	− 13.6	− 11.4	+ 26.0	+ 0.6	+0.4
+4	−3	− 1.2	− 0.8	− 0.8	+ 1.6		
+1	−4	+ 0.6	− 0.1		+ 0.2		
+2		− 13.4	− 6.0	− 2.5	+ 4.1	+ 0.3	+1.0
+3		− 0.6	− 19.3	− 12.2	+ 0.9	− 1.6	+0.6
+4		− 7.3	+ 2.7	+ 2.0	+ 5.9		
+5	−4	− 0.5	+ 0.1	+ 0.2	+ 0.5		
+2	−5	+ 1.9	− 9.5	+ 0.4	+ 0.1		
+3		− 21.1	+ 11.5	+ 5.1	+ 9.8	+ 2.1	+1.3
+4		− 5.1	− 3.5	− 2.1	+ 3.8	− 0.1	+0.5
+5		− 1.0	+ 2.8	+ 2.3	+ 0.9		
+6	−5	− 0.1	+ 0.2	+ 0.3	+ 0.1		
+4	−6	+ 0.2	− 1.2	− 0.8	− 0.1		
+5		− 1.1	+ 0.2	+ 0.2	+ 0.9		
+6	−6	+ 0.4	+ 0.6	+ 0.6	− 0.3		
+6	−7	− 0.2	+ 0.4	+ 0.3	+ 0.1		
+7	−7	+ 0.3		+ 0.1	− 0.2		

The constant part in $n\delta z$ is included in the element $g_\circ$.
The nontrigonometrical term multiplied by the time in $n\delta z$ is included in the element n.
The constant part of ν is included in the constant c_r.
The constant part of $u/\cos i$ is included in the constant c_β.
All other terms are included in Tables II–V.

Tables of (103) Hera—Continued.

TABLE II.—$n\delta z$.

PERIODIC TERMS. Unit=0°.001.

Arg's. 1, 3	$(n\delta z)_1$	Diff. for 1°	$(n\delta z)_3$	Diff. for 1°
°				
0	85.0	−2.08	1.8	+0.44
6	74.5	−1.36	5.4	+0.75
12	68.8	−0.53	10.9	+1.06
18	68.2	+0.36	18.2	+1.36
24	73.1	+1.25	27.3	+1.61
30	83.1	+2.08	38.0	+1.89
36	97.8	+2.78	50.1	+2.14
42	116.1	+3.28	63.6	+2.33
48	136.6	+3.56	78.2	+2.53
54	158.1	+3.56	93.8	+2.67
60	178.9	+3.31	110.2	+2.78
66	197.3	+2.81	127.1	+2.86
72	212.3	+2.17	144.5	+2.92
78	222.9	+1.36	162.0	+2.92
84	228.4	+0.50	179.4	+2.89
90	228.8	−0.36	196.7	+2.83
96	223.9	−1.22	213.5	+2.75
102	214.1	−2.00	229.7	+2.64
108	200.0	−2.69	245.0	+2.50
114	182.0	−3.25	259.6	+2.33
120	161.4	−3.61	273.0	+2.14
126	139.0	−3.81	285.2	+1.94
132	115.9	−3.89	296.2	+1.69
138	92.7	−3.81	305.7	+1.47
144	70.6	−3.56	313.8	+1.22
150	50.2	−3.19	320.3	+0.94
156	32.6	−2.69	325.2	+0.69
162	18.1	−2.08	328.6	+0.42
168	7.6	−1.39	330.3	+0.14
174	1.5	−0.64	330.3	−0.14
180	0.1	+0.19	328.7	−0.42
186	3.8	+1.03	325.4	−0.67
192	12.1	+1.75	320.6	−0.94
198	24.8	+2.44	314.1	−1.19
204	41.4	+3.06	306.1	−1.44
210	61.3	+3.56	296.7	−1.69
216	84.0	+3.94	285.9	−1.92
222	108.6	+4.22	273.8	−2.11
228	134.4	+4.33	260.6	−2.31
234	160.4	+4.33	246.3	−2.47
240	186.2	+4.19	231.1	−2.47
246	210.5	+3.92	215.1	−2.61
252	232.8	+3.53	198.5	−2.81
258	252.5	+3.00	181.6	−2.86
264	268.6	+2.39	164.3	−2.89
270	280.9	+1.72	147.0	−2.86
276	289.1	+1.00	129.8	−2.83
282	292.8	+0.22	113.0	−2.75
288	291.9	−0.50	96.8	−2.67
294	286.8	−1.22	81.1	−2.53
300	277.3	−1.94	66.4	−2.36
306	263.8	−2.56	52.9	−2.17
312	246.7	−3.11	40.6	−1.94
318	226.8	−3.50	29.5	−1.69
324	205.1	−3.75	20.2	−1.42
330	182.2	−3.86	12.6	−1.14
336	159.2	−3.78	6.6	−0.83
342	137.3	−3.56	2.5	−0.53
348	116.9	−3.19	0.3	−0.19
354	99.2	−2.67	0.1	+0.11
360	85.0	−2.08	1.8	+0.44

$[n\delta z = (n\delta z)_1 + (n\delta z)_2 + \dots\dots\dots\dots + (n\delta z)_t \; T - c_z.]$

Tables of (103) Hera—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit=0°001.

Arg's. 2, 4–8	$(n\delta z)_2$	Diff. for 1°	$(n\delta z)_4$	Diff. for 1°	$(n\delta z)_5$	Diff. for 1°	$(n\delta z)_6$	$(n\delta z)_7$	$(n\delta z)_8$
°									
0	9. 6	−0. 75	1. 7	+0. 19	104. 5	−0. 83	9. 7	3. 1	0. 1
10	3. 5	−0. 44	4. 1	+0. 28	95. 5	−0. 94	10. 2	3. 0	0. 2
20	0. 4	−0. 17	7. 5	+0. 39	85. 7	−1. 03	10. 5	2. 8	0. 4
30	0. 4	+0. 17	11. 7	+0. 47	75. 1	−1. 08	10. 5	2. 6	0. 6
40	3. 7	+0. 47	16. 7	+0. 53	64. 2	−1. 08	10. 3	2. 4	1. 0
50	10. 0	+0. 78	22. 1	+0. 56	53. 4	−1. 08	9. 9	2. 1	1. 4
60	19. 2	+1. 06	28. 1	+0 61	42. 7	−1. 03	9. 3	1. 9	1. 8
70	30. 8	+1. 28	34. 3	+0. 61	32. 7	−0. 94	8. 6	1. 6	2. 2
80	44. 4	+1. 44	40. 4	+0. 61	23. 7	−0. 86	7. 8	1. 4	2. 7
90	59. 6	+1. 56	46. 5	+0. 58	15. 7	−0. 72	6. 9	1. 1	3. 2
100	75. 6	+1. 61	52. 2	+0. 56	9. 2	−0. 58	6. 2	0. 9	3. 7
110	91. 8	+1. 61	57. 4	+0. 47	4. 4	−0. 39	5. 5	0. 6	4. 1
120	107. 8	+1. 56	61. 9	+0. 42	1. 3	−0. 22	4. 9	0. 4	4. 5
130	122. 9	+1. 47	65. 8	+0. 33	0. 0	−0. 03	4. 3	0. 2	4. 8
140	136. 9	+1. 31	68. 5	+0. 22	0. 7	+0. 17	3. 8	0. 1	5. 1
150	149. 1	+1. 14	70. 4	+0. 14	3. 4	+0. 36	3. 3	0. 0	5. 2
160	159. 5	+0. 94	71. 2	+0. 03	7. 8	+0. 53	2. 8	0. 0	5. 4
170	167. 7	+0. 72	70. 8	−0. 08	13. 9	+0. 69	2. 3	0. 1	5. 4
180	173. 8	+0. 50	69. 5	−0. 19	21. 6	+0. 83	1. 8	0. 2	5. 3
190	177. 5	+0. 25	67. 1	−0. 28	30. 6	+0. 94	1. 2	0. 3	5. 2
200	178. 9	+0. 03	63. 7	−0. 39	40. 6	+1. 03	0. 7	0. 5	5. 0
210	178. 1	−0. 19	59. 5	−0. 44	51. 3	+1. 08	0. 3	0. 8	4. 8
220	175. 0	−0. 42	54. 5	−0. 53	62. 4	+1. 11	0. 1	1. 1	4. 4
230	169. 8	−0. 61	49. 0	−0. 58	73. 5	+1. 11	0. 0	1. 4	4. 0
240	162. 7	−0. 81	43. 0	−0. 61	84. 3	+1. 06	0. 2	1. 8	3 6
250	153. 5	−1. 00	36. 9	−0. 61	94. 5	+0. 97	0. 6	2. 1	3. 1
260	142. 7	−1. 17	30. 7	−0. 61	103. 7	+0. 86	1. 2	2. 4	2. 7
270	130. 4	−1. 31	24. 7	−0. 58	111. 6	+0. 72	1. 9	2. 6	2. 2
280	116. 8	−1. 42	19. 0	−0. 56	118. 1	+0. 56	2. 8	2. 9	1. 7
290	102. 2	−1. 50	13. 8	−0. 50	122. 8	+0. 39	3. 7	3. 1	1. 3
300	86. 9	−1. 53	9. 2	−0. 42	125. 8	+0. 19	4. 6	3. 2	0. 9
310	71. 6	−1. 53	5. 5	−0. 33	126. 8	0. 00	5. 6	3. 3	0. 6
320	56. 6	−1. 47	2. 6	−0. 22	125. 9	−0. 19	6. 6	3. 4	0. 3
330	42. 3	−1. 36	0. 8	−0. 14	123. 1	−0. 36	7. 4	3. 4	0. 1
340	29. 4	−1. 22	0. 0	−0. 03	118. 5	−0. 56	8. 3	3. 3	0. 0
350	18. 2	−1. 00	0. 3	+0. 08	112. 2	−0. 69	9. 1	3. 2	0. 0
360	9. 6	−0. 75	1. 7	+0. 19	104. 5	−0. 83	9. 7	3. 1	0. 1

$[n\delta z=(n\delta z)_1 + (n\delta z)_2 + \cdots\cdots\cdots\cdots + (n\delta z)_t\ T - c_z]$

Tables of (103) Hera—Continued.

TABLE II—$n\delta z$—Continued.

PERIODIC TERMS. Unit=0°001.

Args. 9–15	$(n\delta z)_9$	$(n\delta z)_{10}$	$(n\delta z)_{11}$	$(n\delta z)_{12}$	$(n\delta z)_{13}$	$(n\delta z)_{14}$	$(n\delta z)_{15}$
°							
0	0.0	0.0	9.9	0.2	0.8	0.4	0.3
10	0.0	0.1	8.9	0.1	0.5	0.3	0.3
20	0.1	0.3	7.7	0.1	0.3	0.3	0.3
30	0.2	0.6	6.6	0.1	0.2	0.2	0.3
40	0.4	1.2	5.4	0.0	0.1	0.2	0.3
50	0.7	1.8	4.3	0.0	0.0	0.1	0.3
60	1.0	2.5	3.2	0.0	0.0	0.1	0.2
70	1.4	3.4	2.3	0.0	0.1	0.1	0.2
80	1.8	4.2	1.5	0.1	0.2	0.0	0.2
90	2.3	5.2	0.9	0.1	0.3	0.0	0.2
100	2.8	6.1	0.4	0.1	0.5	0.0	0.1
110	3.2	7.1	0.1	0.2	0.7	0.0	0.1
120	3.7	7.9	0.0	0.2	1.0	0.0	0.1
130	4.1	8.7	0.2	0.3	1.2	0.1	0.1
140	4.5	9.4	0.5	0.4	1.6	0.1	0.0
150	4.8	9.9	1.0	0.4	1.9	0.1	0.0
160	5.1	10.4	1.7	0.5	2.1	0.2	0.0
170	5.2	10.6	2.5	0.6	2.4	0.2	0.0
180	5.4	10.7	3.5	0.6	2.7	0.3	0.0
190	5.3	10.6	4.5	0.7	2.9	0.3	0.0
200	5.2	10.4	5.7	0.8	3.1	0.4	0.0
210	5.0	10.1	6.9	0.8	3.3	0.4	0.0
220	4.7	9.6	8.0	0.8	3.4	0.5	0.0
230	4.4	8.9	9.1	0.8	3.4	0.6	0.1
240	4.0	8.2	10.2	0.8	3.4	0.6	0.1
250	3.6	7.4	11.1	0.8	3.4	0.6	0.1
260	3.2	6.5	11.9	0.8	3.3	0.6	0.1
270	2.7	5.5	12.5	0.8	3.1	0.6	0.2
280	2.2	4.6	13.0	0.7	2.9	0.6	0.2
290	1.8	3.7	13.3	0.7	2.7	0.7	0.2
300	1.4	2.8	13.4	0.6	2.5	0.6	0.2
310	1.0	2.0	13.2	0.5	2.2	0.6	0.3
320	0.7	1.4	12.9	0.5	1.9	0.6	0.3
330	0.4	0.8	12.4	0.4	1.6	0.6	0.3
340	0.2	0.4	11.7	0.3	1.3	0.5	0.3
350	0.1	0.1	10.8	0.2	1.0	0.4	0.3
360	0.0	0.0	9.9	0.2	0.8	0.4	0.3

$[n\delta z=(n\delta z)_1+(n\delta z)_2+\ldots\ldots\ldots\ldots+(n\delta z)_t\ T-c_t]$

Tables of (103) Hera—Continued.

PERIODIC TERMS.

TABLE III—∂ log r.

Unit=0.00001.

Arg. 1	$(\partial \log r)$	Diff. for 1°	Arg. 1	$(\partial \log r)$	Diff. for 1°	Arg. 2–7, 9–14	$(\partial \log r)_2$	$(\partial \log r)_3$	$(\partial \log r)_4$	$(\partial \log r)_5$	$(\partial \log r)_6$	$(\partial \log r)_7$	$(\partial \log r)_9$	$(\partial \log r)_{10}$	$(\partial \log r)_{11}$	$(\partial \log r)_{12}$	$(\partial \log r)_{13}$	$(\partial \log r)_{14}$
°						°												
0	83.8	−1.51	180	54.2	−1.70	0	19.0	54.0	4.1	39.3	1.5	1.6	2.0	2.8	4.4	0.7	1.7	0.4
6	74.3	−1.65	186	44.0	−1.68	10	16.6	42.4	4.6	41.4	1.3	1.7	2.2	2.4	4.5	0.7	1.5	0.4
12	64.1	−1.77	192	34.2	−1.58	20	14.0	31.8	5.0	43.0	1.1	1.7	1.8	1.9	4.6	0.5	1.2	0.4
18	53.3	−1.78	198	25.2	−1.42	30	11.4	22.1	5.3	43.9	1.0	1.8	1.4	1.5	4.6	0.4	0.9	0.3
24	43.0	−1.67	204	17.2	−1.23	40	8.8	13.9	5.5	44.2	0.8	1.9	1.1	1.1	4.6	0.3	0.6	0.3
30	33.5	−1.47	210	10.5	−1.00	50	6.4	7.6	5.7	43.9	0.6	1.9	0.8	0.8	4.4	0.2	0.3	0.2
36	25.6	−1.14	216	5.3	−0.72	60	4.3	3.1	5.8	42.9	0.5	1.9	0.5	0.5	4.3	0.1	0.1	0.1
42	20.0	−0.71	222	1.9	−0.42	70	2.6	0.6	5.8	41.3	0.4	1.9	0.3	0.2	4.0	0.0	0.0	0.1
48	17.1	−0.25	228	0.2	−0.13	80	1.3	0.0	5.7	39.0	0.3	1.9	0.1	0.1	3.7	0.0	0.0	0.1
54	17.0	+0.23	234	0.3	+0.17	90	0.4	1.6	5.6	36.5	0.3	1.9	0.0	0.0	3.4	0.0	0.1	0.0
60	19.9	+0.71	240	2.2	+0.45	100	0.0	5.0	5.3	33.4	0.3	1.9	0.0	0.0	3.0	0.0	0.3	0.0
66	25.4	+1.12	246	5.7	+0.73	110	0.1	9.8	5.0	29.9	0.4	1.8	0.0	0.1	2.6	0.0	0.6	0.0
72	33.1	+1.42	252	10.9	+0.98	120	0.6	16.3	4.6	26.2	0.4	1.8	0.2	0.3	2.2	0.1	0.9	0.1
78	42.3	+1.64	258	17.4	+1.20	130	1.5	24.0	4.2	22.4	0.4	1.6	0.3	0.5	1.8	0.2	1.2	0.1
84	52.6	+1.74	264	25.2	+1.40	140	2.7	32.5	3.7	18.6	0.4	1.4	0.6	0.8	1.4	0.2	1.5	0.2
90	63.0	+1.75	270	34.0	+1.50	150	4.2	41.9	3.2	14.8	0.3	1.2	0.8	1.1	1.0	0.4	1.7	0.3
96	73.4	+1.67	276	43.1	+1.56	160	5.9	51.8	2.6	11.3	0.2	1.1	1.1	1.5	0.7	0.5	1.8	0.3
102	82.9	+1.49	282	52.7	+1.62	170	7.7	61.8	2.2	8.1	0.1	0.8	1.5	2.0	0.4	0.7	1.8	0.3
108	91.2	+1.26	288	62.4	+1.61	180	9.7	71.8	1.7	5.3	0.1	0.6	1.8	2.4	0.2	0.7	1.7	0.4
114	98.0	+0.99	294	72.0	+1.59	190	11.7	81.6	1.2	3.1	0.0	0.4	2.2	2.9	0.0	0.8	1.5	0.4
120	103.0	+0.67	300	81.3	+1.48	200	13.7	91.0	0.8	1.4	0.0	0.3	2.6	3.3	0.0	0.8	1.2	0.4
126	106.0	+0.33	306	89.5	+1.25	210	15.6	99.7	0.5	0.4	0.0	0.1	3.0	3.7	0.0	0.7	0.9	0.3
132	107.0	0.00	312	96.3	+1.02	220	17.4	107.5	0.3	0.0	0.1	0.0	3.3	4.1	0.0	0.6	0.6	0.3
138	106.0	−0.35	318	101.7	+0.76	230	19.2	114.2	0.1	0.4	0.3	0.0	3.6	4.4	0.2	0.5	0.3	0.2
144	102.8	−0.68	324	105.3	+0.43	240	20.9	119.5	0.0	1.4	0.4	0.0	3.9	4.7	0.3	0.4	0.1	0.1
150	97.9	−0.96	330	106.8	+0.09	250	22.4	123.4	0.0	3.1	0.6	0.0	4.1	5.0	0.6	0.3	0.0	0.1
156	91.3	−1.23	336	106.3	−0.28	260	23.8	125.6	0.1	5.3	0.8	0.1	4.3	5.1	0.9	0.1	0.0	0.1
162	83.2	−1.44	342	103.5	−0.63	270	24.9	125.8	0.2	8.2	1.0	0.3	4.4	5.2	1.2	0.1	0.1	0.0
168	74.1	−1.58	348	98.8	−0.94	280	25.8	124.2	0.5	11.3	1.1	0.4	4.4	5.2	1.6	0.0	0.3	0.0
174	64.3	−1.67	354	92.2	−1.26	290	26.3	120.6	0.8	14.9	1.2	0.6	4.4	5.1	2.0	0.0	0.6	0.0
180	54.2	−1.70	360	83.8	−1.51	300	26.5	115.1	1.2	18.7	1.4	0.7	4.3	4.9	2.4	0.0	0.9	0.1
						310	26.3	107.8	1.6	22.5	1.5	0.9	4.1	4.7	2.8	0.2	1.2	0.1
						320	25.6	98.9	2.1	26.4	1.6	1.1	3.9	4.4	3.2	0.3	1.5	0.2
						330	24.5	88.7	2.6	30.0	1.6	1.2	3.6	4.1	3.6	0.4	1.7	0.3
						340	23.0	77.4	3.2	33.5	1.5	1.4	3.3	3.7	3.9	0.5	1.8	0.3
						350	21.1	65.8	3.6	36.6	1.5	1.5	2.9	3.3	4.2	0.7	1.8	0.3
						360	19.0	54.0	4.1	39.3	1.5	1.6	2.6	2.8	4.4	0.7	1.7	0.4

$$[\partial \log r=(\partial \log r)_1+(\partial \log r)_2+\ldots\ldots+(\partial \log r)_t \; T-c_r]$$

Tables of (103) Hera—Continued.

TABLE IV.—$\partial\beta$.

PERIODIC TERMS. Unit=0.00001.

Arg's. 1–7, 9–11, 13, 15	$(\partial\beta)_1$	$(\partial\beta)_2$	$(\partial\beta)_3$	$(\partial\beta)_4$	$(\partial\beta)_5$	$(\partial\beta)_6$	$(\partial\beta)_7$	$(\partial\beta)_9$	$(\partial\beta)_{10}$	$(\partial\beta)_{11}$	$(\partial\beta)_{13}$	$(\partial\beta)_{15}$
°												
0	4.6	16.4	12.3	0.6	30.7	10.4	5.3	1.4	3.0	4.8	1.4	2.0
10	4.9	16.5	14.9	0.4	33.7	8.5	4.9	1.4	2.6	5.2	1.4	1.9
20	4.6	16.4	17.6	0.2	36.2	6.8	4.5	1.4	2.2	5.6	1.3	1.8
30	4.2	15.7	20.1	0.0	38.1	5.8	4.1	1.4	1.8	5.9	1.2	1.7
40	3.6	14.7	22.5	0.0	39.5	5.7	3.8	1.4	1.4	6.1	1.2	1.5
50	3.0	13.6	24.4	0.0	40.3	5.8	3.3	1.3	1.1	6.2	1.1	1.4
60	2.5	11.8	26.1	0.1	40.6	6.1	2.8	1.2	0.8	6.2	1.0	1.2
70	2.4	10.1	27.3	0.2	40.4	6.9	2.4	1.1	0.5	6.1	0.9	1.0
80	2.6	8.5	28.0	0.3	39.3	7.9	1.9	1.0	0.3	6.0	0.8	0.8
90	3.3	6.9	28.3	0.5	37.8	8.6	1.5	0.9	0.1	5.7	0.7	0.6
100	4.1	5.5	28.2	0.8	35.8	8.8	1.1	0.8	0.0	5.4	0.6	0.4
110	5.3	4.2	27.7	1.1	33.3	8.4	0.7	0.7	0.0	5.1	0.5	0.3
120	6.3	3.1	26.7	1.4	30.3	7.5	0.4	0.6	0.0	4.7	0.4	0.2
130	7.0	2.1	25.4	1.8	27.0	5.9	0.2	0.4	0.1	4.1	0.3	0.1
140	7.4	1.3	23.9	2.2	23.6	4.0	0.1	0.3	0.3	3.5	0.2	0.0
150	7.0	0.7	22.1	2.6	20.2	2.4	0.0	0.2	0.5	3.0	0.1	0.0
160	6.6	0.5	20.2	2.8	16.6	1.1	0.2	0.2	0.7	2.4	0.0	0.0
170	5.6	0.3	18.1	3.1	13.2	0.2	0.3	0.1	1.0	1.9	0.0	0.0
180	4.4	0.1	15.9	3.4	10.0	0.0	0.5	0.0	1.4	1.4	0.0	0.0
190	3.2	0.0	13.7	3.6	7.0	0.7	0.9	0.0	1.8	1.0	0.0	0.0
200	2.1	0.0	11.4	3.8	4.6	2.0	1.3	0.0	2.2	0.6	0.1	0.2
210	1.3	0.1	9.3	4.0	2.6	4.0	1.7	0.0	2.6	0.3	0.2	0.3
220	0.6	0.4	7.3	4.0	1.2	6.5	2.0	0.0	3.0	0.1	0.2	0.4
230	0.3	0.8	5.4	4.0	0.4	9.0	2.5	0.1	3.3	0.0	0.4	0.6
240	0.1	1.3	3.7	3.9	0.0	11.4	3.0	0.2	3.6	0.0	0.5	0.8
250	0.0	2.1	2.1	3.8	0.4	13.3	3.5	0.3	3.9	0.1	0.6	1.0
260	0.1	3.1	1.0	3.7	1.4	14.9	3.9	0.4	4.1	0.2	0.8	1.2
270	0.3	4.2	0.3	3.5	2.9	16.3	4.3	0.5	4.2	0.4	0.8	1.4
280	0.5	5.6	0.0	3.1	5.0	17.2	4.7	0.6	4.3	0.7	0.9	1.6
290	0.7	7.1	0.1	2.9	7.5	17.7	5.1	0.7	4.4	1.1	1.0	1.8
300	1.1	8.7	0.7	2.6	10.4	17.6	5.4	0.8	4.3	1.5	1.1	1.8
310	1.8	10.5	1.6	2.2	13.8	17.2	5.6	1.1	4.2	2.1	1.2	1.9
320	2.6	12.1	3.1	1.8	17.2	16.5	5.7	1.1	4.1	2.7	1.4	2.0
330	3.3	13.8	4.9	1.4	20.6	15.5	5.7	1.2	3.9	3.3	1.4	2.0
340	3.9	15.0	7.2	1.2	24.2	14.1	5.6	1.2	3.7	3.8	1.4	2.0
350	4.4	15.9	9.7	1.0	27.6	12.3	5.5	1.3	3.4	4.3	1.4	2.0
360	4.6	16.5	12.3	0.6	30.7	10.4	5.3	1.4	3.0	4.8	1.4	2.0

$[\partial\beta=(\partial\beta)_1+(\partial\beta)_2+\ldots\ldots\ldots\ldots\ldots\ldots+(\partial\beta)_t\,T-c_\beta.]$

Tables of (103) Hera—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY T=(t−t$_0$) IN JULIAN YEARS.

Arg. 3	$(n\delta z)_t$ Unit=0°001			Arg. 3	$(\delta \log r)_t$ Unit=0.00001			Arg. 3	$(\delta\beta)_t$ Unit=0.00001		
°		°		°		°		°		°	
0	−1.82	180	+1.75	0	−0.28	180	+0.21	0	−4.84	180	+5.68
6	−1.74	186	+1.68	6	−0.35	186	+0.28	6	−4.86	186	+5.71
12	−1.64	192	+1.58	12	−0.42	192	+0.34	12	−4.82	192	+5.69
18	−1.52	198	+1.48	18	−0.49	198	+0.40	18	−4.71	198	+5.61
24	−1.38	204	+1.35	24	−0.55	204	+0.45	24	−4.52	204	+5.51
30	−1.23	210	+1.21	30	−0.60	210	+0.50	30	−4.29	210	+5.34
36	−1.06	216	+1.06	36	−0.65	216	+0.55	36	−4.01	216	+5.14
42	−0.88	222	+0.90	42	−0.69	222	+0.59	42	−3.64	222	+4.87
48	−0.69	228	+0.73	48	−0.72	228	+0.62	48	−3.24	228	+4.55
54	−0.50	234	+0.54	54	−0.74	234	+0.65	54	−2.81	234	+4.21
60	−0.30	240	+0.35	60	−0.75	240	+0.67	60	−2.34	240	+3.82
66	−0.10	246	+0.16	66	−0.76	246	+0.68	66	−1.84	246	+3.38
72	+0.10	252	−0.03	72	−0.75	252	+0.69	72	−1.32	252	+2.91
78	+0.30	258	−0.23	78	−0.74	258	+0.69	78	−0.75	258	+2.41
84	+0.49	264	−0.42	84	−0.72	264	+0.68	84	−0.21	264	+1.90
90	+0.68	270	−0.61	90	−0.69	270	+0.67	90	+0.33	270	+1.36
96	+0.86	276	−0.80	96	−0.65	276	+0.64	96	+0.87	276	+0.80
102	+1.03	282	−0.98	102	−0.61	282	+0.61	102	+1.42	282	+0.23
108	+1.19	288	−1.14	108	−0.57	288	+0.57	108	+1.94	288	−0.35
114	+1.33	294	−1.30	114	−0.52	294	+0.52	114	+2.45	294	−0.92
120	+1.46	300	−1.45	120	−0.46	300	+0.47	120	+2.94	300	−1.47
126	+1.57	306	−1.57	126	−0.40	306	+0.41	126	+3.39	306	−2.00
132	+1.66	312	−1.69	132	−0.33	312	+0.34	132	+3.81	312	−2.51
138	+1.74	318	−1.78	138	−0.27	318	+0.28	138	+4.19	318	−2.98
144	+1.80	324	−1.85	144	−0.20	324	+0.20	144	+4.54	324	−3.40
150	+1.84	330	−1.90	150	−0.13	330	+0.12	150	+4.84	330	−3.79
156	+1.86	336	−1.93	156	−0.06	336	+0.04	156	+5.10	336	−4.12
162	+1.86	342	−1.93	162	+0.01	342	−0.04	162	+5.32	342	−4.39
168	+1.84	348	−1.92	168	+0.08	348	−0.12	168	+5.48	348	−4.60
174	+1.80	354	−1.88	174	+0.15	354	−0.20	174	+5.62	354	−4.76
180	+1.75	360	−1.82	180	+0.21	360	−0.28	180	+5.68	360	−4.84

The perturbations are to be computed in the form—

$$n\delta z=(n\delta z)_1+n\delta z)_2+\dots\dots\dots\dots+(n\delta z)_t\ T-c_t$$
$$\delta \log r=(\delta \log r)_1+(\delta \log r)_2+\dots\dots\dots\dots+(\delta \log r)_t\ T-c_r$$
$$\delta\beta=(\delta\beta)_1+(\delta\beta)_2+\dots\dots\dots\dots+(\delta\beta)_t\ T-c_\beta$$

Tables of (103) Hera—Continued.

TABLE VI. CONSTANTS FOR THE EQUATOR.

Year	A'	B'	C'	log sin a	log sin b	log sin c
	°	°	°			
1868.0	51.2144	322.5520	31.7396	9.99906	9.97429	9.53220
69	.2283	.5656	.7557	06	29	218
1870	.2423	.5792	.7717	06	29	216
1	.2562	.5927	.7878	06	29	214
2	.2702	.6063	.8038	06	29	212
3	.2841	.6198	.8199	06	29	209
4	.2981	.6334	.8359	06	29	207
1875	51.3120	322.6469	310.8520	9.99906	9.97430	205
6	.3260	.6605	.8680	06	30	203
7	.3399	.6740	.8841	06	30	201
8	.3539	.6875	.9002	06	30	198
9	.3678	.7011	.9162	06	31	196
1880	51.3818	322.7146	310.9323	9.99907	9.97431	9.53194
1	.3957	.7282	.9483	07	31	192
2	.4097	.7417	.9644	07	31	190
3	.4236	.7553	.9804	07	32	187
4	.4376	.7688	310.9965	07	32	185
1885	51.4515	322.7823	311.0126	9.99907	9.97432	183
6	.4655	.7959	.0286	07	32	181
7	.4794	.8094	.0447	07	33	179
8	.4933	.8230	.0607	07	33	176
9	.5073	.8365	.0768	07	33	174
1890	51.5212	322.8501	311.0928	9.99907	9.97433	9.53172
1	.5352	.8636	.1088	07	34	170
2	.5491	.8771	.1249	07	34	167
3	.5631	.8907	.1409	07	34	165
4	.5770	.9042	.1570	07	34	163
1895	51.5910	322.9178	311.1730	9.99907	9.97435	160
6	.6049	.9313	.1891	07	35	158
7	.6189	.9449	.2051	07	35	156
8	.6328	.9584	.2212	07	35	154
9	.6467	.9719	.2373	07	36	151
1900	51.6607	322.9855	311.2534	9.99908	9.97436	9.53149
1	.6747	322.9990	.2695	08	36	147
2	.6886	323.0126	.2856	08	36	145
3	.7026	.0261	.3017	08	37	142
4	.7165	.0397	.3177	08	37	140
1905	51.7305	323.0532	311.3338	9.99908	9.97437	138
6	.7444	.0668	.3499	08	37	136
7	.7584	.0803	.3660	08	38	134
8	.7723	.0938	.3821	08	38	131
9	.7863	.1074	.3982	08	38	129
1910	51.8002	323.1209	311.4143	9.99908	9.97438	9.53127
1	.8142	.1345	.4304	08	39	125
2	.8281	.1480	.4464	08	39	123
3	.8421	.1616	.4625	08	39	120
4	.8560	.1751	.4786	08	39	118
1915	51.8700	323.1886	311.4947	9.99908	9.97440	116
6	.8839	.2022	.5108	08	40	114
7	.8979	.2157	.5269	08	40	112
8	.9119	.2293	.5430	08	40	109
9	.9258	.2428	.5591	08	41	107
1920	51.9398	323.2564	311.5751	9.99908	9.97441	9.53105
1	.9537	.2699	.5912	09	41	103
2	.9677	.2834	.6073	09	41	101
3	.9816	.2970	.6234	09	42	098
4	51.9956	.3105	.6395	09	42	096
1925	52.0095	323.3241	311.6556	9.99909	9.97442	094
6	.0235	.3376	.6717	09	42	092
7	.0374	.3512	.6877	09	42	090
8	.0514	.3647	.7038	09	43	087
9	.0653	.3782	.7199	09	43	085
1930	52.0793	323.3918	311.7360	9.99909	9.97443	9.53083

Year	log cos a	log cos b	log cos c
1870.0	8.816	9.524 *n*	9.973
1930.0	8.812	9.523 *n*	9.973

TABLES OF (119) ALTHAEA.

OSCULATING ELEMENTS.

Epoch and Osculation, 1894, Aug. 23.0, M. T. Berlin=1894.643, M. T. Berlin.

$$\begin{array}{rrrrl}
 & {}^{\circ} & {}' & {}'' & \\
g_0= & 332 & 43 & 50 & =332\overset{\circ}{.}7306 \\
\omega= & 168 & 2 & 24 & =168.0400 \\
\Omega= & 203 & 54 & 3 & =203.9008 \\
i= & 5 & 43 & 54 & =5.7317 \\
\varphi= & 4 & 36 & 2 & =4.6006 \\
n= & \multicolumn{3}{l}{855.''4057} & =0.23761270
\end{array}
\left.\begin{array}{l}\\ \\ \\ \\ \end{array}\right\}\text{Mean equinox and ecliptic 1894.0.}$$

g_0 and n are mean elements.

The elements are based on oppositions extending from 1872 to 1900 and on the perturbations of the first order by *Jupiter*, as given on page 350.

AUXILIARY QUANTITIES.

$\log a=0.41189$ $\log 57.2958\, e=0.66234$ $\log\sqrt{\frac{1-e}{1+e}}=9.96509$

$\log e=8.90422$ $\log p=0.40909$

NUMERICAL DESIGNATION OF THE ARGUMENTS FOR TABLES II-V.

$1=g$
$2=g-g'$
$3=g-3g'$
$4=g-2g'$
$5=2g-3g'$
$6=2g-g'$
$7=3g-2g'$
$8=3g-4g'$
$9=4g-3g'$
$10=-g'$
$11=-g-g'$

CONSTANTS TO BE SUBTRACTED FROM THE TABULATED PERTURBATIONS.

$c_z=0\overset{\circ}{.}4072$ $c_r=0.001098$ $c_\beta=0.001607$

Derivation of c_z, c_r, c_β. (See also page 208.)

	Arg.	$n\partial z$ Unit=$0\overset{\circ}{.}001$	$\partial \log r$ Unit=0.00001	$\partial\beta$ Unit=0.00001
Constants added to make all numbers positive.	1	117.78	46.1	69.3
	2	106.47	42.6	5.8
	3	115.08	3.0	5.9
	4	51.28	9.0	9.4
	5	10.56	3.4	51.5
	6	1.47	0.9	2.8
	7	1.89	1.5	
	8	0.36	0.2	1.8
	9	0.25		
	10	1.86	0.8	13.5
	11	0.25		2.2
	Sum.	407.2	107.5	162.2

$c_z=0\overset{\circ}{.}4072.$

$c_r=0.001075-$(constant part $\partial \log r +$ correction for difference between mean and osculating values of semimajor axis).
$=0.001075-(27.''4-38.''4)\sin 1''\,\text{Mod}.$
$=0.001075+0.000023.$
$c_r=0.001098.$

$c_\beta=0.001622-$(constant part of $\partial\beta$).
$=0.001622-0.000008.$
$=0.001614.$

Tables of (119) Althaea—Continued.

TABLE I.—MEAN ANOMALY (g).

Jan. 0.0 of common years; Jan. 1.0 of leap years			
Year	*g*	Year	*g*
	°		°
B 1872	167. 67357	1901	164. 22968
3	254. 40221	2	250. 95831
4	341. 13084	3	337. 68695
5	67. 85948	B 4	64. 65320
B 6	154. 82573	5	151. 38183
7	241. 55436	6	238. 11047
8	328. 28300	7	324. 83910
9	55. 01163	B 8	51. 80535
B 1880	141. 97788	9	138. 53399
1	228. 70652	1910	225. 26262
2	315. 43515	1	311. 99126
3	42. 16379	B 2	38. 95751
B 4	129. 13004	3	125. 68614
5	215. 85867	4	212. 41478
6	302. 58731	5	299. 14341
7	29. 31594	B 6	26. 10966
B 8	116. 28219	7	112. 83830
9	203. 01083	8	199. 56693
1890	289. 73946	9	286. 29557
1	16. 46810	B 1920	13. 26181
B 2	103. 43434	1	99. 99045
3	190. 16298	2	186. 71909
4	276. 89162	3	273. 44772
5	3. 62025	B 4	0. 41397
B 6	90. 58650	5	87. 14260
7	177. 31513	6	173. 87124
8	264. 04377	7	260. 59988
9	350. 77241	B 8	347. 56612
1900	77. 50104	9	74. 29476
		1930	161. 02340

NOTE.—When *g* is used as an argument of the perturbations add to the *g* of this table $\Delta\pi=\pi-\pi_0= -0.^{\circ}0261$. For explanation see page 203.

Table for beginning of month	
Month	*g*
	°
Jan. 0.0 1.0	0. 00000
Feb. 0.0 1.0	7. 36599
Mar. 0.0	14. 01915
Apr. 0.0	21. 38514
May 0.0	28. 51352
June 0.0	35. 87952
July 0.0	43. 00790
Aug. 0.0	50. 37389
Sept. 0.0	57. 73989
Oct. 0.0	64. 86827
Nov. 0.0	72. 23426
Dec. 0.0	79. 36264

Change for *n* days[a]			
n	*g*	*n*	*g*
	°		°
1	0. 23761	16	3. 80180
2	0. 47523	17	4. 03942
3	0. 71284	18	4. 27703
4	0. 95045	19	4. 51464
5	1. 18806	20	4. 75225
6	1. 42568	21	4. 98987
7	1. 66329	22	5. 22748
8	1. 90090	23	5. 46509
9	2. 13851	24	5. 70270
10	2. 37613	25	5. 94032
11	2. 61374	26	6. 17793
12	2. 85135	27	6. 41554
13	3. 08897	28	6. 65316
14	3. 32658	29	6. 89077
15	3. 56419	30	7. 12838

[a] For days during January and February of leap years subtract one day before entering this table.

Tables of (119) Althaea—Continued.

PERTURBATIONS.

Arg. $ig-ig'$		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	0				+ 27.4		+ 0.7
0	0				+ 0.051nt		+ 0.362nt
+1	0	+418.6	+78.9	+39.9	−207.5	−43.0	− 4.0
+1		− 1.218nt	− 3.238nt	− 1.619nt	+ 0.609nt	− 1.346nt	− 3.004nt
+2		+ 8.2	+ 1.3	+ 1.4	− 8.2	− 1.5	− 0.2
+2	0	− 0.024nt	− 0.065nt	+ 0.065nt	+ 0.024nt	− 0.054nt	− 0.120nt
0	−1	+ 3.1	− 3.1	− 1.5	+ 2.1	−10.2	− 4.4
0	−2	− 3.0	+ 1.9	− 1.0	− 1.3	+ 1.3	+ 0.6
0	−3	+ 0.2	− 1.8	+ 0.9	+ 0.1	− 0.4	+ 0.2
+1	−1	−174.6	+ 2.0	+ 0.8	+ 61.2	+ 2.7	+ 1.3
+2	−2	+264.0	− 7.2	− 4.2	−156.2	− 1.2	− 0.6
+3	−3	+ 25.2	− 0.8	− 0.6	− 18.3	− 1.6	− 0.6
+4	−4	+ 5.7	− 0.4	− 0.3	− 4.7		
+5	−5	+ 1.6	− 0.1	− 0.1	− 1.4		
+6	−6	+ 0.5			− 0.5		
+2	−1	− 5.2	+ 0.9	+ 0.6	+ 4.0	− 2.0	+ 1.0
+1	−2	+185.2	+ 2.1	+ 0.1	− 43.3	− 6.6	− 2.7
+2	−4	− 1.1	− 0.7		+ 0.4	− 0.5	− 0.2
+1	−3	+404.9	−87.1	+ 3.2	+ 14.6	+ 4.4	+ 1.7
+2	−3	− 37.2	+ 8.0	+ 3.8	+ 16.1	−38.2	−14.9
+3	−2	+ 6.8			− 7.1	− 0.5	+ 0.2
+3	−4	+ 0.9	− 0.9	− 0.7	− 1.0	+ 1.3	+ 0.5
+4	−3	+ 0.9		0.0	− 0.7	− 0.2	
−1	−1	+ 0.2	− 0.9	+ 0.6	+ 0.2	− 1.6	− 0.6

The constant part in $n\delta z$ is included in the element g_o.
The nontrigonometrical term multiplied by the time in $n\delta z$ is included in the element n.
The constant part of ν is included in the constant c_r.
The constant part of $u/\cos i$ is included in the constant c_β.
All other terms are contained in Tables II–V.

Tables of (119) Althaea—Continued.

TABLE II.—$n\delta z$.

PERIODIC TERMS. Unit=0°.001.

Arg. 2	$(n\delta z)_2$	Diff. for 1°	Arg. 2	$(n\delta z)_2$	Diff. for 1°
°			°		
0	104.7	+2.22	180	104.0	+3.14
3	111.3	+2.17	183	113.3	+3.14
6	117.9	+2.14	186	122.6	+3.06
9	124.3	+2.08	189	131.8	+3.06
12	130.3	+1.94	192	140.8	+2.97
15	135.8	+1.75	195	149.4	+2.83
18	140.8	+1.58	198	157.9	+2.69
21	145.2	+1.33	201	165.8	+2.58
24	148.8	+1.19	204	173.3	+2.42
27	151.7	+0.92	207	180.3	+2.22
30	153.6	+0.50	210	186.8	+2.03
33	154.8	+0.22	213	192.6	+1.86
36	155.0	0.00	216	197.8	+1.60
39	154.4	−0.28	219	202.2	+1.33
42	152.9	−0.64	222	205.9	+1.06
45	150.5	−0.97	225	208.8	+0.83
48	147.4	−1.22	228	211.0	+0.61
51	143.4	−1.39	231	212.2	+0.33
54	138.8	−1.61	234	212.8	+0.08
57	133.5	−1.89	237	212.4	−0.22
60	127.6	−2.08	240	211.4	−0.50
63	121.2	−2.17	243	209.4	−0.75
66	114.3	−2.31	246	206.8	−0.97
69	107.2	−2.44	249	203.5	−1.25
72	99.7	−2.56	252	199.4	−1.47
75	92.0	−2.58	255	194.7	−1.67
78	84.2	−2.58	258	189.4	−1.75
81	76.4	−2.58	261	183.6	−1.97
84	68.5	−2.58	264	197.3	−2.17
87	60.8	−2.56	267	170.5	−2.31
90	53.3	−2.44	270	163.4	−2.44
93	46.0	−2.36	273	155.9	−2.50
96	39.1	−2.28	276	148.3	−2.56
99	32.5	−2.14	279	140.5	−2.64
102	26.4	−1.95	282	132.6	−2.64
105	20.8	−1.75	285	124.7	−2.58
108	15.8	−1.58	288	116.9	−2.58
111	11.4	−1.39	291	109.3	−2.50
114	7.6	−1.11	294	101.9	−2.42
117	4.6	−0.89	297	94.7	−2.31
120	2.3	−0.64	300	88.1	−2.14
123	0.8	−0.36	303	81.9	−2.00
126	0.1	−0.08	306	76.2	−1.81
129	0.2	+0.19	309	71.2	−1.53
132	1.1	+0.42	312	66.8	−1.31
135	2.8	+0.69	315	63.3	−1.06
138	5.3	+0.97	318	60.5	−0.78
141	8.6	+1.25	321	58.5	−0.50
144	12.6	+1.47	324	57.4	−0.22
147	17.4	+1.72	327	57.3	+0.08
150	22.9	+1.94	330	58.0	+0.42
153	29.0	+2.14	333	59.6	+0.69
156	35.8	+2.31	336	62.1	+0.92
159	43.0	+2.50	339	65.4	+1.20
162	50.8	+2.64	342	69.4	+1.47
165	59.0	+2.78	345	74.2	+1.67
168	67.4	+2.92	348	79.5	+1.89
171	76.4	+3.00	351	85.3	+2.03
174	85.5	+3.06	354	91.5	+2.14
177	94.7	+3.06	357	98.0	+2.17
180	104.0	+3.14	360	104.7	+2.22

$$[n\delta z=(n\delta z)_1+(n\delta z)_2+\ .\ .\ .\ +(n\delta z)_t T-c_z]$$

Tables of (119) Althaea—Continued.

TABLE II.—$n\partial z$—Continued.

PERIODIC TERMS. Unit=0°.001.

Arg's. 1, 3-5	$(n\partial z)_1$	Diff. for 1°	$(n\partial z)_3$	Diff. for 1°	$(n\partial z)_4$	Diff. for 1°	$(n\partial z)_5$
°							
0	140.0	+2.14	91.1	+1.94	51.7	+0.89	12.8
6	152.8	+2.06	102.8	+1.97	57.0	+0.89	11.7
12	164.4	+1.94	114.7	+2.00	62.2	+0.89	10.6
18	176.1	+1.89	126.7	+1.97	67.4	+0.86	9.5
24	187.0	+1.72	138.3	+1.94	72.4	+0.81	8.4
30	196.9	+1.61	150.0	+1.89	77.1	+0.78	7.3
36	206.1	+1.44	161.1	+1.81	81.6	+0.72	6.3
42	214.2	+1.25	171.7	+1.72	85.8	+0.67	5.3
48	221.1	+1.06	181.7	+1.61	89.6	+0.61	4.3
54	226.9	+0.89	190.8	+1.47	93.0	+0.50	3.5
60	231.7	+0.61	199.4	+1.33	95.9	+0.45	2.7
66	234.4	+0.36	206.9	+1.17	98.4	+0.37	2.0
72	236.1	+0.19	213.3	+0.97	100.3	+0.28	1.4
78	236.7	0.00	218.6	+0.81	101.8	+0.23	0.9
84	236.1	−0.22	223.1	+0.61	102.6	+0.10	0.5
90	233.9	−0.47	226.1	+0.42	102.9	0.00	0.2
96	230.6	−0.64	228.1	+0.23	102.6	−0.10	0.1
102	226.1	−0.89	228.6	0.00	101.8	−0.16	0.0
108	220.0	−1.06	228.3	−0.19	100.3	−0.28	0.0
114	213.3	−1.19	226.4	−0.42	98.4	−0.37	0.2
120	205.6	−1.36	223.3	−0.61	95.9	−0.45	0.5
126	196.9	−1.53	219.2	−0.81	92.9	−0.53	0.9
132	187.2	−1.67	213.6	−1.00	89.4	−0.64	1.4
138	176.9	−1.75	207.2	−1.17	85.6	−0.67	2.0
144	166.1	−1.81	199.7	−1.33	81.3	−0.75	2.7
150	155.3	−1.89	191.4	−1.44	76.7	−0.81	3.4
156	143.6	−1.94	182.2	−1.61	71.8	−0.83	4.3
162	131.9	−1.97	172.2	−1.72	66.7	−0.86	5.2
168	120.0	−2.00	161.7	−1.81	61.4	−0.92	6.2
174	107.8	−2.00	150.6	−1.89	55.9	−0.92	7.2
180	96.1	−1.94	139.2	−1.94	50.5	−0.92	8.3
186	84.4	−1.89	127.2	−2.00	45.1	−0.92	9.4
192	73.3	−1.81	115.3	−1.97	39.7	−0.89	10.5
198	62.8	−1.72	103.6	−1.97	34.5	−0.86	11.6
204	52.5	−1.69	91.7	−1.94	29.5	−0.81	12.7
210	42.5	−1.56	80.3	−1.89	24.7	−0.78	13.8
216	33.9	−1.39	69.2	−1.81	20.2	−0.72	14.8
222	25.8	−1.25	58.6	−1.72	16.1	−0.64	15.8
228	18.9	−1.04	48.4	−1.61	12.4	−0.58	16.8
234	13.1	−0.92	39.2	−1.44	9.1	−0.50	17.6
240	7.8	−0.78	30.8	−1.33	6.3	−0.45	18.4
246	3.9	−0.50	23.3	−1.17	4.0	−0.37	19.1
252	1.6	−0.33	16.7	−1.00	2.1	−0.25	19.7
258	0.0	−0.14	11.4	−0.81	0.9	−0.17	20.2
264	0.0	+0.08	6.9	−0.61	0.2	−0.07	20.6
270	1.1	+0.28	3.9	−0.42	0.0	−0.03	20.9
276	3.3	+0.50	1.9	−0.22	0.0	+0.11	21.1
282	7.2	+0.75	1.4	0.00	1.4	+0.17	21.1
288	12.2	+0.92	1.9	+0.22	2.9	+0.30	21.1
294	18.3	+1.17	3.9	+0.42	4.9	+0.39	20.9
300	26.1	+1.33	6.9	+0.61	7.4	+0.44	20.6
306	34.2	+1.47	11.1	+0.78	10.4	+0.53	20.2
312	43.9	+1.67	16.4	+0.97	13.8	+0.61	19.7
318	54.2	+1.75	22.8	+1.17	17.6	+0.64	19.1
324	65.0	+1.86	30.3	+1.33	21.8	+0.72	18.4
330	76.4	+2.00	38.9	+1.47	26.2	+0.78	17.7
336	89.2	+2.11	48.1	+1.58	31.0	+0.81	16.8
342	101.7	+2.11	57.8	+1.72	35.9	+0.83	15.9
348	114.4	+2.14	68.6	+1.81	41.1	+0.89	14.9
354	127.2	+2.14	79.5	+1.89	46.4	+0.89	13.8
360	140.0	+2.14	91.1	+1.94	51.7	+0.89	12.8

$$[n\partial z=(n\partial z)_1+(n\partial z)_2+\ .\ .\ .\ +(n\partial z)_t T-c_z]$$

Tables of (119) Althaea—Continued.

TABLE II.—$n\partial z$—Continued.

PERIODIC TERMS. Unit=0°.001.

Arg's. 6–11	$(n\partial z)_6$	$(n\partial z)_7$	$(n\partial z)_8$	$(n\partial z)_9$	$(n\partial z)_{10}$	$(n\partial z)_{11}$
°						
0	1.7	1.9	0.1	0.3	1.1	0.0
10	1.5	2.2	0.2	0.3	1.0	0.0
20	1.2	2.5	0.2	0.3	1.0	0.0
30	1.0	2.8	0.3	0.4	1.1	0.0
40	0.8	3.1	0.3	0.4	1.3	0.1
50	0.5	3.3	0.4	0.4	1.5	0.1
60	0.3	3.5	0.4	0.5	1.7	0.1
70	0.2	3.7	0.5	0.5	1.9	0.2
80	0.1	3.8	0.6	0.5	2.1	0.2
90	0.0	3.8	0.6	0.5	2.2	0.3
100	0.0	3.8	0.7	0.5	2.4	0.3
110	0.0	3.7	0.7	0.5	2.7	0.3
120	0.1	3.5	0.7	0.5	3.0	0.4
130	0.2	3.3	0.7	0.4	3.4	0.4
140	0.4	3.1	0.7	0.4	3.8	0.4
150	0.5	2.8	0.7	0.4	4.0	0.5
160	0.8	2.5	0.7	0.3	4.2	0.5
170	1.0	2.2	0.6	0.3	4.1	0.5
180	1.2	1.9	0.6	0.3	3.8	0.5
190	1.5	1.6	0.6	0.2	3.3	0.5
200	1.7	1.3	0.5	0.2	2.5	0.5
210	2.0	0.9	0.4	0.1	1.8	0.5
220	2.2	0.7	0.4	0.1	1.0	0.4
230	2.4	0.4	0.3	0.1	0.4	0.4
240	2.6	0.3	0.3	0.0	0.1	0.4
250	2.8	0.1	0.2	0.0	0.0	0.3
260	2.8	0.0	0.2	0.0	0.2	0.3
270	2.9	0.0	0.1	0.0	0.5	0.3
280	2.9	0.0	0.1	0.0	0.9	0.2
290	2.9	0.1	0.0	0.0	1.3	0.2
300	2.8	0.3	0.0	0.1	1.7	0.1
310	2.7	0.4	0.0	0.1	1.8	0.1
320	2.6	0.7	0.0	0.1	1.8	0.1
330	2.4	0.9	0.0	0.1	1.7	0.0
340	2.2	1.3	0.1	0.2	1.5	0.0
350	2.0	1.6	0.1	0.2	1.3	0.0
360	1.7	1.9	0.1	0.3	1.1	0.0

$$[n\partial z=(n\partial z)_1+(n\partial z)_2+\ \ldots\ +(n\partial z)_t T-c_z]$$

Tables of (119) Althaea—Continued.

TABLE III.—$\partial \log r$.

PERIODIC TERMS. Unit=0.00001.

Arg's. 1–8, 10	$(\partial \log r)_1$	$(\partial \log r)_2$	$(\partial \log r)_3$	$(\partial \log r)_4$	$(\partial \log r)_5$	$(\partial \log r)_6$	$(\partial \log r)_7$	$(\partial \log r)_8$	$(\partial \log r)_{10}$
°									
0	0. 6	17. 5	6. 1	0. 0	6. 8	1. 7	0. 0	0. 0	1. 0
10	3. 0	19. 9	6. 2	0. 1	6. 9	1. 7	0. 0	0. 0	1. 0
20	6. 8	27. 0	6. 2	0. 5	6. 8	1. 7	0. 1	0. 0	0. 9
30	11. 9	37. 4	6. 1	1. 2	6. 7	1. 6	0. 2	0. 0	0. 9
40	18. 1	49. 1	5. 8	2. 1	6. 5	1. 6	0. 4	0. 0	0. 8
50	25. 1	60. 2	5. 5	3. 3	6. 2	1. 5	0. 5	0. 0	0. 7
60	32. 7	69. 1	5. 2	4. 6	5. 8	1. 4	0. 8	0. 0	0. 6
70	40. 6	74. 7	4. 8	6. 0	5. 3	1. 3	1. 0	0. 0	0. 6
80	48. 6	76. 5	4. 3	7. 5	4. 8	1. 2	1. 2	0. 1	0. 6
90	56. 3	74. 7	3. 7	9. 1	4. 2	1. 0	1. 5	0. 1	0. 6
100	63. 7	69. 5	3. 2	10. 7	3. 6	0. 8	1. 7	0. 1	0. 6
110	70. 4	60. 9	2. 7	12. 2	3. 0	0. 7	2. 0	0. 2	0. 6
120	76. 3	50. 3	2. 1	13. 6	2. 4	0. 5	2. 2	0. 2	0. 7
130	81. 1	38. 6	1. 6	15. 0	1. 8	0. 4	2. 5	0. 3	0. 6
140	84. 8	26. 7	1. 1	16. 1	1. 3	0. 3	2. 6	0. 4	0. 6
150	87. 2	16. 1	0. 7	17. 0	0. 9	0. 2	2. 8	0. 4	0. 5
160	88. 7	7. 6	0. 4	17. 6	0. 5	0. 1	2. 9	0. 4	0. 4
170	88. 9	2. 1	0. 2	18. 0	0. 2	0. 0	3. 0	0. 4	0. 2
180	87. 8	0. 0	0. 0	18. 2	0. 0	0. 0	3. 0	0. 5	0. 1
190	85. 8	1. 5	0. 0	18. 1	0. 0	0. 0	3. 0	0. 5	0. 0
200	82. 8	6. 5	0. 0	17. 6	0. 0	0. 0	2. 9	0. 5	0. 0
210	78. 8	14. 6	0. 1	17. 0	0. 1	0. 1	2. 8	0. 5	0. 1
220	73. 7	25. 0	0. 3	16. 1	0. 3	0. 1	2. 6	0. 5	0. 2
230	67. 9	36. 8	0. 6	15. 0	0. 6	0. 2	2. 4	0. 5	0. 5
240	61. 4	48. 8	0. 9	13. 6	1. 0	0. 3	2. 2	0. 5	0. 8
250	54. 3	59. 7	1. 4	12. 2	1. 5	0. 4	2. 0	0. 5	1. 2
260	46. 7	68. 7	1. 9	10. 7	2. 0	0. 6	1. 7	0. 4	1. 4
270	39. 1	74. 7	2. 4	9. 1	2. 6	0. 7	1. 5	0. 4	1. 6
280	31. 6	77. 2	2. 9	7. 5	3. 2	0. 9	1. 2	0. 4	1. 7
290	24. 5	75. 8	3. 5	6. 0	3. 9	1. 0	1. 0	0. 3	1. 6
300	17. 9	70. 6	4. 0	4. 6	4. 5	1. 1	0. 8	0. 3	1. 6
310	12. 0	62. 0	4. 5	3. 3	5. 0	1. 3	0. 6	0. 2	1. 4
320	7. 1	50. 9	5. 0	2. 1	5. 5	1. 4	0. 4	0. 1	1. 4
330	3. 3	39. 0	5. 4	1. 2	5. 9	1. 5	0. 2	0. 1	1. 2
340	0. 9	28. 1	5. 7	0. 5	6. 3	1. 6	0. 1	0. 1	1. 1
350	0. 0	20. 5	6. 0	0. 1	6. 6	1. 6	0. 0	0. 1	1. 0
360	0. 6	17. 5	6. 1	0. 0	6. 8	1. 7	0. 0	0. 0	1. 0

$[\partial \log r = (\partial \log r)_1 + (\partial \log r)_2 + \ldots\ldots\ldots\ldots + (\partial \log r)_t \ T - c_r.]$

Tables of (119) Althaea—Continued.

TABLE IV.—$\delta\beta$.

PERIODIC TERMS.

Unit=0.00001.

Arg's. 1–6, 8, 10, 11	$(\delta\beta)_1$	$(\delta\beta)_2$	$(\delta\beta)_3$	$(\delta\beta)_4$	$(\delta\beta)_5$	$(\delta\beta)_6$	$(\delta\beta)_8$	$(\delta\beta)_{10}$	$(\delta\beta)_{11}$
°									
0	64. 3	5. 8	7. 9	6. 0	32. 9	4. 0	2. 4	9. 0	1. 5
10	54. 6	5. 1	8. 9	4. 4	24. 8	3. 6	2. 6	7. 1	1. 2
20	44. 9	4. 8	9. 7	3. 0	17. 5	3. 0	2. 9	5. 4	0. 9
30	36. 4	5. 1	10. 4	1. 9	11. 4	2. 6	3. 0	3. 7	0. 6
40	28. 9	6. 1	10. 9	0. 9	6. 3	2. 2	3. 3	2. 2	0. 4
50	22. 7	7. 6	11. 4	0. 2	2. 6	1. 6	3. 4	1. 2	0. 3
60	18. 5	9. 1	11. 5	0. 1	0. 6	1. 2	3. 5	0. 5	0. 1
70	15. 9	10. 5	11. 6	0. 1	0. 0	0. 8	3. 5	0. 1	0. 0
80	14. 5	11. 5	11. 5	0. 4	0. 9	0. 4	3. 5	0. 0	0. 1
90	15. 4	11. 8	11. 3	1. 1	3. 5	0. 3	3. 4	0. 4	0. 2
100	17. 4	11. 2	10. 8	2. 0	7. 5	0. 1	3. 3	1. 1	0. 4
110	21. 6	10. 1	10. 2	3. 1	12. 8	0. 0	3. 1	2. 3	0. 6
120	26. 8	8. 6	9. 5	4. 4	19. 4	0. 0	2. 9	3. 7	0. 9
130	33. 1	7. 1	8. 6	5. 8	26. 8	0. 1	2. 6	5. 5	1. 2
140	40. 2	5. 7	7. 6	7. 3	35. 0	0. 3	2. 2	7. 8	1. 6
150	48. 3	4. 7	6. 6	8. 6	43. 8	0. 5	2. 0	10. 5	1. 9
160	56. 8	4. 3	5. 6	10. 0	52. 7	0. 8	1. 7	13. 4	2. 3
170	65. 6	4. 1	4. 6	11. 5	61. 6	1. 1	1. 4	16. 4	2. 6
180	74. 4	4. 0	3. 6	12. 8	70. 4	1. 5	1. 1	19. 5	3. 0
190	83. 0	3. 8	3. 6	13. 9	78. 4	1. 9	0. 9	22. 4	3. 3
200	91. 2	3. 5	3. 8	15. 0	85. 6	2. 5	0. 6	24. 9	3. 6
210	99. 1	2. 9	3. 9	15. 9	91. 8	3. 0	0. 5	26. 9	3. 9
220	106. 2	2. 1	4. 1	16. 7	96. 8	3. 5	0. 3	28. 2	4. 1
230	112. 3	1. 1	4. 3	17. 3	100. 4	3. 9	0. 1	28. 8	4. 2
240	116. 9	0. 3	4. 7	17. 7	102. 4	4. 3	0. 0	28. 5	4. 4
250	120. 3	0. 0	5. 0	17. 9	103. 0	4. 7	0. 0	27. 7	4. 5
260	122. 8	0. 0	5. 4	17. 9	102. 0	5. 0	0. 0	26. 5	4. 4
270	123. 3	1. 0	5. 7	17. 7	99. 5	5. 2	0. 1	25. 1	4. 2
280	122. 3	2. 3	6. 1	17. 1	95. 5	5. 4	0. 2	23. 3	4. 1
290	119. 6	4. 0	6. 5	16. 3	90. 1	5. 4	0. 4	21. 5	3. 9
300	115. 2	5. 9	6. 8	15. 4	83. 8	5. 4	0. 6	19. 8	3. 6
310	109. 4	7. 2	7. 1	14. 2	76. 2	5. 4	0. 9	18. 1	3. 2
320	102. 0	8. 1	7. 3	12. 7	68. 1	5. 2	1. 2	16. 3	2. 9
330	93. 6	8. 3	7. 5	11. 1	59. 3	5. 0	1. 5	14. 7	2. 6
340	84. 4	7. 7	7. 7	9. 5	50. 4	4. 7	1. 8	12. 9	2. 2
350	74. 4	6. 9	7. 8	7. 7	41. 3	4. 3	2. 1	11. 1	1. 9
360	64. 3	5. 7	7. 9	6. 0	32. 5	4. 0	2. 4	9. 0	1. 5

$[\delta\beta=(\delta\beta)_1+(\delta\beta)_2+ \dots\dots\dots\dots +(\delta\beta)_t\ T-c_{\beta}.]$

Tables of 119 Althaea—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY $T=(t-t_0)$ IN JULIAN YEARS.

Arg. 1	$(n\delta z)_t$ Unit=0°.001.			Arg. 1	$(\delta \log r)_t$ Unit=0.00001.			Arg. 1	$(\delta\beta)_t$ Unit=0.00001.		
°		°		°		°		°		°	
0	−1.39	180	+1.33	0	+0.21	180	−0.17	0	−5.25	180	+6.15
6	−1.44	186	+1.38	10	+0.12	190	−0.08	10	−5.61	190	+6.47
12	−1.47	192	+1.41	20	+0.02	200	+0.02	20	−5.78	200	+6.69
18	−1.48	198	+1.42	30	−0.07	210	+0.11	30	−5.74	210	+6.68
24	−1.48	204	+1.42	40	−0.16	220	+0.20	40	−5.46	220	+6.54
30	−1.46	210	+1.41	50	−0.25	230	+0.29	50	−4.98	230	+6.23
36	−1.42	216	+1.38	60	−0.33	240	+0.37	60	−4.35	240	+5.77
42	−1.37	222	+1.34	70	−0.40	250	+0.44	70	−3.54	250	+5.15
48	−1.30	228	+1.28	80	−0.45	260	+0.49	80	−2.64	260	+4.38
54	−1.22	234	+1.21	90	−0.50	270	+0.54	90	−1.63	270	+3.47
60	−1.12	240	+1.13	100	−0.52	280	+0.56	100	−0.59	280	+2.46
66	−1.01	246	+1.03	110	−0.53	290	+0.57	110	+0.46	290	+1.39
72	−0.89	252	+0.92	120	−0.52	300	+0.56	120	+1.52	300	+0.27
78	−0.76	258	+0.80	130	−0.50	310	+0.54	130	+2.52	310	−0.87
84	−0.62	264	+0.68	140	−0.46	320	+0.50	140	+3.46	320	−1.97
90	−0.48	270	+0.54	150	−0.41	330	+0.45	150	+4.31	330	−3.00
96	−0.34	276	+0.40	160	−0.34	340	+0.38	160	+5.05	340	−3.92
102	−0.19	282	+0.25	170	−0.26	350	+0.30	170	+5.69	350	−4.67
108	−0.04	288	+0.10	180	−0.17	360	+0.21	180	+6.15	360	−5.25
114	+0.11	294	−0.06								
120	+0.26	300	−0.21								
126	+0.41	306	−0.37								
132	+0.54	312	−0.52								
138	+0.68	318	−0.66								
144	+0.80	324	−0.80								
150	+0.92	330	−0.92								
156	+1.02	336	−1.04								
162	+1.12	342	−1.15								
168	+1.21	348	−1.24								
174	+1.28	354	−1.32								
180	+1.33	360	−1.39								

The perturbations are to be computed in the form—

$$n\delta z=(n\delta z)_1+(n\delta z)_2+\dots\dots\dots+(n\delta z)_t\,T-c_z.$$
$$\delta\log r=(\delta\log r)_1+(\delta\log r)_2+\dots\dots\dots+(\delta\log r)_t\,T-c_r.$$
$$\delta\beta=(\delta\beta)_1+(\delta\beta)_2+\dots\dots\dots+(\delta\beta)_t\,T-c_\beta.$$

Tables of (119) Althaea—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	A'	B'	C'	log sin a	log sin b	log sin c
	°	°	°			
1872.0	101.5286	10.7759	18.4605	9.99965	9.97775	9.49775
3	.5425	.7894	.4780	65	75	777
4	.5564	.8028	.4956	65	75	779
1875	101.5703	10.8163	18.5131	9.99965	9.97775	9.49780
6	.5842	.8297	.5307	65	75	782
7	.5981	.8432	.5482	65	75	783
8	.6120	.8567	.5658	65	75	785
9	.6260	.8702	.5833	65	74	787
1880	101.6399	10.8837	18.6009	9.99965	9.97774	9.49789
1	.6538	.8971	.6184	65	74	790
2	.6677	.9105	.6360	65	74	792
3	.6816	.9240	.6535	65	74	793
4	.6955	.9375	.6711	65	74	795
1885	101.7094	10.9510	18.6886	9.99965	9.97774	9.49796
6	.7233	.9644	.7061	65	73	9.49798
7	.7372	.9779	.7237	65	73	9.49800
8	.7512	10.9914	.7412	65	73	801
9	.7651	11.0048	.7588	65	73	803
1890	101.7790	11.0182	18.7763	9.99965	9.97773	9.49805
1	.7929	.0317	.7939	65	73	806
2	.8068	.0451	.8114	64	73	808
3	.8207	.0586	.8290	64	72	810
4	.8346	.0720	.8465	64	72	811
1895	101.8485	11.0855	18.8640	9.99964	9.97772	9.49813
6	.8624	.0989	.8816	64	72	814
7	.8763	.1124	.8992	64	72	816
8	.8902	.1259	.9167	64	72	818
9	.9041	.1393	.9342	64	72	819
1900	101.9180	11.1527	18.9518	9.99964	9.97772	9.49821
1	.9319	.1662	.9693	64	71	823
2	.9458	.1796	18.9868	64	71	824
3	.9597	.1931	19.0043	64	71	826
4	.9736	.2065	.0219	64	71	828
1905	101.9875	11.2200	19.0394	9.99964	9.97771	9.49829
6	102.0014	.2336	.0569	64	71	831
7	.0153	.2470	.0744	64	71	833
8	.0292	.2605	.0919	64	71	834
9	.0432	.2739	.1094	64	70	836
1910	102.0571	11.2873	19.1270	9.99964	9.97770	9.49838
1	.0710	.3008	.1445	64	70	839
2	.0849	.3142	.1620	64	70	841
3	.0988	.3277	.1795	64	70	842
4	.1127	.3411	.1970	64	70	844
1915	102.1266	11.3546	19.2145	9.99964	9.97770	9.49846
6	.1405	.3681	.2321	64	69	847
7	.1544	.3815	.2496	64	69	849
8	.1683	.3950	.2671	63	69	851
9	.1822	.4084	.2846	63	69	852
1920	102.1962	11.4219	19.3021	9.99963	9.97769	9.49854
1	.2101	.4354	.3196	63	69	856
2	.2240	.4488	.3372	63	69	857
3	.2379	.4623	.3547	63	68	859
4	.2518	.4757	.3722	63	68	861
1925	102.2658	11.4892	19.3897	9.99963	9.97768	9.49862
6	.2797	.5027	.4072	63	68	864
7	.2936	.5161	.4247	63	68	866
8	.3075	.5296	.4423	63	68	867
9	.3214	.5431	.4598	63	68	869
1930	102.3354	11.5567	19.4773	9.99963	9.97767	9.49871

Year	log cos a	log cos b	log cos c
1872.0	8.602 n	9.494 n	9.977
1930.0	8.615 n	9.495 n	9.977

TABLES OF (93) MINERVA.

$n\partial z$, $\partial \log r$, and $\partial\beta$ are tabulated in the form

$$\Sigma_i\,[a_i + (\Delta b_i)_t] \sin i\varepsilon + \Sigma_i\,[b_i + (\Delta b_i)_t] \cos i\varepsilon + (\Delta b_0)_t.$$

TABLES OF (93) MINERVA.

OSCULATING ELEMENTS.

Epoch and osculation, Jan. 0.0, M. T. Greenwich=1875.0, M. T. Greenwich.

$$\begin{array}{rrrrl} & {}^\circ & ' & '' & \\ g_0= & 278 & 32 & 8= & 278^\circ\!.5356 \\ \omega= & 269 & 44 & 33= & 269.7426 \\ ☊= & 5 & 7 & 8= & 5.1189 \\ i= & 8 & 36 & 20= & 8.6055 \\ \varphi= & 8 & 4 & 54= & 8.0816 \\ n= & \multicolumn{3}{r}{775''.9214=} & 0.21553373 \end{array}$$

(ω, ☊, i:) Mean equinox and ecliptic 1875.0.

g_0 and n are mean elements.

The elements are based on oppositions extending from 1867 to 1902 and on the perturbations of the first order by *Jupiter*, as given on page 362.

AUXILIARY QUANTITIES.

$\log a = 0.44013$ $\quad \log 57.2958\, e = 0.90606$ $\quad \log \sqrt{\frac{1-e}{1+e}} = 9.93854$

$\log e = 9.14793$ $\quad \log p = 0.43146$

TABLE I.—MEAN ANOMALY (g); AND (g—g′).

Jan. 0.0 of common years; Jan. 1.0 of leap years.

Year.	g	$g-g'$	Year.	g	$g-g'$
	°	°		°	°
1865	211. 40636	328. 117	1900	86. 57408	221. 129
6	290. 07617	16. 458	1	165. 24389	269. 471
7	8. 74598	64. 800	2	243. 91370	317. 812
B 8	87. 63133	113. 274	3	322. 58352	6. 154
9	166. 30114	161. 615	B 4	41. 46887	54. 628
1870	244. 97096	209. 957	1905	120. 13868	102. 969
1	323. 64077	258. 298	6	198. 80849	151. 311
B 2	42. 52612	306. 772	7	277. 47830	199. 653
3	121. 19593	355. 114	B 8	356. 36365	248. 126
4	199. 86574	43. 455	9	75. 03346	296. 468
1875	278. 53556	91. 797	1910	153. 70327	344. 810
B 6	357. 42090	140. 271	1	232. 37309	33. 151
7	76. 09071	188. 612	B 2	311. 25843	81. 625
8	154. 76053	236. 954	3	29. 92824	129. 967
9	233. 43034	285. 295	4	108. 59805	178. 308
B 1880	312. 31569	333. 769	1915	187. 26787	226. 650
1	30. 98550	22. 111	B 6	266. 15322	275. 124
2	109. 65531	70. 452	7	344. 82303	323. 465
3	188. 32512	118. 794	8	63. 49284	11. 807
B 4	267. 21047	167. 268	9	142. 16266	60. 148
1885	345. 88028	215. 609	B 1920	221. 04801	108. 622
6	64. 55010	263. 951	1	299. 71782	156. 964
7	143. 21992	312. 292	2	18. 38763	205. 305
B 8	222. 10527	0. 766	3	97. 05744	253. 647
9	300. 77508	49. 108	B 4	175. 94279	302. 121
1890	19. 44489	97. 449	1925	254. 61260	350. 462
1	98. 11470	145. 791	6	333. 28241	38. 804
B 2	177. 00005	194. 265	7	51. 95222	87. 146
3	255. 66986	242. 606	B 8	130. 83757	135. 620
4	334. 33967	290. 948	9	209. 50738	183. 962
1895	53. 00949	339. 289	1930	288. 17720	232. 304
B 6	131. 89484	27. 763			
7	210. 56465	76. 105			
8	289. 23446	124. 446			
9	7. 90427	172. 788			

NOTE.—When g is used as an argument of the perturbations, add to the g of this table $\Delta\pi = \pi - \pi_0 = +0^\circ\!.0666$. For explanation see page 203.

Table for beginning of month.

Month.	g	$g-g'$
	°	°
Jan. 0.0 1.0	0. 00000	0. 000
Feb. 0.0 1.0	6. 68154	4. 106
Mar. 0.0	12. 71649	7. 814
Apr. 0.0	19. 39804	11. 920
May 0.0	25. 86405	15. 893
June 0.0	32. 54559	19. 999
July 0.0	39. 01160	23. 972
Aug. 0.0	45. 69315	28. 078
Sept. 0.0	52. 37470	32. 184
Oct. 0.0	58. 84071	36. 157
Nov. 0.0	65. 52226	40. 263
Dec. 0.0	71. 98827	44. 236

Change for n days [a]

n	g	$g-g'$	n	g	$g-g'$
	°	°		°	°
1	0. 21553	0. 132	16	3. 44854	2. 119
2	0. 43107	0. 265	17	3. 66407	2. 252
3	0. 64660	0. 397	18	3. 87961	2. 384
4	0. 86213	0. 530	19	4. 09514	2. 516
5	1. 07767	0. 662	20	4. 31067	2. 649
6	1. 29320	0. 795	21	4. 52621	2. 781
7	1. 50874	0. 927	22	4. 74174	2. 914
8	1. 72427	1. 060	23	4. 95728	3. 046
9	1. 93980	1. 192	24	5. 17281	3. 179
10	2. 15534	1. 324	25	5. 38834	3. 311
11	2. 37087	1. 457	26	5. 60388	3. 444
12	2. 58640	1. 589	27	5. 81941	3. 576
13	2. 80194	1. 722	28	6. 03494	3. 708
14	3. 01747	1. 854	29	6. 25048	3. 841
15	3. 23301	1. 987	30	6. 46601	3. 973

[a] For days during January and February of leap year subtract one day before entering this table.

Tables of (93) Minerva—Continued.

PERTURBATIONS.

Arg. $ig-i'g'$		$n\delta z$		ν		$u/\cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
0	0				− 9.5		− 9.4
0	0				− 0.195 T		− 0.198 T
+1	0	−104.9	−516.3	−259.0	+ 57.9	+43.8	+50.6
+1		+ 2.746 T	− 14.832 T	− 7.416 T	− 1.387 T	+ 9.290 T	+ 1.409 T
+2		+ 2.4	+ 17.9	− 0.2	+ 0.9	− 0.3	+ 0.6
+2		− 0.098 T	+ 0.521 T				
+3	0	+ 0.1					
−2	−1	+ 0.1	+ 0.2	− 0.1	+ 0.1	− 0.1	+ 0.1
−1		− 0.2	− 2.5	+ 1.3	+ 0.3	+ 4.0	− 2.8
0		+ 26.2	+ 37.9	+ 1.1	+ 3.7	+12.7	− 4.1
+1		+ 36.2	+214.2	+ 71.3	− 11.9	−12.0	+ 3.9
+2		+ 1.2	− 2.2	+ 2.7	− 1.4	− 5.6	+ 0.1
+3	−1	− 0.2	+ 0.2	+ 0.3		+ 0.3	
−1	−2	− 0.4	− 0.1	+ 0.2	+ 0.3	+ 0.5	+ 0.3
0		+ 6.5	+ 2.2	+ 3.0	+ 12.5	+10.7	+13.7
+1		−768.8	+307.1	+ 55.1	+151.3	− 7.1	−13.1
+2		−431.7	+119.4	+ 70.8	+253.7	− 6.2	−11.1
+3		+ 17.5	− 5.7	− 0.7	− 0.2	+ 0.2	+ 1.3
+4	−2	+ 0.2			− 0.2		− 0.1
−1	−3	+ 0.3	+ 0.1		+ 0.1		+ 0.1
0		− 2.6	− 1.5	+ 1.8	− 3.2	+ 1.2	− 5.4
+1		−235.6	− 74.9	+ 25.8	− 47.6	+ 6.1	− 6.9
+2		+374.1	+301.7	+139.6	−170.1	−25.3	+20.2
+3		+ 3.6	+ 26.7	+ 26.0	− 11.2	− 1.3	+ 1.1
+4		− 1.0	− 1.4	+ 0.3	+ 0.2	+ 0.4	− 0.1
+5	−3		− 0.1	− 0.1			
0	−4	− 0.1		+ 0.2		+ 0.3	− 0.1
+1		− 1.0	− 4.2	+ 4.4	− 0.4	+ 3.0	0.0
+2		+ 1.6	+106.3	+ 34.1	+ 2.4	− 5.0	− 1.1
+3		− 27.5	+ 44.4	+ 28.9	+ 16.2	− 3.8	− 3.4
+4		+ 8.5	− 6.4	− 3.5	− 5.9	+ 0.4	+ 0.3
+5	−4	− 0.1	+ 0.3		− 0.2	− 0.1	− 0.1

The constant part in $n\delta z$ is included in the element g_0.

The nontrigonometrical term multiplied by the time in $n\delta z$ is included in the element n.

All other terms are contained in Tables II–V.

The constant part of ν contains the correction due to difference between mean and osculating values of the semimajor axis.

Tables of (93) Minerva—Continued.

PERTURBATIONS—Continued.

Arg *ig*	 *ιg′*	$n\delta z$		ν		$u \cos i$	
		sin	cos	sin	cos	sin	cos
i	i'	″	″	″	″	″	″
+1	− 5	+ 2.2	− 1.5	+ 1.7	+ 2.5	+2.3	+ 2.7
+2		−332.4	+320.7	+17.5	+30.0	−1.1	+ 1.2
+3		−178.9	− 24.6	+14.3	+93.8	+2.4	−21.1
+4		+ 15.6	+ 2.7	+ 2.4	− 6.5	−0.5	+ 0.9
+5		− 1.9	− 2.1	− 1.6	+ 1.3	+0.1	− 0.2
+6	− 5	+ 0.1		− 0.1			
+1	− 6	− 0.1			− 0.1		− 0.1
+2		− 3.6	− 0.6	+ 0.8	− 1.6	+0.5	− 0.5
+3		+ 17.4	+ 14.9	+ 6.6	− 7.0	−1.8	+ 1.2
+4		+ 1.8	+ 7.3	+ 4.8	− 1.6	−1.2	
+5		+ 0.6	− 3.1	− 2.2	− 0.5	+0.3	+ 0.1
+6		− 0.6	+ 0.7	+ 0.5	+ 0.5	−0.1	
+7	− 6				+ 0.1		
+2	− 7		− 0.3	+ 0.3		+0.3	
+3		+ 0.8	+ 10.2	+ 2.6	+ 0.3	−0.3	
+4		− 4.6	+ 6.7	+ 3.9	+ 2.4	−0.9	− 1.0
+5		+ 2.1	− 1.1	− 0.7	− 1.3	+0.1	+ 0.3
+6		− 1.1	− 0.1	− 0.1	+ 0.8		− 0.1
+7	− 7	+ 0.3	+ 0.2	+ 0.2	− 0.2		
+2	− 8	− 0.1	+ 0.1	− 0.1	− 0.1	−0.1	− 0.1
+3		− 10.7	+ 12.0	− 0.8	− 1.5		− 0.3
+4		+ 13.0	− 2.0	− 0.9	− 6.3	−0.3	+ 1.9
+5		+ 0.8	+ 0.7	+ 0.3	− 0.8	−0.2	+ 0.2
+6		− 0.5	− 0.7	− 0.5	+ 0.3	+0.1	
+7			+ 0.4	+ 0.3			
+8	− 8		− 0.1	− 0.1			
+3	− 9	− 0.1			− 0.1		
+4		+ 1.1	+ 0.8	+ 0.3	− 0.4	−0.1	+ 0.1
+5		+ 0.2	+ 0.9	+ 0.5	− 0.2	−0.2	
+6		+ 0.1	− 0.5	− 0.3	− 0.1	+0.1	
+7		− 0.2	+ 0.2	+ 0.2	+ 0.2		
+8	− 9	+ 0.2	0.0		− 0.1		
+4	−10	+ 0.6	+ 1.8	+ 0.3			
+5		− 0.7	+ 1.1	+ 0.6	+ 0.4	−0.2	− 0.2
+6		+ 0.2	− 0.1	− 0.1	− 0.1		+ 0.1
+7	−10	− 0.2			+ 0.1		
+5	−11	+ 0.4	− 0.1		− 0.2		
		+ 4.0	+ 11.1	− 0.2			
+5	−13						
+6	−13	+ 0.5	− 1.1	− 0.5	− 0.2	+0.2	+ 0.2

The constant part in $n\delta z$ is included in the element g_0.

The nontrigonometrical term multiplied by the time in $n\delta z$ is included in the element n.

All other terms are contained in Tables II–V.

The constant part of ν contains the correction due to difference between mean and osculating values of the semimajor axis.

Tables of (93) Minerva—Continued.

TABLE II.—$n\delta z$.

PERIODIC TERMS.

Unit of a and b=0°.001.

Arg.	a_1	Diff. for 1°	b_1	Diff. for 1°	Arg.	a_1	Diff. for 1°	b_1	Diff. for 1°
°					°				
0	+81.5	+8.48	+45.9	−1.90	180	+311.8	−0.85	−142.2	−13.71
3	+106.9	+8.43	+38.5	−3.10	183	+306.5	−2.67	−182.8	−13.33
6	+131.9	+8.20	+27.3	−4.32	186	+295.9	−4.41	−221.9	−12.72
9	+155.9	+7.77	+12.5	−5.54	189	+280.2	−6.02	−258.9	−11.87
12	+178.3	+7.15	−5.9	−6.72	192	+259.9	−7.48	−292.9	−10.82
15	+198.6	+6.34	−27.7	−7.83	195	+235.5	−8.75	−323.6	−9.59
18	+216.2	+5.34	−52.8	−8.85	198	+207.7	−9.81	−350.3	−8.22
21	+230.5	+4.18	−80.7	−9.72	201	+176.9	−10.64	−372.8	−6.73
24	+241.1	+2.88	−111.0	−10.45	204	+144.0	−11.25	−390.6	−5.17
27	+247.6	+1.46	−143.2	−10.99	207	+109.7	−11.61	−403.8	−3.58
30	+249.8	−0.06	−176.7	−11.33	210	+74.6	−11.73	−412.1	−1.99
33	+247.2	−1.64	−210.9	−11.45	213	+39.5	−11.61	−415.8	−0.44
36	+240.0	−3.22	−245.2	−11.36	216	+5.1	−11.28	−414.8	+1.01
39	+227.9	−4.81	−278.8	−11.02	219	−27.9	−10.74	−409.6	+2.41
42	+211.1	−6.42	−311.1	−10.45	222	−59.1	−10.02	−400.5	+3.64
45	+189.9	−7.81	−341.3	−9.68	225	−87.9	−9.15	−387.9	+4.73
48	+164.4	−9.08	−368.9	−8.69	228	−113.9	−8.17	−372.3	+5.64
51	+135.2	−10.33	−393.3	−7.52	231	−136.8	−7.10	−354.3	+6.35
54	+102.6	−11.33	−413.9	−6.18	234	−156.4	−5.96	−334.4	+6.90
57	+67.4	−12.13	−430.2	−4.72	237	−172.6	−4.80	−313.1	+7.26
60	+30.1	−12.71	−442.1	−3.15	240	−185.3	−3.66	−291.0	+7.41
63	−8.7	−13.07	−449.1	−1.51	243	−194.6	−2.54	−268.8	+7.40
66	−48.1	−13.19	−451.1	+0.13	246	−200.6	−1.48	−246.8	+7.23
69	−87.6	−13.08	−448.3	+1.78	249	−203.5	−0.51	−225.5	+6.91
72	−126.4	−12.74	−440.5	+3.40	252	−203.7	+0.36	−205.4	+6.47
75	−163.8	−12.19	−427.9	+4.94	255	−201.5	+1.11	−186.8	+5.92
78	−199.3	−11.46	−410.9	+6.39	258	−197.2	+1.73	−169.9	+5.31
81	−232.4	−10.54	−389.8	+7.71	261	−191.2	+2.21	−155.0	+4.65
84	−262.4	−9.48	−364.8	+8.91	264	−184.0	+2.56	−142.1	+3.96
87	−289.1	−8.29	−336.4	+9.97	267	−176.0	+2.77	−131.2	+3.27
90	−312.1	−6.99	−305.2	+10.86	270	−167.6	+2.85	−122.4	+2.60
93	−331.0	−5.60	−271.4	+11.61	273	−159.0	+2.81	−115.6	+1.99
96	−345.6	−4.15	−235.7	+12.19	276	−150.8	+2.67	−110.4	+1.44
99	−355.8	−2.64	−198.4	+12.61	279	−143.1	+2.44	−106.8	+0.98
102	−361.4	−1.09	−160.2	+12.86	282	−136.2	+2.13	−104.5	+0.61
105	−362.4	+0.48	−121.4	+12.95	285	−130.4	+1.78	−103.1	+0.34
108	−358.6	+2.06	−82.7	+12.87	288	−125.6	+1.41	−102.3	+0.18
111	−350.0	+3.63	−44.4	+12.62	291	−121.9	+1.03	−101.9	+0.15
114	−336.8	+5.18	−7.1	+12.20	294	−119.4	+0.66	−101.3	+0.21
117	−319.0	+6.69	+28.6	+11.59	297	−117.9	+0.34	−100.5	+0.37
120	−296.8	+8.13	+62.3	+10.81	300	−117.3	+0.07	−99.0	+0.62
123	−270.3	+9.48	+93.3	+9.86	303	−117.4	−0.11	−96.7	+0.95
126	−240.0	+10.72	+121.2	+8.73	306	−117.9	−0.22	−93.3	+1.35
129	−206.1	+11.84	+145.6	+7.44	309	−118.7	−0.24	−88.6	+1.78
132	−169.1	+12.77	+165.7	+5.99	312	−119.2	−0.15	−82.6	+2.23
135	−129.6	+13.56	+181.4	+4.42	315	−119.4	+0.07	−75.2	+2.68
138	−88.1	+14.08	+192.1	+2.74	318	−118.7	+0.39	−66.6	+3.10
141	−45.4	+14.39	+197.7	+0.98	321	−116.9	+0.81	−56.6	+3.49
144	−2.1	+14.46	+198.0	−0.83	324	−113.8	+1.33	−45.7	+3.82
147	+41.1	+14.28	+192.8	−2.64	327	−108.9	+1.94	−33.8	+4.05
150	+83.4	+13.84	+182.2	−4.44	330	−102.1	+2.62	−21.5	+4.18
153	+123.9	+13.15	+166.2	−6.16	333	−93.1	+3.36	−8.9	+4.19
156	+162.0	+12.23	+145.3	−7.78	336	−81.9	+4.13	+3.6	+4.06
159	+197.0	+11.07	+119.7	−9.28	339	−68.3	+4.91	+15.4	+3.80
162	+228.2	+9.72	+89.9	−10.59	342	−52.4	+5.68	+26.2	+3.39
165	+255.2	+8.20	+56.4	−11.70	345	−34.2	+6.41	+35.6	+2.82
168	+277.3	+6.52	+19.9	−12.61	348	−14.0	+7.06	+43.0	+2.11
171	+294.2	+4.74	−19.0	−13.27	351	+8.0	+7.62	+48.1	+1.28
174	+305.7	+2.90	−59.5	−13.67	354	+31.6	+8.05	+50.6	+0.31
177	+311.6	+1.02	−100.8	−13.82	357	+56.2	+8.35	+49.9	−0.76
180	+311.8	−0.85	−142.2	−13.71	360	+81.5	+8.48	+45.9	−1.90

[$n\delta z$, $\delta \log r$, and $\delta\beta$ are to be computed in the form $\Sigma_i[a_i+(\Delta b_i)t]\sin i\varepsilon+\Sigma_i[bi+(\Delta b_i)t]\cos i\varepsilon+(\Delta b_0)t$.]

Tables of (93) Minerva—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS.

Unit of a and b=0°001.

Arg.	b_0	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°	a_5	Diff. for 1°	b_5	Diff. for 1°
0°	+98.0	−3.85	+112.7	+1.72	+22.0	−7.56	−3.6	+0.25	+1.9	+0.48	+2.9	+0.54	+3.8	−0.40
5	+78.0	−4.13	+114.4	−1.08	−16.9	−7.81	−1.6	+0.52	+3.8	+0.22	+4.7	+0.14	+1.0	−0.66
10	+56.9	−4.30	+102.1	−3.79	−54.3	−6.99	+1.2	+0.55	+4.0	−0.16	+4.2	−0.32	−2.3	−0.60
15	+35.2	−4.34	+77.3	−6.01	−85.2	−5.24	+3.6	+0.33	+2.3	−0.49	+1.7	−0.64	−4.5	−0.24
20	+13.6	−4.26	+43.3	−7.42	−105.6	−2.81	+4.2	−0.06	−0.5	−0.60	−1.7	−0.64	−4.5	+0.24
25	−7.2	−4.06	+4.7	−7.85	−112.8	−0.05	+3.0	−0.44	−3.3	−0.43	−4.2	−0.33	−2.3	+0.60
30	−26.8	−3.75	−33.4	−7.25	−106.2	+2.62	+0.2	−0.63	−4.5	−0.66	−4.7	+0.14	+1.0	+0.67
35	−44.6	−3.33	−66.3	−5.76	−87.3	+4.83	−2.9	−0.55	−3.7	+0.37	−2.9	+0.54	+3.8	+0.41
40	−59.9	−2.82	−89.9	−3.61	−59.1	+6.31	−4.9	−0.19	−1.0	+0.66	+0.2	+0.67	+4.8	−0.04
45	−72.6	−2.22	−101.9	−1.17	−25.8	+6.86	−4.6	+0.28	+2.4	+0.66	+3.3	+0.48	+3.4	−0.46
50	−82.0	−1.54	−101.7	+1.18	+7.9	+6.46	−2.2	+0.65	+5.1	+0.36	+4.7	+0.06	+0.5	−0.66
55	−87.9	−0.82	−90.8	+3.12	+37.8	+5.33	+1.4	+0.76	+5.7	−0.13	+3.9	−0.37	−2.6	−0.54
60	−90.1	−0.04	−71.7	+4.37	+60.4	+3.65	+4.9	+0.54	+3.8	−0.59	+1.3	−0.62	−4.5	−0.17
65	−88.4	+0.74	−48.3	+4.85	+74.0	+1.79	+6.5	+0.07	+0.1	−0.83	−1.9	−0.58	−4.2	+0.26
70	−82.7	+1.51	−24.4	+4.59	+78.5	+0.27	+5.5	−0.46	−4.0	−0.74	−4.1	−0.28	−2.0	+0.57
75	−73.3	+2.24	−3.2	+3.79	+75.4	−1.23	+2.2	−0.83	−6.8	−0.32	−4.4	+0.15	+1.1	+0.61
80	−60.5	+2.88	+13.1	+2.70	+67.1	−1.96	−2.3	−0.88	−6.9	+0.24	−2.7	+0.51	+3.7	+0.37
85	−44.7	+3.41	+23.8	+1.63	+56.7	−2.11	−6.1	−0.58	−4.4	+0.73	+0.2	+0.62	+4.5	−0.04
90	−26.7	+3.77	+29.8	+0.82	+46.7	−1.82	−7.7	−0.02	0.0	+0.95	+3.1	+0.46	+3.3	−0.42
95	−7.3	+3.96	+32.7	+0.44	+38.9	−1.30	−6.3	+0.55	+4.5	+0.79	+4.5	+0.09	+0.6	−0.62
100	+12.6	+3.95	+34.9	+0.51	+33.6	−0.83	−2.5	+0.91	+7.4	+0.32	+3.9	−0.32	−2.4	−0.53
105	+31.9	+3.74	+38.3	+0.89	+30.1	−0.64	+2.3	+0.93	+7.5	−0.28	+1.5	−0.59	−4.3	−0.20
110	+49.7	+3.35	+44.0	+1.38	+26.5	−0.88	+6.2	+0.58	+4.8	−0.78	−1.6	−0.59	−4.3	+0.22
115	+65.1	+2.81	+51.9	+1.71	+20.6	−1.54	+7.8	+0.01	+0.2	−0.96	−4.0	−0.32	−2.3	+0.55
120	+77.6	+2.14	+60.4	+1.63	+10.6	−2.51	+6.4	−0.55	−4.3	−0.77	−4.6	+0.10	+0.8	+0.63
125	+86.4	+1.39	+67.2	+1.00	−4.6	−3.53	+2.6	−0.89	−7.1	−0.30	−3.0	+0.49	+3.6	+0.42
130	+91.4	+0.60	+69.5	−0.18	−24.3	−4.33	−2.0	−0.87	−7.1	+0.28	0.0	+0.66	+4.7	+0.01
135	+92.4	−0.19	+64.7	−1.82	−46.9	−4.55	−5.6	−0.52	−4.5	+0.72	+3.1	+0.51	+3.7	−0.42
140	+89.5	−0.96	+51.1	−3.62	−69.2	−4.11	−6.9	+0.01	−0.3	+0.86	+4.8	+0.12	+0.8	−0.66
145	+82.9	−1.68	+28.7	−5.28	−87.4	−3.00	−5.5	+0.51	+3.6	+0.66	+4.2	−0.33	−2.5	−0.59
150	+72.9	−2.32	−0.9	−6.45	−97.9	−1.11	−2.2	+0.76	+5.9	+0.22	+1.6	−0.64	−4.6	−0.23
155	+59.8	−2.90	−34.5	−6.87	−97.8	+1.21	+1.6	+0.71	+5.7	−0.27	−1.8	−0.64	−4.6	+0.24
160	+44.1	−3.37	−68.1	−6.38	−85.6	+3.66	+4.4	+0.36	+3.4	−0.61	−4.3	−0.33	−2.3	+0.61
165	+26.2	−3.74	−96.8	−4.96	−61.6	+5.88	+5.1	−0.08	0.0	−0.66	−4.8	+0.15	+1.1	+0.68
170	+6.8	−4.02	−116.3	−2.75	−27.9	+7.45	+3.7	−0.44	−2.8	−0.44	−3.0	+0.56	+4.0	+0.41
175	−13.7	−4.18	−123.4	−0.04	+11.5	+8.16	+1.0	−0.58	−4.1	−0.06	+0.3	+0.69	+4.9	−0.07
180	−34.8	−4.23	−116.5	+2.82	+51.9	+7.82	−1.7	−0.44	−3.4	+0.30	+3.5	+0.49	+3.5	−0.49
185	−55.8	−4.17	−95.8	+5.39	+88.0	+6.46	−3.1	−0.12	−1.3	+0.48	+4.9	+0.05	+0.4	−0.69
190	−76.3	−4.00	−63.6	+7.32	+115.0	+4.22	−2.9	+0.21	+1.0	+0.41	+3.9	−0.41	−2.9	−0.54
195	−95.6	−3.73	−24.1	+8.32	+129.3	+1.42	−1.2	+0.41	+2.5	+0.16	+1.1	−0.66	−4.7	−0.14
200	−113.4	−3.36	+17.7	+8.22	+129.0	−1.54	+0.8	+0.39	+2.5	−0.16	−2.2	−0.59	−4.2	+0.32
205	−129.1	−2.90	+56.3	+7.06	+114.3	−4.26	+2.3	+0.17	+1.1	−0.36	−4.3	−0.23	−1.7	+0.61
210	−142.2	−2.36	+86.8	+5.00	+87.5	−6.32	+2.4	−0.12	−0.8	−0.37	−4.3	+0.22	+1.5	+0.60
215	−152.5	−1.75	+105.4	+2.37	+52.6	−7.46	+1.2	−0.34	−2.3	−0.19	−2.3	+0.55	+3.9	+0.31
220	−159.7	−1.09	+110.2	−0.43	+14.7	−7.53	−0.7	−0.37	−2.6	+0.09	+0.7	+0.60	+4.4	−0.12
225	−163.4	−0.39	+101.5	−2.98	−21.0	−6.57	−2.2	−0.22	−1.5	+0.31	+3.3	+0.38	+2.8	−0.47
230	−163.5	+0.34	+81.4	−4.91	−49.6	−4.78	−2.7	+0.04	+0.3	+0.38	+4.2	−0.01	0.0	−0.58
235	−160.0	+1.08	+53.9	−5.93	−67.9	−2.46	−1.9	+0.27	+1.9	+0.25	+3.2	−0.37	−2.6	−0.42
240	−152.7	+1.82	+23.8	−5.98	−74.1	−0.04	−0.2	+0.36	+2.6	+0.02	+0.8	−0.54	−3.9	−0.09
245	−141.9	+2.52	−4.3	−5.11	−68.8	+2.07	+1.5	+0.28	+2.1	−0.22	−1.9	−0.47	−3.5	+0.27
250	−127.6	+3.18	−26.2	−3.54	−54.5	+3.57	+2.3	+0.06	+0.6	−0.34	−3.6	−0.19	−1.5	+0.49
255	−110.2	+3.76	−39.1	−1.61	−34.5	+4.25	+2.0	−0.17	−1.0	−0.28	−3.6	+0.16	+1.1	+0.48
260	−90.1	+4.27	−42.3	+0.32	−13.4	+4.04	+0.8	−0.29	−1.9	−0.08	−2.1	+0.42	+3.1	+0.28
265	−67.7	+4.67	−36.6	+1.88	+4.7	+3.09	−0.6	−0.26	−1.8	+0.13	+0.2	+0.49	+3.7	−0.04
270	−43.6	+4.96	−24.6	+2.78	+16.6	+1.61	−1.6	−0.09	−0.8	+0.26	+2.5	+0.36	+2.7	−0.33
275	−18.3	+5.13	−10.1	+2.91	+20.5	−0.04	−1.5	+0.11	+0.6	+0.24	+3.6	+0.08	+0.6	−0.48
280	+7.5	+5.18	+3.2	+2.27	+16.5	−1.51	−0.5	+0.24	+1.4	+0.08	+3.2	−0.24	−1.8	−0.42
285	+33.2	+5.09	+11.6	+1.01	+6.2	−2.50	+0.7	+0.22	+1.3	−0.13	+1.4	−0.46	−3.4	−0.19
290	+58.1	+4.87	+12.8	−0.56	−7.4	−2.78	+1.5	+0.06	+0.3	−0.25	−1.1	−0.48	−3.6	+0.14
295	+81.7	+4.52	+6.1	−2.10	−20.3	−2.26	+1.3	−0.14	−1.0	−0.23	−3.1	−0.29	−2.1	+0.42
300	+103.2	+4.07	−7.6	−3.28	−28.8	−1.04	+0.2	−0.28	−1.8	−0.06	−3.8	+0.03	+0.3	+0.52
305	+122.2	+3.51	−25.7	−3.80	−29.9	+0.66	−1.2	−0.26	−1.5	+0.13	−2.8	+0.36	+2.7	+0.39
310	+138.1	+2.86	−44.3	−3.51	−22.0	+2.50	−2.2	−0.09	−0.3	+0.31	−0.4	+0.54	+3.9	+0.08
315	+150.6	+2.14	−59.3	−2.43	−5.2	+4.12	−2.0	+0.16	+1.4	+0.32	+2.2	+0.48	+3.4	−0.29
320	+159.4	+1.38	−66.9	−0.57	+18.3	+5.20	−0.7	+0.35	+2.6	+0.14	+4.0	+0.18	+1.2	−0.54
325	+164.4	+0.59	−64.4	+1.62	+45.2	+5.42	+1.3	+0.38	+2.6	−0.14	+3.9	−0.22	−1.7	−0.55
330	+165.3	−0.20	−50.8	+3.82	+70.9	+4.72	+2.9	+0.22	+1.3	−0.38	+1.9	−0.53	−3.9	−0.28
335	+162.4	−0.96	−26.8	+5.65	+90.9	+3.12	+3.2	−0.08	−0.9	−0.45	−1.1	−0.60	−4.3	+0.14
340	+155.8	−1.69	+4.5	+6.74	+101.1	+0.86	+2.1	−0.36	−2.9	−0.31	−3.7	−0.38	−2.6	+0.50
345	+145.6	−2.36	+39.0	+6.89	+98.9	−1.73	−0.2	−0.50	−3.7	−0.01	−4.6	+0.04	+0.4	+0.65
350	+132.3	−2.95	+71.7	+6.02	+83.8	−4.26	−2.6	−0.41	−2.9	+0.32	−3.2	+0.46	+3.3	+0.47
355	+116.2	−3.45	+97.6	+4.21	+57.1	−6.32	−3.9	−0.11	−0.7	+0.52	−0.3	+0.66	+4.7	+0.50
360	+98.0	−3.85	+112.7	+1.72	+22.0	−7.56	−3.6	+0.25	+1.9	+0.48	+2.9	+0.54	+3.8	−0.40

[$n\delta z$ $\delta \log r$, and $\delta\beta$ are to be computed in the form $\Sigma_i[a_i+(\Delta b_i)t] \sin i\varepsilon+\Sigma_i[b_i+(\Delta b_i)]t \cos i\varepsilon+(\Delta b_0)t$.]

Tables of (93) Minerva—Continued.

TABLE II.—$n\delta z$—Continued.

PERIODIC TERMS. Unit of a and b=0°001.

Arg.	a_3	Diff. for 1°	b_3	Diff. for 1°	Arg.	a_3	Diff. for 1°	b_3	Diff. for 1°
°					°				
0	+89.6	+8.34	+93.5	−7.73	180	−99.0	−7.59	−87.3	+8.76
3	+111.3	+6.06	+67.3	−9.68	183	−118.0	−5.02	−58.4	+10.40
6	+125.5	+3.33	+36.1	−10.97	186	−128.8	−2.13	−25.6	+11.31
9	+131.1	+0.35	+2.2	−11.51	189	−130.6	+0.89	+8.7	+11.44
12	+127.6	−2.68	−32.1	−11.24	192	−123.5	+3.82	+42.2	+10.76
15	+115.2	−5.54	−64.5	−10.18	195	−108.0	+6.47	+72.6	+9.36
18	+94.7	−8.04	−92.5	−8.40	198	−85.2	+8.64	+97.8	+7.33
21	+67.5	−9.99	−114.3	−6.03	201	−56.7	+10.20	+116.1	+4.81
24	+35.4	−11.24	−128.3	−3.22	204	−24.7	+11.05	+126.4	+2.00
27	+0.8	−11.71	−133.4	−0.16	207	+8.8	+11.14	+128.0	−0.93
30	−34.1	−11.37	−129.2	+2.91	210	+41.4	+10.47	+120.9	−3.76
33	−66.6	−10.23	−116.1	+5.80	213	+71.0	+9.10	+105.7	−6.32
36	−94.7	−8.36	−94.8	+8.29	216	+95.4	+7.13	+83.4	−8.41
39	−116.2	−5.90	−66.9	+10.19	219	+113.3	+4.69	+55.8	−9.91
42	−129.7	−3.04	−34.4	+11.39	222	+123.3	+1.97	+24.7	−10.73
45	−134.2	+0.04	+0.6	+11.78	225	+125.0	−0.85	−7.9	−10.82
48	−129.5	+3.12	+35.5	+11.36	228	+118.3	−3.59	−39.6	−10.18
51	−115.8	+5.98	+68.0	+10.15	231	+103.7	−6.06	−68.3	−8.88
54	−94.0	+8.41	+95.7	+8.22	234	+82.4	−8.09	−92.2	−6.99
57	−65.9	+10.26	+116.8	+5.75	237	+55.7	−9.56	−109.8	−4.66
60	−33.2	+11.39	+129.8	+2.91	240	+25.6	−10.40	−119.9	−2.04
63	+1.7	+11.72	+133.9	−0.20	243	−5.9	−10.53	−122.0	+0.68
66	+36.3	+11.26	+128.7	−3.22	246	−36.8	−9.95	−116.0	+3.32
69	+68.4	+10.01	+114.8	−6.02	249	−64.9	−8.74	−102.3	+5.72
72	+95.8	+8.09	+93.0	−8.41	252	−88.6	−6.96	−82.1	+7.72
75	+116.5	+5.63	+64.9	−10.20	255	−106.2	−4.74	−56.5	+9.20
78	+129.2	+2.79	+32.5	−11.29	258	−116.8	−2.24	−27.4	+10.07
81	+133.1	−0.22	−2.1	−11.62	261	−119.6	+0.39	+3.2	+10.27
84	+127.9	−3.22	−36.4	−11.35	264	−114.5	+2.98	+33.5	+9.81
87	+113.9	−5.99	−68.3	−9.94	267	−101.9	+5.36	+61.4	+8.71
90	+92.3	−8.34	−95.4	−8.04	270	−82.7	+7.37	+85.2	+7.06
93	+64.4	−10.14	−116.0	−5.61	273	−58.2	+8.91	+103.3	+4.95
96	+32.2	−11.24	−128.7	−2.80	276	−29.9	+9.86	+114.6	+2.53
99	−2.2	−11.58	−132.6	+0.20	279	+0.4	+10.18	+118.4	−0.05
102	−36.5	−11.14	−127.5	+3.18	282	+30.5	+9.83	+114.3	−2.64
105	−68.3	−9.94	−113.7	+5.96	285	+58.7	+8.84	+102.7	−5.04
108	−95.5	−8.07	−92.1	+8.34	288	+83.0	+7.28	+84.4	−7.13
111	−116.2	−5.64	−64.2	+10.15	291	+101.9	+5.24	+60.4	−8.77
114	−128.9	−2.82	−31.9	+11.28	294	+114.1	+2.85	+32.3	−9.83
117	−132.9	+0.20	+2.7	+11.64	297	+118.8	+0.26	+2.1	−10.25
120	−127.7	+3.22	+37.2	+11.20	300	+115.6	−2.38	−28.5	−10.02
123	−113.8	+6.03	+69.1	+9.99	303	+104.7	−4.88	−57.4	−9.11
126	−91.9	+8.44	+96.4	+8.09	306	+86.7	−7.06	−82.6	−7.58
129	−63.7	+10.28	+117.1	+5.62	309	+62.7	−8.81	−102.4	−5.55
132	−31.0	+11.39	+129.8	+2.76	312	+34.4	−9.99	−115.5	−3.12
135	+3.9	+11.73	+133.5	−0.32	315	+3.4	−10.50	−120.9	−0.44
138	+38.6	+11.26	+127.9	−3.38	318	−27.9	−10.31	−118.1	+2.28
141	+70.6	+9.99	+113.4	−6.20	321	−57.8	−9.44	−107.4	+4.87
144	+97.8	+8.03	+91.1	−8.61	324	−83.9	−7.90	−89.2	+7.18
147	+118.2	+5.49	+62.4	−10.41	327	−104.6	−5.81	−64.8	+9.03
150	+130.4	+2.60	+29.4	−11.48	330	−118.3	−3.30	−35.6	+10.28
153	+133.5	−0.52	−5.7	−11.76	333	−124.1	−0.52	−3.8	+10.83
156	+127.3	−3.58	−40.4	−11.21	336	−121.4	+2.31	+28.7	+10.66
159	+112.2	−6.39	−72.2	−9.87	339	−110.4	+5.02	+59.5	+9.75
162	+89.4	−8.74	−98.9	−7.84	342	−91.6	+7.42	+86.5	+8.16
165	+60.4	−10.48	−118.7	−5.27	345	−66.3	+9.33	+107.8	+5.98
168	+27.3	−11.47	−130.2	−2.33	348	−36.2	+10.63	+121.9	+3.36
171	−7.6	−11.65	−132.6	+0.74	351	−3.2	+11.19	+127.8	+0.48
174	−41.8	−11.02	−125.8	+3.75	354	+30.2	+10.98	+124.8	−2.46
177	−73.0	−9.64	−110.3	+6.49	357	+61.9	+10.01	+113.1	−5.26
180	−99.0	−7.59	−87.3	+8.76	360	+89.6	+8.34	+93.5	−7.73

[$n\delta z$, $\delta \log r$, and $\delta\beta$ are to be computed in the form $\Sigma_i[a_i+(\Delta b_i)t] \sin i\varepsilon+\Sigma_i[b_i+(\Delta b_i)t] \cos i\varepsilon+(\Delta b_0)t$.]

Tables of (93) Minerva—Continued.

TABLE III.—δ log r.

PERIODIC TERMS.

Unit of *a* and *b*=0.00001.

Arg.	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_2	Diff. for 1°	b_2	Diff. for 1°
°										
0	+45.6	+1.00	−101.5	−0.64	+10.8	+2.38	−17.3	+1.28	+12.6	+1.15
10	+52.8	+0.41	−101.1	+0.73	+36.1	+2.55	− 2.5	+1.48	+17.4	−0.19
20	+53.6	−0.24	− 87.2	+2.01	+59.2	+1.96	+ 8.7	+0.63	+10.2	−1.12
30	+48.0	−0.88	− 62.5	+2.82	+73.2	+0.78	+ 9.2	−0.52	− 1.3	−1.00
40	+36.2	−1.44	− 33.1	+2.93	+73.7	−0.69	+ 0.5	−1.06	− 6.8	−0.03
50	+19.6	−1.85	− 6.3	+2.30	+59.9	−2.03	− 8.5	−0.57	− 1.7	+0.97
60	+ 0.1	−2.02	+ 11.0	+1.10	+34.9	−2.86	− 8.6	+0.59	+ 9.8	+1.15
70	−19.8	−1.90	+ 15.0	−0.30	+ 5.0	−3.01	+ 2.5	+1.49	+17.6	+0.24
80	−36.7	−1.44	+ 5.7	−1.51	−23.2	−2.53	+17.5	+1.30	+13.0	−1.15
90	−47.6	−0.69	− 14.1	−2.35	−44.3	−1.66	+24.7	0.00	− 3.4	−1.92
100	−50.1	+0.22	− 40.1	−2.81	−55.8	−0.61	+16.7	−1.53	−21.0	−1.39
110	−43.5	+1.07	− 69.0	−2.90	−56.3	+0.51	− 2.5	−2.08	−27.6	+0.16
120	−29.4	+1.70	− 96.8	−2.57	−45.4	+1.67	−20.4	−1.19	−18.2	+1.59
130	−10.6	+2.00	−118.7	−1.71	−23.2	+2.70	−25.6	+0.26	+ 0.4	+1.90
140	+ 9.5	+1.98	−129.4	−0.36	+ 7.2	+3.28	−16.4	+1.43	+15.6	+0.99
150	+28.1	+1.71	−125.2	+1.29	+40.0	+3.15	− 0.8	+1.47	+18.6	−0.37
160	+42.8	+1.22	−106.2	+2.54	+67.7	+2.27	+ 9.8	+0.53	+ 9.9	−1.20
170	+52.0	+0.62	− 76.3	+3.31	+83.7	+0.84	+ 9.1	−0.62	− 1.8	−0.96
180	+54.9	+0.04	− 42.5	+3.30	+83.8	−0.82	− 0.2	−1.07	− 6.5	+0.08
190	+51.2	−0.68	− 13.0	+2.49	+68.3	−2.22	− 8.7	−0.47	− 0.5	+1.04
200	+41.6	−1.23	+ 5.2	+1.09	+41.3	−3.05	− 7.6	+0.73	+11.2	+1.11
210	+27.1	−1.65	+ 8.1	−0.50	+10.1	−3.05	+ 4.6	+1.56	+18.1	+0.05
220	+ 9.2	−1.89	− 3.8	−1.82	−17.1	−2.27	+20.0	+1.30	+12.1	−1.29
230	−10.1	−1.95	− 26.2	−2.53	−33.7	−0.99	+26.9	−0.05	− 5.5	−2.07
240	−29.0	−1.80	− 52.0	−2.49	−36.5	+0.42	+18.1	−1.66	−24.8	−1.56
250	−45.6	−1.49	− 73.6	−1.73	−26.3	+1.54	− 3.5	−2.44	−33.0	+0.05
260	−58.3	−1.03	− 85.3	−0.56	− 7.9	+2.03	−25.9	−1.80	−23.1	+1.83
270	−65.9	−0.47	− 84.8	+0.63	+12.0	+1.82	−35.6	−0.01	+ 0.4	+2.65
280	−67.7	+0.13	− 73.9	+1.46	+26.5	+1.01	−25.9	+1.86	+24.6	+1.93
290	−63.5	+0.71	− 57.7	+1.66	+31.2	−0.09	− 2.1	+2.67	+35.2	+0.08
300	−53.6	+1.23	− 42.8	+1.20	+25.0	−1.10	+21.1	+1.92	+26.2	−1.78
310	−39.2	+1.63	− 35.3	+0.25	+10.9	−1.63	+32.8	+0.12	+ 3.4	−2.54
320	−21.5	+1.88	− 38.4	−0.86	− 5.4	−1.51	+24.6	−1.63	−19.4	−1.79
330	− 2.2	+1.94	− 51.6	−1.72	−17.3	−0.76	+ 3.8	−2.28	−29.2	−0.10
340	+16.6	+1.80	− 71.0	−2.03	−19.3	+0.39	−16.4	−1.54	−21.8	+1.46
350	+33.1	+1.47	− 89.8	−1.64	− 9.4	+1.57	−24.3	0.00	− 3.7	+1.93
360	+45.6	+1.00	−101.5	−0.64	+10.8	+2.38	−17.3	+1.28	+12.6	+1.15

[$n\delta z$, $\delta \log r$, and $\delta\beta$ are to be computed in the form $\Sigma_i[a_i+(\Delta b_i)_t] \sin i\varepsilon+\Sigma_i[b_i+(\Delta bi)_i] \cos i\varepsilon+(\Delta b_0)_t$.]

Tables of (93) Minerva—Continued.

TABLE III.—∂ log r—Continued.

PERIODIC TERMS.

Unit of a and b=0.00001.

Arg.	a_3	Diff. for 1°	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°	a_5	Diff. for 1°	b_5	Diff. for 1°
°												
0	−7.2	+0.40	+4.5	+0.65	−1.0	−0.19	−1.2	+0.11	−0.1	−0.04	−0.3	+0.02
10	−0.9	+0.78	+8.5	+0.08	−1.7	+0.07	+0.8	+0.23	−0.3	+0.01	0.0	+0.04
20	+6.2	+0.53	+5.8	−0.59	+0.3	+0.27	+2.2	−0.01	−0.1	+0.03	+0.2	0.00
30	+8.2	−0.18	−1.6	−0.78	+2.3	+0.07	+0.5	−0.28	+0.2	+0.02	+0.2	−0.02
40	+3.3	−0.73	−7.5	−0.24	+1.3	−0.25	−2.1	−0.16	+0.2	−0.02	−0.1	−0.02
50	−4.2	−0.65	−6.8	+0.42	−1.4	−0.22	−1.9	+0.19	0.0	−0.04	−0.3	0.00
60	−7.8	−0.04	−0.5	+0.74	−2.1	+0.10	+0.6	+0.26	−0.3	−0.01	0.0	+0.04
70	−5.0	+0.56	+6.0	+0.46	−0.1	+0.25	+2.0	−0.01	−0.1	+0.05	+0.4	+0.02
80	+1.7	+0.67	+7.6	−0.15	+1.5	+0.04	+0.6	−0.21	+0.4	+0.04	+0.2	−0.05
90	+6.9	+0.31	+3.6	−0.59	+0.7	−0.16	−1.1	−0.07	+0.2	−0.05	−0.4	−0.03
100	+7.3	−0.23	−2.9	−0.63	−0.7	−0.08	−0.6	+0.14	−0.3	−0.04	−0.3	+0.04
110	+2.8	−0.63	−7.6	−0.25	−0.4	+0.12	+0.7	+0.08	−0.3	+0.04	+0.3	+0.05
120	−3.9	−0.64	−7.3	+0.31	+0.8	+0.08	+0.4	−0.13	+0.2	+0.05	+0.3	−0.04
130	−8.2	−0.18	−1.8	+0.72	+0.6	−0.14	−1.1	−0.10	+0.3	−0.03	−0.2	−0.04
140	−6.7	+0.47	+5.3	+0.60	−1.2	−0.16	−1.0	+0.14	−0.1	−0.05	−0.3	+0.02
150	+0.1	+0.79	+8.6	0.00	−1.6	+0.11	+1.1	+0.21	−0.3	+0.02	+0.1	+0.04
160	+6.9	+0.46	+5.0	−0.65	+0.6	+0.27	+2.1	−0.05	0.0	+0.05	+0.3	0.00
170	+8.0	−0.26	−2.6	−0.75	+2.4	+0.03	+0.2	−0.29	+0.2	+0.01	+0.1	−0.02
180	+2.4	−0.75	−7.8	−0.21	+1.0	−0.28	−2.2	−0.13	+0.2	−0.02	−0.2	−0.01
190	−4.9	−0.59	−6.3	+0.49	−1.7	−0.19	−1.7	+0.22	−0.1	−0.03	−0.2	+0.01
200	−7.8	+0.05	+0.4	+0.74	−2.0	+0.14	+1.0	+0.24	−0.3	0.00	0.0	+0.04
210	−4.2	+0.61	+6.4	+0.38	+0.2	+0.24	+1.9	−0.06	−0.1	+0.04	+0.4	+0.02
220	+2.6	+0.64	+7.1	−0.25	+1.5	−0.01	+0.3	−0.20	+0.4	+0.03	+0.2	−0.05
230	+7.0	+0.19	+2.3	−0.62	+0.4	−0.16	−1.0	−0.02	+0.2	−0.06	−0.4	−0.04
240	+6.0	−0.35	−3.7	−0.50	−0.6	−0.03	−0.3	+0.12	−0.4	−0.05	−0.3	+0.06
250	+1.2	−0.55	−6.7	−0.07	0.0	+0.11	+0.5	+0.01	−0.3	+0.06	+0.4	+0.05
260	−3.7	−0.39	−5.3	+0.31	+0.7	0.00	−0.1	−0.12	+0.4	+0.06	+0.4	−0.06
270	−6.0	−0.07	−1.2	+0.55	−0.1	−0.13	−0.9	−0.01	+0.4	−0.06	−0.4	−0.06
280	−5.2	+0.21	+3.0	+0.36	−1.1	−0.03	−0.1	+0.14	−0.4	−0.06	−0.4	+0.06
290	−2.1	+0.39	+5.7	+0.16	−0.4	+0.14	+1.1	+0.06	−0.4	+0.06	+0.4	+0.06
300	+2.2	+0.44	+5.9	−0.13	+0.9	+0.08	+0.7	−0.12	+0.4	+0.05	+0.4	−0.06
310	+6.0	+0.28	+3.1	−0.43	+0.8	−0.10	−0.7	−0.10	+0.4	−0.05	−0.3	−0.06
320	+6.9	−0.12	−2.2	−0.56	−0.5	−0.10	−0.7	+0.08	−0.3	−0.06	−0.4	+0.05
330	+3.4	−0.55	−6.9	−0.32	−0.6	+0.09	+0.5	+0.10	−0.4	+0.04	+0.3	+0.06
340	−3.0	−0.65	−7.5	+0.23	+0.6	+0.10	+0.5	−0.09	+0.2	+0.06	+0.4	−0.04
350	−7.9	−0.25	−2.7	+0.69	+0.7	−0.11	−0.9	−0.13	+0.4	−0.03	−0.2	−0.06
360	−7.2	+0.40	+4.5	+0.65	−1.0	−0.19	−1.2	+0.11	−0.1	−0.04	−0.3	+0.02

[$n\delta z$, ∂ log r, and $\delta\beta$ are to be computed in the form $\Sigma_i[a_i+(\Delta b_i)t]\sin i\varepsilon+\Sigma_i[b_i+(\Delta b_i)t]\cos i\varepsilon+(\Delta b_0)t$.]

Tables of (93) Minerva—Continued.

TABLE IV.—$\delta\beta$.

PERIODIC TERMS. Unit of a and b = 0.00001.

Arg.	a_2	Diff. for 1°	b_2	Diff. for 1°
°				
0	−23.0	−2.42	−23.1	+0.70
5	−34.5	−2.09	−16.9	+1.77
10	−43.1	−1.33	− 5.8	+2.62
15	−47.1	−0.24	+ 8.8	+3.11
20	−45.3	+0.98	+24.6	+3.13
25	−37.5	+2.13	+39.3	+2.66
30	−24.5	+3.00	+50.5	+1.77
35	− 8.0	+3.49	+56.5	+0.59
40	+ 9.6	+3.48	+56.3	−0.68
45	+26.0	+2.98	+49.8	−1.86
50	+38.8	+2.07	+38.1	−2.75
55	+46.4	+0.91	+23.0	−3.21
60	+47.9	−0.31	+ 6.8	−3.15
65	+43.6	−1.37	− 8.0	−2.67
70	+34.7	−2.10	−19.3	−1.81
75	+23.3	−2.39	−25.8	−0.77
80	+11.6	−2.22	−27.2	+0.21
85	+ 1.9	−1.64	−24.1	+0.97
90	− 4.4	−0.84	−18.2	+1.33
95	− 6.5	−0.02	−11.6	+1.26
100	− 4.9	+0.61	− 6.3	+0.79
105	− 1.0	+0.90	− 4.0	+0.10
110	+ 3.3	+0.76	− 5.4	−0.65
115	+ 6.0	+0.25	−10.2	−1.22
120	+ 5.4	−0.52	−17.0	−1.47
125	+ 0.7	−1.37	−24.0	−1.28
130	− 8.1	−2.08	−29.1	−0.69
135	−19.6	−2.49	−30.4	+0.23
140	−32.1	−2.45	−26.6	+1.28
145	−43.3	−1.96	−17.7	+2.28
150	−51.0	−1.06	− 4.3	+3.03
155	−53.5	+0.10	+12.0	+3.38
160	−49.9	+1.34	+28.7	+3.24
165	−40.3	+2.45	+43.6	+2.64
170	−25.8	+3.27	+54.4	+1.63
175	− 8.4	+3.64	+59.5	+0.38
180	+ 9.7	+3.50	+58.1	−0.92
185	+25.8	+2.87	+50.6	−2.06
190	+37.8	+1.87	+38.1	−2.85
195	+44.2	+0.66	+22.8	−3.19
200	+44.3	−0.56	+ 7.1	−3.02
205	+38.8	−1.59	− 6.6	−2.39
210	+29.0	−2.24	−16.3	−1.43
215	+17.1	−2.45	−20.6	−0.30
220	+ 5.4	−2.15	−19.4	+0.73
225	− 3.8	−1.46	−13.4	+1.58
230	− 8.7	−0.49	− 4.2	+2.02
235	− 8.6	+0.56	+ 6.0	+1.99
240	− 3.3	+1.49	+15.0	+1.51
245	+ 5.9	+2.17	+20.6	+0.59
250	+17.3	+2.35	+21.5	−0.36
255	+28.6	+2.11	+17.0	−1.41
260	+37.6	+1.44	+ 7.7	−2.27
265	+42.5	+0.45	− 5.2	−2.82
270	+41.9	−0.67	−19.6	−2.87
275	+35.8	−1.75	−33.1	−2.47
280	+24.8	−2.58	−43.6	−1.68
285	+10.6	−3.03	−49.4	−0.62
290	− 4.7	−3.01	−49.6	+0.54
295	−18.8	−2.53	−44.2	+1.57
300	−29.5	−1.70	−34.3	+2.32
305	−35.4	−0.65	−21.6	+2.67
310	−35.9	+0.43	− 8.4	+2.54
315	−31.4	+1.33	+ 3.1	+2.00
320	−23.1	+1.91	+11.0	+1.14
325	−12.9	+2.07	+14.2	+0.13
330	− 3.1	+1.77	+12.4	−0.72
335	+ 4.2	+1.09	+ 6.4	−1.54
340	+ 7.4	+0.16	− 2.4	−1.89
345	+ 5.6	−0.84	−11.8	−1.80
350	− 0.9	−1.72	−19.7	−1.26
355	−11.0	−2.28	−23.8	−0.38
360	−23.0	−2.42	−23.1	+0.70

[$n\delta z$, $\delta \log r$, and $\delta\beta$ are to be computed in the form $\Sigma_i[a_i+(\Delta b_i)t] \sin i\varepsilon+\Sigma_i[b_i+\Delta b_i)t] \cos i\varepsilon+(\Delta b_0)t$.]

Tables of (93) Minerva—Continued.

Table IV.—$\delta\beta$—Continued.

PERIODIC TERMS.

Unit of a and b=0.00001.

Arg.	b_0	Diff. for 1°	a_1	Diff. for 1°	b_1	Diff. for 1°	a_3	Diff. for 1°
°								
0	−20.6	−0.62	+ 83.6	+0.44	+ 69.8	−2.28	− 1.0	−0.18
10	−26.1	−0.48	+ 81.6	−0.85	+ 46.1	−2.31	− 4.2	+0.10
20	−30.0	−0.29	+ 67.2	−1.96	+ 25.8	−1.64	− 8.1	+0.49
30	−32.0	−0.09	+ 44.1	−2.56	+ 14.9	−0.47	− 8.6	+0.61
40	−31.9	+0.11	+ 18.3	−2.48	+ 16.8	+0.85	− 4.3	+0.53
50	−29.8	+0.29	− 3.1	−1.72	+ 31.3	+1.96	+ 1.8	+0.56
60	−26.0	+0.45	− 14.4	−0.50	+ 54.5	+2.57	+ 5.8	+0.23
70	−21.1	+0.52	− 12.9	+0.79	+ 80.5	+2.55	+ 6.8	0.00
80	−15.9	+0.50	+ 0.6	+1.86	+103.8	+2.04	+ 6.3	−0.08
90	−11.6	+0.34	+ 22.8	+2.51	+120.5	+1.28	+ 5.0	−0.19
100	− 9.4	+0.08	+ 49.7	+2.80	+129.0	+0.45	+ 2.4	−0.31
110	− 9.9	−0.19	+ 77.9	+2.77	+128.8	−0.48	− 0.6	−0.23
120	−12.9	−0.40	+103.8	+2.35	+119.4	−1.36	− 1.6	+0.02
130	−17.6	−0.53	+123.4	+1.49	+101.2	−2.20	− 0.7	+0.08
140	−23.0	−0.53	+132.4	+0.27	+ 76.7	−2.61	− 1.1	−0.19
150	−27.8	−0.43	+128.5	−1.06	+ 51.1	−2.39	− 4.4	−0.41
160	−31.5	−0.29	+112.1	−2.12	+ 30.9	−1.55	− 8.0	−0.22
170	−33.5	−0.10	+ 88.0	−2.60	+ 21.4	−0.31	− 7.9	+0.27
180	−33.5	+0.11	+ 62.6	−2.37	+ 24.8	+0.99	− 3.2	+0.60
190	−31.4	+0.31	+ 42.8	−1.50	+ 40.0	+1.96	+ 2.7	+0.52
200	−27.4	+0.50	+ 33.8	−0.27	+ 61.9	+2.32	+ 6.4	+0.21
210	−21.8	+0.62	+ 37.6	+0.98	+ 83.9	+1.96	+ 7.4	+0.02
220	−15.0	+0.72	+ 52.1	+1.82	+ 99.1	+0.99	+ 7.4	0.00
230	− 7.5	+0.76	+ 71.8	+2.01	+102.9	−0.25	+ 7.1	−0.09
240	0.0	+0.73	+ 90.0	+1.50	+ 94.4	−1.39	+ 4.7	−0.45
250	+ 6.9	+0.65	+100.2	+0.48	+ 76.5	−2.09	− 2.2	−0.87
260	+12.6	+0.50	+ 98.8	−0.75	+ 54.9	−2.11	−11.2	−0.81
270	+16.8	+0.32	+ 85.6	−1.81	+ 36.5	−1.46	−16.0	−0.09
280	+19.0	+0.12	+ 64.4	−2.33	+ 27.2	−0.36	−12.0	+0.84
290	+19.1	−0.10	+ 41.3	−2.16	+ 29.9	+0.87	− 1.0	+1.21
300	+17.1	−0.30	+ 23.3	−1.35	+ 43.6	+1.80	+ 9.6	+0.77
310	+13.2	−0.48	+ 15.6	−0.16	+ 63.9	+2.14	+13.0	−0.10
320	+ 7.5	−0.63	+ 20.1	+1.03	+ 84.1	+1.78	+ 8.9	−0.63
330	+ 0.8	−0.72	+ 35.1	+1.85	+ 97.6	+0.85	+ 2.6	−0.53
340	− 6.6	−0.74	+ 55.1	+2.04	+ 99.8	−0.41	− 0.6	−0.11
350	−13.9	−0.73	+ 73.5	+1.52	+ 89.6	−1.58	− 0.6	+0.04
360	−20.6	−0.62	+ 83.6	+0.44	+ 69.8	−2.28	− 1.0	−0.18

[$n\delta z$, $\delta \log r$, and $\delta\beta$ are to be computed in the form $\Sigma_i[a_i+(\Delta b_i)t] \sin i\varepsilon + \Sigma_i[b_i+\Delta b_i)t] \cos i\varepsilon + (\Delta b_0)t$.]

Tables of (93) Minerva—Continued.

Table IV.—$\partial\beta$—Continued.

PERIODIC TERMS.

Unit of a and b=0.00001.

Arg.	b_3	Diff. for 1°	a_4	Diff. for 1°	b_4	Diff. for 1°	a_5	Diff. for 1°	b_5	Diff. for 1°
°										
0	−4.6	−0.14	−3.1	+0.60	+5.5	+0.22	−0.1	−0.10	−0.8	−0.01
10	−5.2	+0.10	+2.3	+0.37	+4.6	−0.33	−1.0	−0.02	−0.1	+0.14
20	−2.1	+0.49	+3.7	−0.07	+0.8	−0.32	−0.2	+0.14	+1.0	+0.04
30	+3.8	+0.61	+2.5	−0.10	−1.0	−0.08	+1.0	+0.05	+0.4	−0.14
40	+8.6	+0.29	+1.9	−0.04	−1.9	−0.13	+0.5	−0.13	−0.9	−0.07
50	+9.0	−0.19	+0.6	−0.26	−3.6	−0.16	−0.8	−0.08	−0.6	+0.12
60	+5.7	−0.41	−3.2	−0.43	−3.7	+0.21	−0.6	+0.10	+0.6	+0.08
70	+1.8	−0.34	−6.0	−0.03	+0.7	+0.61	+0.4	+0.07	+0.6	−0.07
80	−1.1	−0.27	−2.9	+0.61	+6.2	+0.37	+0.5	−0.05	−0.3	−0.06
90	−3.6	−0.23	+4.3	+0.67	+6.1	−0.42	−0.1	−0.06	−0.4	+0.02
100	−5.3	−0.07	+7.7	−0.06	−0.8	−0.81	−0.4	−0.01	0.0	+0.05
110	−4.8	+0.16	+3.1	−0.76	−7.1	−0.33	−0.2	+0.04	+0.4	+0.02
120	−2.8	+0.18	−4.5	−0.61	−6.0	+0.51	+0.3	+0.05	+0.3	−0.03
130	−2.2	−0.08	−6.9	+0.16	+0.9	+0.71	+0.5	−0.02	−0.3	−0.08
140	−3.9	−0.18	−2.4	+0.60	+5.6	+0.15	−0.2	−0.10	−0.7	+0.02
150	−4.5	+0.11	+2.7	+0.33	+4.2	−0.35	−0.9	−0.01	+0.1	+0.12
160	−1.1	+0.53	+3.6	−0.09	+0.5	−0.29	−0.1	+0.15	+1.0	+0.03
170	+4.8	+0.57	+2.4	−0.10	−1.2	−0.07	+1.0	+0.04	+0.3	−0.14
180	+9.0	+0.21	+1.8	−0.04	−2.1	−0.14	+0.4	−0.14	−1.0	−0.06
190	+8.7	−0.23	+0.3	−0.29	−3.8	−0.15	−0.9	−0.07	−0.6	+0.14
200	+5.2	−0.40	−3.7	−0.42	−3.5	+0.27	−0.6	+0.12	+0.7	+0.08
210	+1.5	−0.32	−6.0	+0.07	+1.4	+0.62	+0.5	+0.06	+0.5	−0.10
220	−1.4	−0.29	−2.1	+0.66	+6.4	+0.25	+0.4	−0.08	−0.4	−0.04
230	−4.8	−0.42	+4.6	+0.53	+5.1	−0.49	−0.3	−0.02	−0.2	+0.06
240	−9.5	−0.47	+6.3	−0.16	−1.3	−0.64	0.0	+0.04	+0.2	0.00
250	−12.6	−0.07	+1.8	−0.57	−5.2	−0.08	+0.2	−0.03	−0.2	−0.05
260	−9.6	+0.68	−2.6	−0.24	−3.4	+0.35	−0.4	−0.06	−0.3	+0.04
270	+0.2	+1.18	−2.8	+0.12	−0.2	+0.21	−0.3	+0.06	+0.4	+0.06
280	+11.4	+0.91	−1.7	+0.04	+0.6	0.00	+0.4	+0.06	+0.4	−0.06
290	+16.2	0.00	−2.0	−0.03	+1.1	+0.15	+0.4	−0.06	−0.4	−0.06
300	+11.6	−0.83	−1.4	+0.23	+3.4	+0.26	−0.2	−0.05	−0.4	+0.04
310	+1.8	−0.99	+2.8	+0.50	+4.3	−0.17	−0.3	+0.02	+0.1	+0.04
320	−5.8	−0.46	+6.3	+0.09	−0.1	−0.65	0.0	+0.01	+0.2	−0.01
330	−7.2	+0.12	+3.4	−0.64	−6.2	−0.41	−0.1	0.00	+0.1	+0.02
340	−4.9	+0.25	−3.8	−0.67	−6.3	+0.40	+0.2	+0.05	+0.3	0.00
350	−3.6	0.00	−7.1	+0.08	+0.2	+0.74	+0.6	0.00	−0.2	−0.09
360	−4.6	−0.14	−3.1	+0.60	+5.5	+0.22	−0.1	−0.10	−0.8	−0.01

[$n\delta z$, $\delta \log r$, and $\delta\beta$ are to be computed in the form $\Sigma_i[a_i+(\Delta b_i)_t] \sin i\varepsilon+\Sigma_i[b_i+\Delta b_i)_t] \cos i\varepsilon+(\Delta b_0)_t$.]

Tables of (93) Minerva—Continued.

TABLE V.—TERMS TO BE MULTIPLIED BY $T=(t-t_0)$ IN JULIAN YEARS.

Year	$n\delta z$ Unit=0°001					$\delta \log r$ Unit=0.00001			$\delta\beta$ Unit=0.00001		
	$(\Delta b_0)_t$	$(\Delta a_1)_t$	$(\Delta b_1)_t$	$(\Delta a_2)_t$	$(\Delta b_2)_t$	$(\Delta b_0)_t$	$(\Delta a_1)_t$	$(\Delta b_1)_t$	$(\Delta b_0)_t$	$(\Delta a_1)_t$	$(\Delta b_1)_t$
1864.0	+2.7	−8.4	+45.3	+0.3	−1.6	+0.5	+17.2	+3.2	+2.9	−136.5	−20.7
6	+2.7	−6.9	+37.5	+0.2	−1.3	+0.4	+14.1	+2.6	+2.4	−111.7	−16.9
8	+2.8	−5.3	+28.8	+0.2	−1.0	+0.3	+10.9	+2.0	+1.9	−86.9	−13.2
1870	+2.8	−3.8	+20.6	+0.1	−0.7	+0.2	+7.8	+1.5	+1.3	−62.1	−9.4
2	+2.9	−2.3	+12.4	+0.1	−0.4	+0.1	+4.7	+0.9	+0.8	−37.2	−5.6
4	+2.9	−0.8	+4.1	0.0	−0.1	0.0	+1.6	+0.3	+0.3	−12.4	−1.9
6	+3.0	+0.8	−4.1	0.0	+0.1	0.0	−1.6	−0.3	−0.3	+12.4	+1.9
8	+3.0	+2.3	−12.4	−0.1	+0.4	−0.1	−4.7	−0.9	−0.8	+37.3	+5.6
1880	+3.1	+3.8	−20.6	−0.1	+0.7	−0.2	−7.8	−1.5	−1.3	+62.1	+9.4
2	+3.1	+5.3	−28.9	−0.2	+1.0	−0.3	−10.9	−2.0	−1.9	+86.9	+13.2
4	+3.1	+6.9	−37.1	−0.2	+1.3	−0.4	−14.1	−2.6	−2.4	+111.8	+17.0
6	+3.2	+8.4	−45.3	−0.3	+1.6	−0.5	−17.2	−3.2	−2.9	+136.6	+20.7
8	+3.2	+9.9	−53.6	−0.3	+1.9	−0.5	−20.3	−3.8	−3.4	+161.4	+24.5
1890	+3.2	+11.4	−61.8	−0.4	+2.2	−0.6	−23.4	−4.4	−4.0	+186.2	+28.2
2	+3.2	+13.0	−70.1	−0.5	+2.5	−0.7	−26.6	−5.0	−4.5	+211.1	+32.0
4	+3.2	+14.5	−78.3	−0.5	+2.8	−0.8	−29.7	−5.6	−5.0	+235.9	+35.8
6	+3.3	+16.0	−86.6	−0.6	+3.0	−0.9	−32.8	−6.1	−5.6	+260.7	+39.5
8	+3.3	+17.6	−94.8	−0.6	+3.3	−0.9	−35.9	−6.7	−6.1	+285.6	+43.3
1900	+3.3	+19.1	−103.0	−0.7	+3.6	−1.0	−39.1	−7.3	−6.6	+310.4	+47.1
2	+3.3	+20.6	−111.3	−0.7	+3.9	−1.1	−42.2	−7.9	−7.1	+335.2	+50.8
4	+3.3	+22.1	−119.5	−0.8	+4.2	−1.2	−45.3	−8.5	−7.7	+360.0	+54.6
6	+3.3	+23.7	−127.8	−0.8	+4.5	−1.3	−48.4	−9.1	−8.2	+384.8	+58.4
8	+3.3	+25.2	−136.0	−0.9	+4.8	−1.4	−51.6	−9.6	−8.7	+409.7	+62.1
1910	+3.2	+26.7	−144.3	−0.9	+5.1	−1.4	−54.7	−10.2	−9.3	+434.5	+65.9
2	+3.2	+28.2	−152.5	−1.0	+5.4	−1.5	−57.8	−10.8	−9.8	+459.3	+69.7
4	+3.2	+29.8	−160.8	−1.1	+5.7	−1.6	−60.9	−11.4	−10.3	+484.2	+73.4
6	+3.2	+31.3	−169.0	−1.1	+5.9	−1.7	−64.1	−12.0	−10.9	+509.0	+77.2
8	+3.2	+32.8	−177.2	−1.2	+6.2	−1.8	−67.2	−12.6	−11.4	+533.8	+81.0
1920	+3.1	+34.3	−185.5	−1.2	+6.5	−1.8	−70.3	−13.1	−11.9	+558.7	+84.7
2	+3.1	+35.9	−193.7	−1.3	+6.8	−1.9	−73.4	−13.7	−12.4	+583.5	+88.5
4	+3.1	+37.4	−202.0	−1.3	+7.1	−2.0	−76.6	−14.3	−13.0	+608.3	+92.3
6	+3.0	+38.9	−210.2	−1.4	+7.4	−2.1	−79.7	−14.9	−13.5	+633.1	+96.0
8	+3.0	+40.4	−218.5	−1.4	+7.7	−2.2	−82.8	−15.5	−14.0	+657.9	+99.8
1930	+3.0	+42.0	−226.7	−1.5	+8.0	−2.3	−85.9	−16.1	−14.6	+682.8	+103.6

Month	$n\delta z$ Unit=0°001			$\delta \log r$ Unit=0.00001		$\delta\beta$ Unit=0.00001		
	$(\Delta a_1)_t$	$(\Delta b_1)_t$	$(\Delta b_2)_t$	$(\Delta a_1)_t$	$(\Delta b_1)_t$	$(\Delta b_1)_t$	$(\Delta a_1)_t$	$(\Delta b_1)_i$
Jan. 0.0	+0.0	−0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb. 0.0	+0.1	−0.4	0.0	−0.1	0.0	0.0	+1.1	+0.2
Mar. 0.0	+0.1	−0.7	0.0	−0.3	0.0	0.0	+2.0	+0.3
Apr. 0.0	+0.2	−1.0	0.0	−0.4	−0.1	−0.1	+3.1	+0.5
May 0.0	+0.2	−1.4	0.0	−0.5	−0.1	−0.1	+4.1	+0.6
June 0.0	+0.3	−1.7	+0.1	−0.6	−0.1	−0.1	+5.1	+0.8
July 0.0	+0.4	−2.0	+0.1	−0.8	−0.1	−0.1	+6.2	+0.9
Aug. 0.0	+0.4	−2.4	+0.1	−0.9	−0.2	−0.2	+7.2	+1.1
Sept. 0.0	+0.5	−2.7	+0.1	−1.0	−0.2	−0.2	+8.3	+1.3
Oct. 0.0	+0.6	−3.1	+0.1	−1.2	−0.2	−0.2	+9.3	+1.4
Nov. 0.0	+0.6	−3.4	+0.1	−1.3	−0.2	−0.2	+10.3	+1.6
Dec. 0.0	+0.7	−3.8	+0.1	−1.4	−0.3	−0.2	+11.4	+1.7

[$n\delta z$, $\delta \log r$, and $\delta\beta$ are to be computed in the form $\Sigma_i[a_i+(\Delta b_i)_t]\sin i\varepsilon+\Sigma_i[b_i+(\Delta b_i)_t]\cos i\varepsilon+(\Delta b_0)_t$.]

Tables of (93) Minerva—Continued.

TABLE VI.—CONSTANTS FOR THE EQUATOR.

Year	A′	B	C′	log sin *a*	log sin *b*	log sin *c*
	°	°	°			
1865. 0	4. 6662	275. 1318	273. 4766	9. 99996	9. 92830	9. 72466
6	. 6800	. 1469	. 4870	6	0	65
7	. 6938	. 1619	. 4975	6	0	65
8	. 7076	. 1770	. 5180	6	0	65
9	. 7214	. 1921	. 5185	6	0	65
1870	4. 7352	275. 2072	273. 5290	9. 99996	9. 92830	9. 72465
1	. 7490	. 2223	. 5395	6	0	65
2	. 7628	. 2374	. 5500	6	0	64
3	. 7766	. 2525	. 5605	6	0	64
4	. 7904	. 2676	. 5710	6	1	64
1875	4. 8042	275. 2827	273. 5815	9. 99996	9. 92831	9. 72464
6	. 8180	. 2978	. 5920	6	1	64
7	. 8318	. 3129	. 6025	6	1	64
8	. 8456	. 3279	. 6130	6	1	63
9	. 8594	. 3430	. 6235	6	1	63
1880	4. 8732	275. 3581	273. 6340	9. 99996	9. 92831	9. 72463
1	. 8870	. 3732	. 6445	6	1	63
2	. 9008	. 3883	. 6550	6	1	63
3	. 9146	. 4034	. 6655	6	1	63
4	. 9284	. 4185	. 6760	6	2	62
1885	4. 9422	275. 4336	273. 6865	9. 99996	9. 92832	9. 72462
6	. 9560	. 4487	. 6970	6	2	62
7	. 9698	. 4638	. 7075	6	2	62
8	. 9837	. 4789	. 7180	6	2	62
9	. 9975	. 4940	. 7285	6	2	61
1890	5. 0113	275. 5090	273. 7390	9. 99996	9 92832	9. 72461
1	. 0251	. 5241	. 7495	6	2	61
2	. 0389	. 5392	. 7600	6	2	61
3	. 0527	. 5543	. 7705	6	2	61
4	. 0665	. 5694	. 7810	6	3	61
1895	5. 0803	275. 5845	273. 7915	9. 99996	9. 92833	9. 72460
6	. 0941	. 5996	. 8020	6	3	60
7	. 1079	. 6147	. 8125	6	3	60
8	. 1217	. 6298	. 8229	6	3	60
9	. 1355	. 6449	. 8334	6	3	60
1900	5. 1493	275. 6600	273. 8439	9. 99996	9. 92833	9. 72460
1	. 1631	. 6751	. 8544	6	3	59
2	. 1769	. 6902	. 8649	6	3	59
3	. 1908	. 7053	. 8754	6	3	59
4	. 2046	. 7204	. 8859	6	4	59
1905	5. 2184	275. 7354	273. 8964	9. 99995	9. 92834	9. 72459
6	. 2322	. 7505	. 9069	5	4	58
7	. 2460	. 7656	. 9174	5	4	58
8	. 2598	. 7807	. 9279	5	4	58
9	. 2736	. 7958	. 9384	5	4	58
1910	5. 2874	275. 8109	273. 9489	9. 99995	9. 92834	9. 72458
1	. 3012	. 8260	. 9594	5	4	58
2	. 3150	. 8411	. 9699	5	4	57
3	. 3288	. 8562	. 9804	5	4	57
4	. 3426	. 8713	. 9909	5	5	57
1915	5. 3564	275. 8864	274. 0014	9. 99995	9. 92835	9. 72457
6	. 3702	. 9015	. 0119	5	5	57
7	. 3840	. 9165	. 0224	5	5	56
8	. 3978	. 9317	. 0329	5	5	56
9	. 4116	. 9467	. 0434	5	5	56
1920	5. 4254	275. 9619	274. 0539	9. 99995	9. 92835	9. 72456
1	. 4392	. 9770	. 0644	5	5	56
2	. 4531	. 9920	. 0749	5	5	55
3	. 4669	276. 0071	. 0854	5	6	55
4	. 4807	. 0222	. 0959	5	6	55
1925	5. 4945	276. 0373	274. 1064	9. 99995	9. 92836	9. 72455
6	. 5083	. 0524	. 1169	5	6	55
7	. 5221	. 0675	. 1274	5	6	54
8	. 5359	. 0826	. 1378	5	6	54
9	. 5497	. 0977	. 1483	5	6	54
1930	. 5635	. 1128	. 1588	9. 99995	9. 92836	9. 72454

Year	log cos *a*	log cos *b*	log cos *c*
1865. 0	8. 114	9. 725 *n*	9. 928
1930. 0	8. 180	9. 724 *n*	9. 928

Tables of (93) Minerva—Continued.

TABLE VII.—REDUCTION OF MEAN TO ECCENTRIC ANOMALY ($\varepsilon-g$), AND CORRECTION $\Delta(g-g')$ TO BE APPLIED TO $(g-g')$ TO FORM ARGUMENT N.

Arg. g	$\Delta(g-g')$	$\varepsilon-g$	Arg. g	Arg. g	$\Delta(g-g')$	$\varepsilon-g$	Arg. g	Arg. g	$\Delta(g-g')$	$\varepsilon-g$	Arg. g
°			°	°			°	°			°
0	0.000	0.000	360	60	4.571	7.438	300	120	3.980	6.477	240
1	0.100	0.164	359	61	4.605	7.494	299	121	3.932	6.399	239
2	0.201	0.327	358	62	4.638	7.547	298	122	3.883	6.320	238
3	0.301	0.490	357	63	4.669	7.597	297	123	3.834	6.238	237
4	0.401	0.653	356	64	4.698	7.645	296	124	3.783	6.156	236
5	0.501	0.816	355	65	4.725	7.690	295	125	3.731	6.072	235
6	0.601	0.978	354	66	4.751	7.732	294	126	3.679	5.987	234
7	0.701	1.140	353	67	4.776	7.772	293	127	3.626	5.900	233
8	0.800	1.302	352	68	4.799	7.809	292	128	3.572	5.812	232
9	0.899	1.463	351	69	4.820	7.844	291	129	3.517	5.723	231
10	0.997	1.623	350	70	4.839	7.875	290	130	3.461	5.632	230
11	1.095	1.782	349	71	4.857	7.904	289	131	3.405	5.540	229
12	1.192	1.940	348	72	4.873	7.931	288	132	3.347	5.447	228
13	1.289	2.098	347	73	4.888	7.955	287	133	3.289	5.353	227
14	1.385	2.255	346	74	4.901	7.976	286	134	3.230	5.257	226
15	1.481	2.410	345	75	4.913	7.995	285	135	3.171	5.160	225
16	1.576	2.564	344	76	4.923	8.011	284	136	3.111	5.062	224
17	1.670	2.718	343	77	4.931	8.024	283	137	3 050	4.963	223
18	1.763	2.869	342	78	4.938	8.036	282	138	2.988	4.863	222
19	1.856	3.020	341	79	4.943	8.044	281	139	2.926	4.762	221
20	1.947	3.169	340	80	4.947	8.050	280	140	2.863	4.659	220
21	2.038	3.317	339	81	4.949	8.054	279	141	2.799	4.556	219
22	2.128	3.463	338	82	4.950	8.055	278	142	2.735	4.451	218
23	2.217	3.608	337	83	4.949	8.053	277	143	2.671	4.346	217
24	2.305	3.750	336	84	4.946	8.050	276	144	2.605	4.240	216
25	2.391	3.892	335	85	4.943	8.044	275	145	2.539	4.132	215
26	2.477	4.031	334	86	4.937	8.035	274	146	2.473	4.024	214
27	2.562	4.168	333	87	4.931	8.024	273	147	2.406	3.916	213
28	2.645	4.305	332	88	4.922	8.011	272	148	2.338	3.806	212
29	2.727	4.438	331	89	4.913	7.995	271	149	2.270	3.695	211
30	2.808	4.570	330	90	4.902	7.977	270	150	2.202	3.584	210
31	2.888	4.700	329	91	4.889	7.957	269	151	2.133	3.471	209
32	2.967	4.828	328	92	4.875	7.934	268	152	2.064	3.358	208
33	3.044	4.954	327	93	4.860	7.909	267	153	1.994	3.245	207
34	3.120	5.078	326	94	4.844	7.882	266	154	1.924	3.130	206
35	3.195	5.199	325	95	4.826	7.853	265	155	1.853	3.015	205
36	3.268	5.318	324	96	4.806	7.822	264	156	1.782	2.900	204
37	3.340	5.435	323	97	4.786	7.788	263	157	1.710	2.784	203
38	3.410	5.550	322	98	4.764	7.752	262	158	1.639	2.667	202
39	3.479	5.662	321	99	4.741	7.715	261	159	1.567	2.549	201
40	3.547	5.772	320	100	4.716	7.675	260	160	1.494	2.431	200
41	3.613	5.879	319	101	4.690	7.633	259	161	1.421	2.313	199
42	3.677	5.984	318	102	4.663	7.589	258	162	1.348	2.194	198
43	3.740	6.087	317	103	4.635	7.543	257	163	1.275	2.075	197
44	3.802	6.187	316	104	4.605	7.495	256	164	1.201	1.955	196
45	3.862	6.285	315	105	4.575	7.445	255	165	1.127	1.835	195
46	3.920	6.380	314	106	4.543	7.393	254	166	1.053	1.714	194
47	3.977	6.473	313	107	4.510	7.339	253	167	0.979	1.593	193
48	4.033	6.563	312	108	4.475	7.283	252	168	0.904	1.472	192
49	4.086	6.650	311	109	4.440	7.226	251	169	0.830	1.350	191
50	4.139	6.735	310	110	4.404	7.166	250	170	0.755	1.228	190
51	4.189	6.817	309	111	4.366	7.105	249	171	0.680	1.106	189
52	4.238	6.897	308	112	4.327	7.042	248	172	0.605	0.984	188
53	4.285	6.974	307	113	4.287	6.977	247	173	0.529	0.861	187
54	4.331	7.048	306	114	4.246	6.911	246	174	0.454	0.739	186
55	4.375	7.120	305	115	4.205	6.844	245	175	0.378	0.616	185
56	4.417	7.189	304	116	4.162	6.773	244	176	0.303	0.493	184
57	4.458	7.255	303	117	4.118	6.701	243	177	0.227	0.370	183
58	4.497	7.319	302	118	4.073	6.628	242	178	0.152	0.246	182
59	4.535	7.380	301	119	4.027	6.553	241	179	0.076	0.123	181
60	4.571	7.438	300	120	3.980	6.477	240	180	0.000	0.000	180

NOTE.—When the argument exceeds 180°, it is found to the right of the function and the function is negative.

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