THE SONG OF BIRDS.

In view of the interest attached to the experiments made by Professor W. E. D. Scott with a view to ascertaining whether the song of birds is instinctive or imitative it may be well to recall that very similar experiments were made over a century ago. Wallace notes in his essays on 'Natural Selection, etc.,' that "The Hon. Daines Barrington was of the opinion that 'notes in birds are no more innate than language is in man, and depend entirely on the master under which they are bred, *as far as their organs will enable them to imitate* the sounds which they have frequent opportunities of hearing." An account of his experiments is given in the *Philosophical Transactions* for 1773, Vol. LXII., and his results were practically the same as those obtained by Professor Scott, the young birds acquiring the song of their foster parents and not the notes of their own species. Barrington notes that the birds must be taken from the nest when very young, as they are apt pupils and learn the call notes of their parents at an early age.

F. A. L.

Museum of the Brooklyn Institute,
August 28, 1904.

DOCTORATES AND FELLOWSHIPS.

To the Editor of Science: In Science for August 19 is the remark: 'It is somewhat surprising that California and Stanford have together conferred the degree (of Ph.D.) but twenty-five times in seven years.' Among the reasons for this are two: the authorities of this institution advise their advanced students, for the sake of breadth of experience, to take a part of their work in the east or in Europe. This is generally the concluding part. On the other hand, the California institutions grant few artificial aids to students as such. At Stanford this is regarded as a matter of principle, tuition being free to graduate students. By the wider introduction of the 'trading stamp system' in higher education, the number of degrees could be greatly increased, but with no gain to science or art.

David Starr Jordan.

*SPECIAL ARTICLES.*

LIMITATIONS OF THE KLINOSTAT AS AN INSTRUMENT FOR SCIENTIFIC RESEARCH.

The klinostat is an instrument used mostly in plant and animal physiology, revolving about either a vertical or a horizontal axis, for the purpose of neutralizing the tropic (curving) effects of light and gravitation. It was first made practical and introduced into laboratory work by Sachs in 1872, and fully described with additional improvements in several papers in that memorable series of pioneer research entitled 'Arbeiten des botanischen Instituts in Würzburg.'

The instrument as commonly manufactured is actuated by springs, and may be given several speeds, usually one revolution in ten, fifteen, twenty or thirty minutes. In the use of the instrument for demonstration and research during the past thirty years, it has generally been thought immaterial to consider the angles at which plants are secured to the horizontal klinostat for the purpose of neutralizing the tropic effect of gravitation, or to consider the distribution of light when plants are revolved on the vertical klinostat for the purpose of neutralizing the tropic effect of light. In addition to the foregoing relations of the instrument to gravitation and light, the present tendency to substitute electric and water motors for springs to drive the machines introduces relations of speed. The research of the past ten years has indicated very important limitations to the use of the klinostat, and the most general of these are pointed out in the following lines, and should be recognized by every one using this instrument.

*Evenness of Speed.*—The first requisite for securing evenness of revolution is the centering of the load. An excentric load will give a slower speed periodically, and this will bring curves. It has been shown in my own laboratory that, in a speed of one revolution in ten minutes, a periodic retardation of but a second or two, due to excentricity of load, will cause, after a long interval, a geotropic curve by the summation of stimuli.

*Avoidance of Centrifugal Effect.*—It is well known that in rapid revolution, plants simulate toward the so-called centrifugal force

their behavior toward gravitation. The revolution must be so slow therefore as not to bring in the centrifugal effect. Czapek* has measured the sensitiveness of plants to centrifugal force when gravitation is neutralized, finding that by sufficiently long continuance of the experiment, curves will come when the rate of revolution gives an acceleration exceeding one thousandth part of the acceleration of gravitation (.001 g.), but do not appear, at least for many hours, at a lower rate of speed. The relation of the acceleration due to rotation to the acceleration of gravitation is found by the formula $F = 4.024\, r/t^2$, in which $r$ is the distance from the center of rotation in meters, $t$ is the time of one revolution in seconds, and $F$ is the ratio of the acceleration of rotation to the acceleration of gravitation. By applying the formula it will be found that an object rotating once in twenty seconds, at a distance of 10 cm. from the center will have an acceleration approximately equal to .001 g. Such a rate of revolution would, therefore, be within the limit of safety for objects less than 10 cm. from the center of rotation. To make the results doubly sure, one could keep a speed not to exceed one revolution per minute.

*Avoidance of too Slow Revolution.*—Not only is there an upper limit of speed, but a lower limit also when one wishes to neutralize the tropic effect of light or gravitation. A revolution that is so slow as to allow a plant to remain in one quadrant of its path, or, in certain cases, in one semicircle, for a period equal to the period required to produce a curvature when the plant is at rest, will produce a curvature of the plant on the klinostat, in which the apex of the plant member will, by combining its curves during a complete revolution of the klinostat, describe a line, as it moves back and forth, or a circle as it circumnutates, the one or the other according to the position of the plant with reference to the axis of revolution of the klinostat. Indeed, the recent work of F. Darwin and Pertz† may be taken to indicate that a plant on the horizontal klinostat, remaining in a quadrant for a period even less than the latent period of curvature may keep up a rhythmic oscillation as it revolves. Since at a temperature of 20° C. the latent period for curvature of some roots and stems is not over twenty minutes, and the perception period of some plants for gravitation at 20° C. is less than fifteen minutes, safety would advise that thirty minutes should be the limit for slow revolution, the plant then being in each quadrant but seven and one half minutes.

*Not All Tropic Influences can be Neutralized by the Klinostat.*—It is often desirable to revolve a plant on the klinostat, thereby freeing it from the tropic effect of gravitation in order that some property of the plant, ordinarily veiled by the control of gravitation, may be brought to expression. Thus the bending of several roots from light has been discovered by the use of the klinostat, the same roots showing no response to light as long as the stronger influence of gravitation was operative. It is well to know, however, that the so-called *autotropism* of plants is uninfluenced by the klinostat, and that this tendency of plants to grow straight must always operate against the formation of curves in plants that might otherwise show responses. This autotropism of roots and stems is of no inconsiderable moment, since curves of several hours' formation are by it completely obliterated while the plant is so revolved on the klinostat as to neutralize the tropic effect of gravitation.

It is of the first importance to know that only those parts of plants which are physiologically radially symmetrical will grow straight while revolving on the klinostat with horizontal axis.* A plant may be radially unsymmetrical toward gravitation, in which case, revolution on the klinostat will not release it wholly from the tropic influence of gravitation; or it may be radially unsymmetrical physiologically because of unsymmetrical behavior due to internal stimuli. In the revolution of the latter kind of plant member on the klinostat (many leaves), we may have curves due to unequal growth on the one side or the

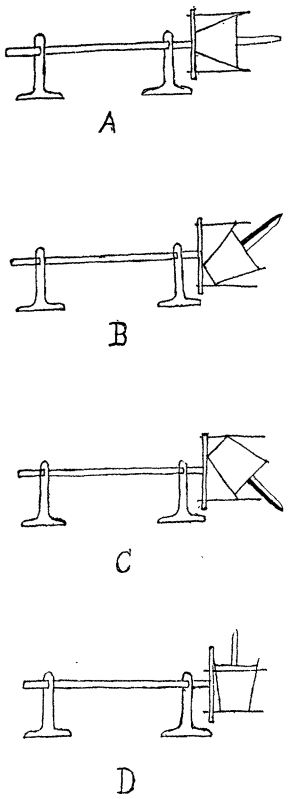
* *Jahrb. wiss. Bot.*, XXVII., 1895, 243.

† *Annals of Botany*, XVII., 1903, 93.

* Noll, *Jahrb. wiss. Bot.*, XXXIV., 1900, 459.

other, this unequal growth being known as *epinasty* or *hyponasty*.

*How May Radially Symmetrical Plant Members be Placed on the Klinostat to Neutralize the Tropic Effect of Gravitation?*—For neutralizing the tropic effect of gravitation the horizontal klinostat is always used. There are three positions the plants may occupy as they are fastened to the klinostat. The positions are illustrated by the four diagrammatic figures *A*, *B*, *C* and *D*. The position in *A*, in




which the axis of the plant is made parallel with the axis of rotation, is the one which has been most used in physiological work. The position in *B* and *C* is one in which plants have seldom been designedly placed, but in which parts of plants have been generally left without concern if in any way they came into this position. The question now to be considered is this: Are orthotropic parts of plants revolving on the klinostat as indicated in *A* and *B* freed from the tropic effect of gravitation? A consideration of the following results of recent investigation answers this question decisively in the negative. Czapek* found some evidence to show that primary roots, and Miss Pertz† showed that grass stems are not equally stimulated by gravitation at equal distances above and below the horizontal plane. Work done in the botanical laboratory here by Miss Haynes and myself, and soon to be published, demonstrates that both orthotropic roots and stems receive their strongest gravitation simulation for bending when those plant members are placed in the horizontal position; and that stems are more strongly stimulated to bend when inclined below the horizontal than at an equal angle above the horizontal, while roots are more strongly influenced when inclined with their tips above the horizontal than at equal angles below the horizontal. A stem, therefore, in the position shown in Fig. *B* does not feel the stimulation of gravitation so effectively as in the position 180° removed as in Fig. *C*. It is, however, entirely conceivable that the foregoing relations may be true for plants at rest, but may not hold for plants rotating on the klinostat. But numerous tests made by myself with several species show that both roots and stems rotated on the klinostat in the position shown in Figs. *B* and *C*, or in any oblique position between the horizontal and vertical, bend toward the horizontal as the experiment progresses. Not only then is the oblique inclination of the plant axis during revolution a faulty one, but the horizontal position as in Fig. *A* is not proper. In the latter position, it is true, the plant will grow straight, but it will grow straight for the same reason that it grows straight when at rest in the vertical position—because with each deviation from the horizontal position its geotropic response will send it back to the horizontal.

If one wishes to rotate orthotropic stems and roots on the klinostat so as to free them from the tropic effect of gravitation there is only one position possible, and that is the vertical position, by which the plant axis dur-

* *Jahrb. wiss. Bot.*, XXVII., 1895, 283.

† *Annals of Bot.*, XIII., 1899, 620.

ing revolution describes a vertical plane as shown in Fig. *D*.

If one wishes while the plant on the klinostat is freed from the tropic effect of gravitation to apply some stimulus for the study of a tropic reaction, the stimulus should be employed so as to cause curves in the plane of revolution; for as soon as the tip of stem or root deviates from the vertical plane, gravitation seizes upon it to turn it to the horizontal.

*Neutralization of the Tropic Effect of Light.*—Experiments in which plants are rotated to neutralize the tropic effects of gravitation have been mostly carried on in the dark-room with seedlings. Such conditions and material are easily obtained and managed. Sometimes, however, when the experiments are prolonged, and older plants are used, it is necessary to do the work in the light to avoid the appearance of pathological conditions. The requirements for such work are as manifold as the end sought and can not be considered here. It may be indicated that when the experimental plants are subjected to one-sided illumination as before a window, there are several adverse conditions that are not easily overcome. The common statement that the plants are to be rotated with the axis of the klinostat parallel with the window in order to neutralize the tropic effects of light leads to humiliation or self-deception. If the part of the plant sensitive to light is not at the center of rotation, it alternately as it revolves approaches and recedes from the light, receiving therefore more light on one side than on the other, and responding with phototropic curves. Or if so placed that it does not approach and recede from the window, it may on the horizontal klinostat, receive on one side its principal illumination from the sky and, on the opposite side of the plant, from the earth, thus again forming phototropic curves because of unequal stimuli. Several plants in a pot revolving on a klinostat with axis parallel with the window are likely to show curves because of the shadows which the plants cast on one another. Finally, the effort to neutralize the tropic effect of both light and gravitation on the same plants at the same time is so difficult as to require very special attention to the management of the light, unless the work is done in a plant-house with full exposure. A klinostat, such as has been devised, giving both vertical and horizontal revolution at the same time is not a guarantee against faulty results.

FREDERICK C. NEWCOMBE.
UNIVERSITY OF MICHIGAN.

## *QUOTATIONS.*

### THE PRESIDENTIAL ADDRESS BEFORE THE BRITISH ASSOCIATION.

MR. BALFOUR'S presidential address to the British Association naturally recalls another occasion in the history of that body when the chair was filled, not exactly by a prime minister, but by one who had been and very shortly again became prime minister. There is a marked resemblance between the address delivered at Oxford in 1894 by the late Lord Salisbury and that delivered yesterday in the seat of the sister University by his nephew and successor in office. It is entirely right and fitting that this should be the case, because on both occasions the British Association has listened, not to an expert in any one of the sciences, but to a student of the true *scientia scientiarum*. In a limited sense that proud title may be bestowed, as it was yesterday by Mr. Balfour, upon the science of physics. But the real *scientia scientiarum* consists in the assimilation by men of broad and sound general culture of the best and most assured results of the labors of specialists in many fields of research, and in the application of these results to life and conduct in domestic affairs, and to the solution of imperial problems in the wider arena of statesmanship. Of the countless millions who own allegiance to the king there is no man so deeply bound by duty and responsibility to master that difficult science as the prime minister of Great Britain. The obligation, it must be confessed, has sat very lightly upon many holders of that high office. We would fain hope that the appearance of two prime ministers in succession, showing incontestably that they possess a genuine appreciation of the vital necessity for knowledge in the direction of affairs, may be taken as a sign that a higher standard than that of political dexterity in appealing to ignorance