GEOTROPIC ORIENTATION OF YOUNG RATS.

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(Accepted for publication, January 12, 1927.)

I.

In describing the geotropic conduct of young rats (Rattus norvegicus), we have stressed the fact that to obtain data suitable for quantitative treatment of the gravitational orientation it is necessary to employ individuals of the closest possible similarity. This has meant, in practice, employing litter mates from lines long inbred, under external conditions as nearly uniform as possible. The result has demonstrated that, with these precautions taken, it is possible to formulate precisely the connection between the intensity of excitation and the extent of the geotropic orientation. On a creeping plane inclined at angle \( \alpha \) to the horizontal, and in which the effective gravitational component is therefore proportional to \( \sin \alpha \), the orientation path is one defined by an angle \( \theta \) on the plane, such that \( \theta = K \log \sin \alpha - C \). The precision of the orientation increases according to the same equation. In addition, \( -\cos \theta = K \sin \alpha \). The speed of progression bears similar relations to the angle \( \alpha \).

It was proposed to interpret these results as signifying that on an inclined plane the rat orients upward until the difference between the work done by the legs of the two sides is reduced to a certain (constant) fraction of the total. It is possible to entertain this view because the differential postures of the legs encourage it, and because they are extended in the plane of creeping. It is supported by the effects of increasing the mass lifted during creeping, as by attaching weights to the base of the animal's tail. This conception of the geotropic excitation controlling the amount of orientation as a proprioceptive matter is strengthened by further findings in this laboratory regarding the

1 Crozier and Pincus, 1926; 1926–27, a, b; Pincus, 1926–27.
orienation of molluscs. Mr. T. J. B. Stier has also observed an identical type of orientation in newts (Notophthalmus), with the additional important fact that when the sign of orientation is reversed, and the animal then becomes positively geotropic, the angle $\theta$ is the same as in the more usual geonegative orientation.

An immediate corollary to these findings in rats of one type (R. norvegicus) was the possibility that certain genetic or specific differences might find expression by means of the constants in the equations for geotropic behavior. This deduction we now propose to illustrate. As material for this purpose we chose a strain of the roof rat (Rattus rattus). Individuals of the proper age, 13 days, were very kindly placed at our disposal by Dr. H. W. Feldman of the Bussey Institution. We are greatly indebted to Professor W. E. Castle, and to Dr. Feldman, for this and other like assistance.

In this rat the geotropic influence could be expected to be more pronounced. Aside from the matter of its persistence into adult life, the relatively greater lengths of the legs, and the somewhat less body weight, were each expected to play a part in modifying the constants of the equations for geotropism.

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$\theta$</th>
<th>P. E. $\theta$ as per cent $\theta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10°</td>
<td>27.0°</td>
<td>8.74</td>
</tr>
<tr>
<td>15°</td>
<td>37.1°</td>
<td>5.78</td>
</tr>
<tr>
<td>20°</td>
<td>48.1°</td>
<td>3.68</td>
</tr>
<tr>
<td>30°</td>
<td>61.9°</td>
<td>2.34</td>
</tr>
<tr>
<td>40°</td>
<td>71.0°</td>
<td>1.88</td>
</tr>
<tr>
<td>50°</td>
<td>80.1°</td>
<td>1.72</td>
</tr>
<tr>
<td>60°</td>
<td>83.5°</td>
<td>1.06</td>
</tr>
</tbody>
</table>

Five members of one litter, 13 days after birth, were employed in securing the final series of observations collected in Table I. The
experiments were made in a dark room, with temperature 20°-23°, following the technique outlined in previous papers.  

Within the limits of the probable errors of the means the measured values of \( \theta \) adhere quite precisely to the relationship already established for the Norway rat, as Fig. 1 shows, and they thus provide an independent confirmation of it. The precision of orientation decreases linearly as \( \log \sin \alpha \) increases (Fig. 2). The observations at the lower-most magnitude of \( \alpha \) are necessarily very variable, because the slight geotropic stimulation does not sufficiently inhibit movements origi-
inating in other ways. The fact that here again, as with the Norway rat, \( \cos \theta \) decreases linearly as \( \sin \alpha \) increases, is made evident in Fig. 3.

To compare these results with those given by the species first used it is necessary to obtain the constants in the several equations. This is most conveniently done from Fig. 2. For the roof rat the "ideal threshold" for geotropic orientation is 3.5° [\( \cos \theta = 1 \)], as compared with 6.5° for \textit{norvegicus}; and 90° orientation is obtained at a slightly lower angle (67.2°) than in \textit{norvegicus} (70.0°). This is in accord with the expectation that the "geotropic sensitivity" of the roof rat should be greater. The equation describing the orientation (Fig. 3) is

\[
1 - \cos \theta = K \sin \alpha - M \tag{1}
\]

![Graph showing variability of measured angle of orientation](image)

**Fig. 2.** The variability of the measured angle of orientation (\( \theta \)) decreases almost linearly in proportion to \( \log \sin \alpha \). At the lowest inclination the variability is disproportionately large, because the "threshold" presumably differs from moment to moment.

For \textit{R. norvegicus}, of the type used in our previous experiments,

\[
K = 1.206 \\
M = 0.113
\]

For \textit{R. rattus},

\[
K = 1.18 \\
M = 0.06
\]

In terms of Fig. 1,

\[
\theta = K' \log \sin \alpha - C \tag{2}
\]
For *R. norvegicus*,

\[
K' = 100 \\
C = 1.998
\]

Fig. 3. As with *R. norvegicus* (Crozier and Pincus, 1926-27, a, b), in *R. rattus* the relationship between \(\cos \theta\) and \(\sin \alpha\) is rectilinear.

For *R. rattus*

\[
K' = 90.4 \\
C = 2.988
\]
III.

Our sole purpose in recording the outcome of the present experiments is to demonstrate that the methods employed are not only capable of yielding statistically significant results in terms of an intelligible mechanism, but also of providing a method for the precise characterization of behavior differences within genetically uniform strains. It is not too much to hope that the obvious development and application of this viewpoint may lead to results significant for inheritance studies. Certain aspects of this matter we expect shortly to have in hand.

IV.

SUMMARY.

The geotropic orientation of *Rattus rattus* (roof rat) obeys the equations previously found applicable for *Rattus norvegicus*. The former is more sensitive, geotropically, and the numerical values of the constants in the equations for the two forms are found to differ significantly. Certain consequences of this difference are pointed out.

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