the equilibrium is also attained in an amazingly short time, and the readings take place while the bubbling goes on.

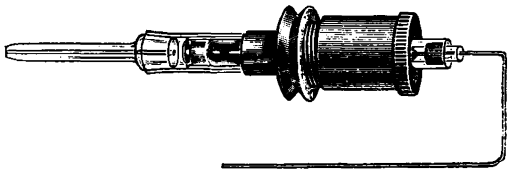

FIG. 3

As will be seen on the figure, the contact between the two half cells is established by raising the lower (calomel) cell until the capillary end of the syringe dips into the KCl.

The calomel element consists simply of a short test-tube, about 18 mm in diameter, with a platinum wire sealed at the bottom. When slipped in place in its water-jacketed stand, it rests on a rubber ring, the platinum wire touches a drop of mercury and the contact is established. The saturated cell may be replaced by others (Normal, 1/10th Normal), in two seconds.

Of course, the principle of the tilted rotatory electrode can be applied in different ways. For example, a simple model can be made by having the electrode and the vessel containing the liquid and $H_2$ connected through a rubber stopper, the whole being then rotated around its axis at such an angle that will allow the liquid to cover about one half of the electrode.

This apparatus, whether used with the simple tubular electrode for ordinary solutions, or with its tilted rotatory electrode, lends itself particularly well to measurements in series, as the setting up, filling of the syringe, saturating with $H_2$, and measuring the E.M.F. never takes more than five minutes with ordinary solutions.

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## A METHOD OF RELACQUERING THE STEMS OF LIVINGSTON ATMOMETER BULBS[1]

IN the course of certain ecological work in the Hawaiian Islands, it was found that the lacquer on the stems of some Livingston atmometer bulbs began to peel off after about six months' service in the field, and the writer was requested to make repairs on these bulbs. The exact cause of this peeling was not determined, but it was believed to be due to over-liberal use of alcohol, used to sponge off the bulbs to prevent algal growth.

Attempts to relacquer with ordinary white shellac proved quite unsuccessful, but after several trials with various mixtures, the following proved very satisfactory.

To 100 cc of prepared white shellac (already dissolved in alcohol), add 30 to 35 cc of absolute alcohol, and shake. To this stock add 30 to 35 cc of fresh Canada Balsam (not the histologist's preparation dissolved in xylol, but the fresh liquid balsam as purchased from a druggist) and mix well.

The bulbs to be repaired are then thoroughly dried out, and all old lacquer removed from the stems with a razor blade. In effecting this removal some care must be used not to damage the surface of the stem more than necessary, since such abraded patches are very absorbent and difficult to relacquer.

The stems are then painted with a thin coat of the above mixture and allowed to dry in a warm room, but *not in an oven,* and when dry are given a second or even a third coat, until when dry, the whole stem has a shiny and polished appearance.

SUMMARY

A method of relacquering the stems of Livingston atmometer bulbs by the use of a mixture of white shellac and Canada Balsam is outlined, together with certain precautions to be observed in the process.

JOHN STANLEY

# SPECIAL ARTICLES

## THE APPARENT PREPOTENT FUNCTION OF THE ADRENAL GLANDS[1]

ACCUMULATING evidence indicates the direction in which solution of the adrenal enigma may be found. The Harvard school of workers led by Cannon have in the last decade delivered a veritable broadside of reports on medulliadrenal activities, and almost universal support of their findings has been forthcoming. Emergency functions which are subserved through medullary agency appear to be established.[2] Observations by Cori and his colleagues direct attention to the importance of carbohydrate changes wrought particularly through the influence of adrenalin.[3] Early work by one of us on the adrenal

[1] Reported *in extenso* at a meeting of the University of Virginia Medical Society, January 18, 1932.

[1] Published with the approval of the director as Miscellaneous Paper No. 12 of the Experiment Station of the Association of Hawaiian Pineapple Canners, University of Hawaii.

[2] W. B. Cannon, "Bodily Changes in Pain, Hunger, Fear, and Rage," 1929.

[3] C. F. Cori, *Physiol. Rev.*, 11: 143, 1931.

medulla has related this tissue to the metabolism of carbohydrates.[4]

The recently devised methods of preparing effective extracts of the adrenal cortex have opened new approaches and allowed rapid advances in a phase of the subject generally acknowledged to be most difficult. For this development great credit is due to Swingle and Pfiffner[5] and to Hartman and his colleagues.[6]

Three years ago investigations were taken up in this laboratory on the nature of cortico-adrenal activity. Preliminary results strongly suggested a relationship of the adrenal cortex to carbohydrate metabolism in the organism. Further experiments in this[7] and other laboratories have indicated, however, that possibly protein metabolism and also renal and sexual activities may be governed by the cortical tissues.

Workers at Princeton and Johns Hopkins[8] have attributed considerable importance to the marked changes in renal secretion which follow adrenalectomy and the amelioration which is brought about by the administration of cortico-adrenal extract. The augmentation of blood urea in adrenal insufficiency, and the reduction effected by the extract, are also believed to be of outstanding significance. In a previous report[7] we have pointed out that such effects are probably indirect or secondary to more fundamental changes. Renal activity appears to follow the general and circulatory conditions in adrenal insufficiency. Animals which have died from adrenal deprivation do not show any significant alteration in kidney tissue; frequently, indeed, no pathological change has been observed in our experiments.

It can hardly be considered that the accumulation of unutilizable protein end-products in the body or the diminution in kidney secretion represent preeminently *critical* conditions in the adrenalectomized animal. Nor can it reasonably be entertained, furthermore, that precocious sexual developments which are observed to be brought about by cortical extract,[9] interestingly significant though they may be, reflect the *primary* activity of the adrenal cortex. That the effects on the sexual organs probably indicate the activity of a hormone of a second-class order, which is present in the crude extract, has been postulated. The essentially important cortical function must evidently be sought in other directions.

[4] S. W. Britton, *Amer. Jour. Physiol.*, 74: 291, 1925; *Physiol. Rev.*, 10: 617, 1930.
[5] W. W. Swingle and J. J. Pfiffner, *Amer. Jour. Physiol.*, 96: 153, 1931.
[6] F. A. Hartman, K. A. Brownell and W. E. Hartman, *Amer. Jour. Physiol.*, 95: 670, 1930.
[7] S. W. Britton *et al.*, *Amer. Jour. Physiol.*, 99: 9, 15, 33, 44, 1931.
[8] G. A. Harrop *et al.*, *Anat. Record*, 51: 39, 1931.
[9] E. L. Corey and S. W. Britton, *Amer. Jour. Physiol.*, 99: 33, 1931.

Apparently convincing testimony of the profound and possibly primary involvement of the adrenal cortex in the regulation of carbohydrate metabolism is now briefly presented. Cortico-adrenal extract prepared in this laboratory according to the method of Swingle and Pfiffner[5] has been employed.

Adrenalectomized animals (cats) have been found to suffer progressively severe derangements in carbohydrate metabolism following the operation. The glucose in the blood and the glycogen in the liver become profoundly reduced, the latter sometimes almost to the disappearing point. Muscle glycogen is greatly diminished, while the blood lactates are increased. The carbohydrate changes which we have observed in cases of experimental adrenal insufficiency are revolutionary enough in themselves to bring about death of the animal. Serious reductions which occur in the blood sugar and hepatic glycogen values appear to be of the greatest significance.

The administration of extract of the adrenal cortex to animals showing symptoms of adrenal insufficiency produces a remarkable reversal of the above disordered conditions. The liver and muscle glycogen and blood sugar levels are increased and the lactic acid values are concurrently decreased to the normal limits. The chemical changes appear in coincidence with the return of the animal to normal activity, *i.e.*, in the few hours following intraperitoneal injection of the extract.

Adrenalectomized animals which are obviously in a terminal dying condition, and which are known to be suffering crucially from glycogen depletion, may be completely recovered by the extract. Adrenalin given in dilution equal to that usually found in the cortico-adrenal extract used does not bring about similar restoration of the animal or such noteworthy carbohydrate changes.

The table herewith presents in summary our experimental results. The average muscle and liver glycogen values of the treated animals (series IV) are increased about threefold and twentyfold, respectively. it may be noted, in contrast to the values found in untreated adrenalectomized animals (series II).

Comparison has also been made of the effects of glucose injections in normal and adrenalectomized cats. In such experiments, large amounts of glycogen were found to be stored by unoperated animals, while those without adrenals showed relatively small glycogen changes from the previously observed low levels.

It is recognized that all theories of adrenal function are at present inadequate. The emergency theory offers an admirable interpretation of the mode of medulliadrenal activity, but knowledge of cortical function has been shrouded in conjecture up to the present

TABLE SHOWING GLUCOSE, GLYCOGEN, AND LACTIC ACID LEVELS UNDER VARIOUS EXPERIMENTAL CONDITIONS

| Series No. | No. cats used | Experimental conditions | Muscle glycogen average per cent. | Liver glycogen average per cent. | Blood sugar average per cent. | Blood lactic acid average per cent. |
|---|---|---|---|---|---|---|
| I | 5 | Normal, fasted 48 hours | .432 | 1.480 | .112 | .025 |
| II | 9 | Adrenalectomized, untreated | .208 | 0.067 | .048 | .038 |
| III | 5 | Adrenalectomized, adrenalin treated | .392 | 0.276 | .051 | .031 |
| IV. | 8 | Adrenalectomized, extract treated | .585 | 1.305 | .097 | .026 |
| V. | 6 | Normal, fasted 48 hours, glucose treated | .336 | 2.120 | .137 | .025 |
| VI. | 5 | Adrenalectomized, glucose treated | .398 | 0.275 | .206 | .035 |

time. That the cortex in contrast to the medulla is of premier importance in the bodily economy has, nevertheless, been long appreciated.

The adrenal glands are indispensable in the maintenance of life processes. Considering their size they are possibly the most important chemical factories in the body. Extirpation of the organs brings about death in a few days. After pituitary, thyroid or parathyroid removal life may be maintained for many weeks or months, or even indefinitely in some cases. The remarkably rapid dissolution following adrenalectomy is due specifically to cortical loss.

Even in the severest conditions of inanition and exposure of animals to cold, in death from insulin or strychnine convulsions, and in experimental diabetes, the hepatic and muscle glycogen values are not often found to be reduced beyond the low levels which we have observed in adrenal insufficiency. The muscle glycogen and blood glucose in hepatectomy are not depleted more thoroughly than in the case of animals dying from adrenal extirpation. And in hepatectomy as well as pancreatectomy death is admitted to be due primarily to carbohydrate deficiency.

The results given herewith indicate that the severity of the carbohydrate changes in adrenalectomized animals is fully sufficient to produce death. This eventuality is readily averted by cortico-adrenal extract administration, which results in rapid restoration of the normal blood glucose and liver and muscle glycogen values. A serious incompetence in storing injected glucose has also been noted in animals without adrenal glands. The cortex is indispensably important in maintaining, in cooperation with other organs, the normal metabolism of carbohydrates. This apparently represents the prepotent function of the adrenal cortex in the organism.

Possibly the primary defect in adrenalectomy is to be found in failure to store liver glycogen. Adrenal insufficiency may perhaps be considered in synonymity with glycogen insufficiency.

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## SOME EFFECTS OF OVARIECTOMY UPON BREEDING FEMALES

IT has previously been observed[1] that the secretions of the ovaries play an important part in the preparation of the mammary tissue of mice for the inception of the cancerous condition.

In a closely inbred strain of mice with a high incidence of breast cancer, it has been found that the age at which the appearance of the tumors was first noted follows a very regular unimodal curve which starts at four months, has its peak at eleven months and extends to the twenty-second month. The lower range of the standard deviation from the mean (11.6) of this curve falls in the 8th month. From this it is evident that the great majority (80–90 per cent.) of the females which are destined to develop cancer of the breast will do so between the seventh and fifteenth months.

The present experiment was conducted in an attempt to determine whether or not the high incidence of tumor in this strain is in any way controlled by ovarian activity.

Breeding females were separated from the males at seven months of age and were ovariectomized. They were then allowed to grow old under the same conditions as the control breeders. An equal number of breeding females were separated from the males at this same age and kept under similar conditions without operation, as controls.

There were then three distinct classes of animals in the experiment:

(1) Normal breeding females.

(2) Ovariectomized females which had been used as breeders for seven months.

(3) Females that were used as breeders for seven months and then separated from the males.

In the first class there were 1,938 females which

[1] Porter Fellow of the American Physiological Society.

[1] W. S. Murray, "Ovarian Secretion and Tumor Incidence," *The Journal of Cancer Research*, Vol. xii, No. 1, March, 1928.