involved, I modified the wink reflex experiment so as to utilize not only a common stimulus, but a final common path terminating in the orbicularis. In this case the spread of excitation was provided for by voluntary closure of the lid. Notwithstanding these precautions the lid reflex was neither eliminated nor diminished in extent by the spread of excitation and subsequent voluntary closure. The agreement of the results in both reflex systems gives them a considerable degree of reliability.

Conclusion.—The theoretical difficulties and the experimental tests combine to render the drainage theory of inhibition improbable in the human neural system. Unless new evidence is discovered, inhibition by drainage ceases to be available as a principle of interpretation of human behavior.

* A more detailed statement of the drainage theory and its difficulties will appear in an early number of the *Psychological Review.*

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A TEST OF THE ELECTROMAGNETIC THEORY OF THE HYDROGEN VORTICES SURROUNDING SUN-SPOTS

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The extensive fields of force shown by the spectroheliograph in the hydrogen atmosphere surrounding sun-spots have been explained in two different ways: (1) as true hydrodynamical vortices, resembling great tornadoes, and (2) as electromagnetic phenomena, in which charged particles moving in the solar atmosphere are constrained by the magnetic fields in the spots to follow their lines of force. The principles involved in the electromagnetic theory have been applied to the explanation of the terrestrial aurora by Störmer, who has also developed this theory for the case of sun-spots.[1]

Störmer starts with the assumption that the magnetic field in a sun-spot is due to electrically charged gas molecules, moving at low levels along spiral paths around the center of the spot. In the numerical example given in this paper the thickness of this plane whirl is regarded as only a small fraction of its diameter, which is assumed to correspond with the diameter of the high-level whirl revealed by the hydrogen flocculi (generally ranging from about five to twenty times that of the spot). Störmer concludes that the projections of the lines of force of the sun-spot field (corresponding in his theory to the whirls in the hydrogen flocculi) are logarithmic spirals cutting the current lines of the underlying (invisible) sun-spot vortex everywhere at right angles. The direction of the apparent whirl shown by the hydrogen flocculi (curvature of the projected lines of force), clockwise or counter-clockwise, should then depend upon the sign, motion and direction of the invisible low level electric current surrounding the spot.

On the assumption that this current represents the flow of negatively[2] charged particles, five cases are possible:

(1) If the flow is circular around an axis corresponding to a solar diameter through the center of the spot, the lines of force will be plane curves situated in planes passing through this axis. Their projections on the solar surface will be straight lines radiating from the center of the spot, and the hydrogen flocculi should, therefore, appear as straight radial lines, if the spot is near the center of the sun.

(2) If the flow is spirally outward in the clockwise direction, the projected lines of force will show a clockwise curvature and the north pole of the spot will be upward; if the flow is spirally outward and counter-clockwise, the curvature of the projected lines of force will be counter-clockwise and the south pole of the spot will be upward.

(3) If the flow is spirally inward and counter-clockwise, the curvature of the projected lines of force will be clockwise and the south pole of the spot upward; if spirally inward and clockwise, the curvature of the projected lines of force will be counter-clockwise and the north pole of the spot upward.

Clockwise curvature, as used above, are such that if a point moves inward along the lines of force, the rotational component of its motion is in a clockwise direction. If the rotational component of the inward motion is counter-clockwise, the curvature is counter-clockwise.

Our studies of the Zeeman effect in sun-spots show that the angle between the lines of force and the solar surface, which is about 90° at the center of the spot, decreases gradually to about 0° near the outer edge of the penumbra, beyond which the field becomes too weak to be detected by the methods hitherto employed.[3] The observed field, therefore, does not correspond with the field of much greater diameter postulated by Störmer in his numerical example, but indicates that if a low level current is its cause,

this must be confined to the region within the penumbra and an extremely narrow zone surrounding it. Moreover, our photographs of the hydrogen vortices almost invariably show a practically radial structure near the spot, even when the curvature is very marked at greater distances. In the shallow layer of the chromosphere, to which the spiral structure studied in this investigation is confined, the projections of the lines of force due to a circular current would be practically straight radial lines. Even if the curved lines in vertical planes extending to higher levels were in question, as they might be in prominences, it is difficult to see how their projections could simulate the observed vortex structure or avoid betrayal by their changes in form as they are carried across the disk by the solar rotation.

If, however, in spite of the limited extent of the magnetic field and the radial structure of the hydrogen flocculi near spots, the electromagnetic theory can be modified so as to call for the observed vortices, the direction of curvature of the lines of force, clockwise or counter-clockwise, must nevertheless conform with the polarity of the spots in question if two assumptions are permissible. These assumptions are that the sign of the charge of the particles producing the field and the direction of any radial component of motion, inward or outward, are invariable in all single spots and in the preceding spots of bipolar groups. The long series of observations from which we have deduced the law of sun-spot polarity points to the invariability of the sign of the charge producing these sun-spot fields and the reversal of the direction (clockwise or counter-clockwise) of these low level whirls at every sun-spot minimum.[4] The question whether the motion in these whirls (at the level where the magnetic field is produced) is approximately circular or has a radial component is not yet settled, but there is no reason to suppose that any such radial component changes from inward to outward or vice versa. Assuming its direction, toward or from the spot, to be invariable, we may proceed to apply the polarity criterion. This is easily done, as the polarities of all spots are recorded at Mount Wilson, while the hydrogen vortices are also photographed there daily.

In spite of the thousands of spectroheliograms available, the number of hydrogen vortices suitable for the test is comparatively small. The great majority of spot-groups must be rejected, because of the disturbing influence of their numerous components, frequently of opposite polarities; the effects of turbulence in the solar atmosphere, especially near active groups; or the variation in the curvature of the stream lines with altitude, which may cause only the radial structure corresponding to a particular level of maximum Hα absorption to appear.

For the purposes of this test, I have selected at random 51 of the best hydrogen vortices on the Mount Wilson negatives, made on various dates scattered over the period 1908–1924. This permits the inclusion of vortices associated with spots belonging to three successive $11^1/_2$-year

cycles, covering two complete reversals of magnetic polarity.[3] Both unipolar spots and the preceding members of bipolar groups are represented, but all vortices are excluded in which there is uncertainty regarding the direction of whirl. The motion of the gases at the Hα level is inward toward the center of the vortex, and the terms clockwise and counter-clockwise correspond with the conventions used in the case of terrestrial cyclones.

UNIPOLAR SPOTS

	NORTHERN HEMISPHERE			SOUTHERN HEMISPHERE		
CYCLE	NO. OF SPOTS	POLARITY	WHIRL	NO. OF SPOTS	POLARITY	WHIRL
First	3	S	Counter-cl.	4	N	Clockwise
Second	8	N	Counter-cl.	6	S	Clockwise
	3	N	Clockwise			
Third	4	S	Counter-cl.			

BIPOLAR SPOTS

	NORTHERN HEMISPHERE			SOUTHERN HEMISPHERE		
CYCLE	NO. OF SPOTS	POLARITY OF PREC. SPOT	WHIRL PREC. SPOT	NO. OF SPOTS	POLARITY OF PREC. SPOT	WHIRL PREC. SPOT
Second	8	N	Counter-cl.	6	S	Clockwise
	2	N	Clockwise	3	S	Counter-cl.
Third	3	S	Counter-cl.			
	1	S	Clockwise			

Summarizing the polarities and directions of whirl without regard to date, spot-type, hemisphere or latitude, we find

NO. OF SPOTS	POLARITY	DIRECTION OF WHIRL
9	N	Clockwise
16	N	Counter-clockwise
13	S	Clockwise
13	S	Counter-clockwise

Evidently no relationship between polarity and direction of whirl is shown by these spots, taken at random from three $11^1/_2$-year cycles. The first table also indicates that after the reversal of the magnetic polarity of the spots at two successive minima[4] there was no corresponding reversal in the direction of whirl in the associated hydrogen vortices. The results therefore do not seem to support the electromagnetic theory.

Grouping for each hemisphere the whirls associated with unipolar spots and with the preceding members of bipolar spots, we find the following directions of whirl:

	NORTHERN HEMISPHERE	SOUTHERN HEMISPHERE
Unipolar Spots	15 counter-clockwise	10 clockwise
	3 clockwise	
Bipolar Spots	11 counter-clockwise	6 clockwise
	3 clockwise	3 counter-clockwise

Thus 81 per cent of the northern vortices and 84 per cent of the southern

vortices, irrespective of the $11^1/_2$-year cycle in which they occur, agree in direction of whirl with terrestrial cyclones. This agreement, taken in conjunction with the test of the electromagnetic hypothesis and the motions in the solar atmosphere above spots observed by Evershed and St. John, suggests that the hydrogen vortices are hydrodynamical phenomena, and that their direction of whirl is generally determined, not by the direction of whirl of the sun-spot vortices below them, but by the eastward and westward deflection, resulting from the solar rotation of currents flowing northward and southward in the solar atmosphere toward centers of attraction above sun-spots.

The exceptions may be due to the following causes, acting singly or in conjunction:

(1) The small relative drift resulting from the slow change with latitude of the linear velocity of the atmosphere caused by the sun's rotation.

(2) The turbulence of the solar atmosphere, especially near active spots, which may prevent the formation of an induced vortex, mask its structure, or determine its directions of whirl.

(3) The fact that about three-quarters of all sun-spots, at the time of their formation, are either unipolar or bipolar groups in which the preceding member is larger than the following member. In such cases, according to the working hypothesis now being tested, the direction of whirl of the hydrogen vortex induced over unipolar spots or over the preceding member of bipolar groups should, in general, follow the law of terrestrial storms. In cases where the following spot is larger than the preceding spot at the time of formation, the direction of the hydrogen whirl above the following spot should, in general, conform with the terrestrial law, while the preceding whirl should be of opposite sign if the influence of the following whirl outweighs that of the rotational drift. In bipolar groups where both spots are equal at the time of formation, each spot has an equal chance of starting a whirl following the terrestrial law, and local conditions may determine the outcome.

By means of a series of vortex experiments, continuing those previously described in these PROCEEDINGS,[5] I have been able to imitate many of the characteristic phenomena of the hydrogen vortices surrounding unipolar and bipolar spots. At a distance from the spots these vortices often closely resemble logarithmic spirals, which also characterize terrestrial cyclones. The tendency of the hydrogen vortices to show a rapid increase in the radial component of motion (suggesting marked acceleration) in approaching the spots is, however, so general that it deserves special consideration. Full details of this investigation will be given in the *Astrophysical Journal.*

I am indebted to Messrs. Nicholson and Ellerman and to Mrs. Humason for valuable assistance in connection with this paper.

[1] Störmer, "Researches on Solar Vortices," *Contributions from the Mount Wilson Observatory, No. 109; Astrophysical Journal*, **43**, 347 (1916). The electromagnetic theory of solar vortices was developed by Professor Störmer merely as a working hypothesis and not as an expression of his opinion regarding the nature of these phenomena. The legend of figure 9 in Professor Störmer's article is incorrect: the words "clockwise" and "counter-clockwise" should be transposed.

[2] This sign is not known. If positive instead of negative, the polarity of the spots in the cases given will be reversed. Near the end of his paper Störmer concludes that galvanic currents are more probable than convection currents of charged particles.

[3] Hale, Ellerman, Nicholson and Joy, "The Magnetic Polarity of Sun-spots," *Contributions from the Mount Wilson Observatory, No. 165; Astrophysical Journal*, **49**, 165 (1919).

[4] Hale, "The Law of Sun-spot Polarity," these PROCEEDINGS, **10**, 53 (1924).

[5] Hale and Luckey, "Some Vortex Experiments Bearing on the Nature of Sun-spots and Flocculi," these PROCEEDINGS, **1**, 385 (1915).

RECENT EVOLUTION IN MILK SECRETION OF GUERNSEY CATTLE

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Under the title of evolution much has been written with regard to the development of the morphological characters in the plant and animal. While such studies will undoubtedly remain the foundation on which the theory of evolution must rest for many years to come, it is of interest to view the progress of evolution in some of the characters which surround us and are familiar in everyday life. Furthermore it is important to consider the evolution of those parts which have to do with the everyday physiology of the animal rather than its more nearly structural form.

In the milk production and butter-fat concentration of milk we have an opportunity to make such a study of the progressive effect of the factors contributing to evolution of a given class of animals. These factors may be those which are innate and due to a selection of a better heredity for the animals making successive generations, or they may be due to those sociological causes found in the advance of our scientific knowledge on the effect of environment on the expression of the animal's innate capacities. Ordinarily it is difficult, if not impossible, to separate these two variables in any study. In dairy cattle it is doubly difficult in view of the rapid progress which has taken place recently in our knowledge of their proper feeding and management. For the purpose of this study it is proposed to show the changes which have taken place in Guernsey Advanced Registry