Weston Electrical Instrument Corporation when we had furnished them with the following information: Nature of the thermocouple, range of temperature desired and total resistance in ohms of the thermocouple and its leads. Comparison of the readings of this instrument with the calculated temperature from e.m.f. measurements from room temperature to 1000° C. agreed to within ± 10° C. As the temperature of various points within the oven may vary by as much as ± 25° C., this accuracy is quite adequate.

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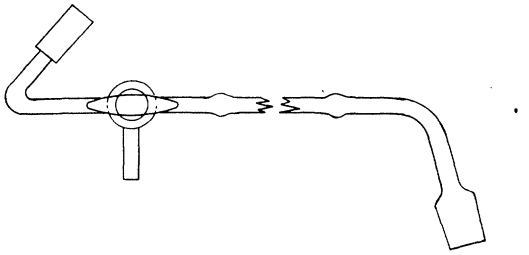
MODIFICATION OF THE BACKLIN-KIRK COMBUSTION CHAMBER FOR MICRO-DETERMINATION OF CARBON AND LIPOIDS

IN the manometric determination of lipoids the combustion chamber is highly evacuated at the time it is to be removed from the Van Slyke manometer. In the original Backlin chamber[1] a stop-cock is present at the top of the combustion chamber which may be opened at this time to relieve this pressure which facilitates removal of the rubber connection to the manometer. At best this operation involves some risk of damaging the manometer. The chamber, as modified by Kirk,[2] has eliminated this stop-cock, thus necessitating removal of the rubber connection against the low internal pressure of the chamber. A simple method of reducing the hazards of such procedure is to add a three-way stop-cock (*cf.* diagram) in the



delivery tube of the chamber. After the upper cock of the Van Slyke absorption chamber has been closed this stop-cock may be turned to admit atmospheric pressure before detaching the delivery tube.

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SPECIAL ARTICLES

A PROOF OF THE LAW OF EFFECT

PSYCHOLOGISTS and physiologists all agree that the behavior of man and of many other animals is modifiable by the experiences of life. He learns, so that the situation, S, which at first evokes, say, responses 1, 2, 3, 4 and 5 equally often, comes to evoke one response, say 4, always or ninety-nine times out of a hundred. The connection S → 4 has become enormously strengthened relatively to S → 1 or S → 2 or S → 3 or S → 5.

Concerning the forces producing learning there has been great disagreement. The writer (1898, 1914 and 1931) has maintained that the after-effects of a modifiable connection work back upon it, and that, in particular, a satisfying state of affairs accompanying or directly following a connection strengthens it. Troland maintained a similar doctrine.

The great majority of psychologists have maintained, on the contrary, that the strengthening of any connection is due to forces operating within the connection itself or prior to it. Repetition or frequency of occurrence, recency, intensity, finality or consummatoriness, tendency to attain equilibrium, and other features of the process have been alleged to be adequate to explain the strengthening of connections.

I have presented recently evidence from a variety of experiments to show that a satisying after-effect of a connection does in fact strengthen it under conditions equalized in respect of all other forces than the satisfying after-effect.[1] It is the purpose of this report to present an entirely independent experimental proof of the strengthening influence of a satisfying state of affairs upon the connection of which it is the after-effect and important new facts concerning the method of action of that influence.

We provide in an experiment a long series of situations to each of which several responses are possible, one of which is arbitrarily followed by a reward, any other being followed by a punishment. For example, a series of words is said by the experimenter, to each of which the subject may respond by any number from 1 to 10. If he says the number that has been chosen to be "right" he is rewarded; if he says any other, he is punished. So we have a long sequence of connections and after-effects, in the form Word 1 → number, reward or punishment, Word 2 → number, reward or punishment, Word 3 → number, reward or punishment, Word 4 → number, reward or punishment, etc.

[1] E. Backlin, *Biochem. Zts.*, 217: 483, 1930.

[2] Peters and Van Slyke, "Quantitative Clinical Chemistry-Methods," Williams and Wilkins, 1932.

[1] "The Fundamentals of Learning," E. L. Thorndike, 1932.

This series is repeated again and again. We quote the results for the first ten words in trials 1 to 4,[2] from a sample record.

	Trial or round 1	Trial or round 2	Trial or round 3	Trial or round 4
catnip	2	4	10	2
cedar	3	3	6	2
chamber	1	2	9	8
chorus	8	10	7	6
dally	4	8	5	4
dazzle	C2	6	9	1
debate	9	7	2	5
deduce	5	2	2	2
early	4	C5	C5	C5
effort	3	6	C7	C7

The time-intervals were as follows: One unit of the series from word to word or number to number took about 2.2 sec. The time from the announcement of "Right" or "Wrong" to the approximate mid-point of the word–number connection to which it belonged was about 0.5½ sec. The time to the mid-point of the next preceding connection was about 2.8 sec., to the next, 5.0 sec., to the next, 7.2 sec., and so on. The time to the mid-point of the word–number connection following the announcement of "Right" or "Wrong" was 1.7 sec. The time to the next following was 3.9 sec.; to the next, 6.1; and so on.

In such a series the rewarded connections are strengthened, but that fact is not our present concern. The fact to which I invite attention now is that the punished connections do not behave alike, but that the ones that are nearest to a reward are strengthened most. The strengthening influence of a reward spreads to influence positively not only the connection which it directly follows and to which it may be said to belong, but also any connections which are near enough to it. We may measure nearness in terms of time or in terms of number of connections or steps. Thus the punished connection *catnip* → *2* in Trial 1 preceded the reward for *dazzle* → *2* by about 11.6 seconds and by 5 connections or steps. The punished connection *cedar* → *3* in Trial 1 preceded the reward of *dazzle* → *2* by about 9.4 seconds and by 4 connections or steps. The punished connection *dally* → *4* in Trial 1 preceded the reward of *dazzle* → *2* by about 2.8 seconds and by one connection or step.

The amount of strengthening is measured by the percentage of repetitions in the following trial. For example, for the ten subjects of the experiment chosen as an illustration we find the following for punished connections alike in all respects save their proximity to a reward:

	N	Percentage of repetitions in the following trial
One step removed	4136	26.4
Two steps removed	2250	23.6
Three or four steps removed	1933	21.0
Five or more steps removed	1228	20.8
Three or more steps removed	3161	20.7

For 905 connections like these in all respects, save that a reward directly followed and belonged to them, the percentage of repetitions was about 50.

In such experiments the fact that a person responds to a word by a certain number makes him more likely to respond to that word at the next trial by that same number, even though the response was punished. The connection is strengthened more by being made than it is weakened by being punished. This has been indicated by Thorndike ('32, p. 112, and p. 280ff), and demonstrated by Lorge in articles to appear shortly in the *Journal of Experimental Psychology* and by the present series of experiments. The best measure of strengthening due to one occurrence of a punished connection at some specified proximity to a reward is then the excess strengthening over that due to one occurrence of a punished connection so remote from a reward as to receive zero influence from it. In the illustrative experiment those excesses are 5½ for one occurrence of a punished connection one step away from a reward, and 2½ for one two steps away.

We have made fifteen experiments, using various sorts of learning. The results show that a satisfying after-effect strengthens greatly the connection which it follows directly and to which it belongs, and also strengthens by a smaller amount the connections preceding and following that, and by a still smaller amount the preceding and succeeding connections two steps removed.

One occurrence of a rewarded connection produces an average excess strengthening of 22 (per hundred) with a probable error of 3. One occurrence of a punished connection next to and preceding a rewarded connection produces an average excess strengthening of 4 (per hundred) with a probable error of 0.4. A punished connection occurring after a rewarded connection receives an excess strengthening of about 5 (per hundred). A punished connection between two rewarded connections receives an

[2] In this experiment the series of words, each with its "right" number, was read to the subject first, so that correct choices even in the first round would be a matter of ability plus chance rather than of chance alone.

excess strengthening of 7½ per hundred. Punished connections two steps and 5 or more seconds away from a rewarded connection are influenced favorably by it.[3]

The proof that a satisfying after-effect strengthens directly the connection producing it, and also other connections in close proximity to it, is important, because it explains selective modifiability. It solves many problems for which the forces of frequency, recency and intensity are inadequate. It accounts for the true contentions of purposivism without recourse to mystical agencies.

The physiological explanation of the influence of a satisfying after-effect is as yet unknown, just as the physiological explanation of the influence of mere repetition of a connection is unknown. But we can now proceed to find out facts about the former which may lead us to a physiological explanation of it, and which are valuable in any case.

Thus, Dr. Rock has measured the effect of differences in the intensity of the reward. I have measured, though as yet very imperfectly, the effect of differences in the time-interval between the connection and its reward. I have measured the effect of differences in the relevance of the reward. Dr. Lorge is proceeding to measure the influence of an occurrence that is neither rewarded nor punished, so that we may compare the strengthening by it with the strengthening by various after-effects.

I can already frame a physiological explanation which demands little more from the nervous system than any doctrine of facilitation demands. And I venture to prophesy that the physiology of strengthening by the after-effects of a connection will be understood sooner than the physiology of strengthening by its sheer repetition.

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IS MALIGNANCY DUE TO A PROCESS ANALOGOUS TO SOMATIC MUTATION?

MALIGNANT tumors develop in the walls of parasitic cysts of *Cysticercus fasciolaris,* the larval stage of *Taenia taeniaeformis* (*crassicollis*), the common tapeworm of the cat. Tumors have been produced experimentally by feeding rats *Taenia* eggs derived from cat feces. The shells of these eggs are digested off in the rat's intestine, and the oncospheres attach themselves to the wall of the intestine, work their way into the blood vessels of the gut wall and are carried to the liver by the portal circulation. They are strained out in the liver capillaries and grow rapidly forming clear vesicles, which about the seventh day become visible to the unaided eye.

At this stage some of the larvae have been transplanted to the subcutaneous tissues of other rats, but for the most part they have been allowed to continue their development in the liver. In either locality the growing larvae initiate considerable proliferative activity in the surrounding tissues which results in the formation of fibrous cyst walls. After from 8 to 27 months the cells of these cysts may show active and often atypical proliferation and may undergo malignant changes.

Most of the tumors produced have been polymorphous cell sarcomata, spindle cell sarcomata or a mixture of the two. The rarer tumors were of the following types: fibroma, chondroma, osteochondroma, chondrosarcoma, osteochondrosarcoma, fibrosarcoma, liposarcoma, adenoma and carcino-osteochondrosarcoma.

At the beginning of the present analysis (June, 1932) 52,223 rats from completed pedigreed matings had been autopsied. Of these 26,172 were infested with the parasite, 13,120 had survived the infestation for at least eight months (the minimum period of infestation observed in the case of a bearer of a *Cysticercus* sarcoma) and 3,285 had *Cysticercus* sarcoma. Besides these, 68 purchased animals and 316 of the unpedigreed descendants of purchased animals had the malignant complication of the *Cysticercus* disease.

Taenia eggs from cats obtained from various parts of the city and suburbs and others infested in the laboratory were equally effective in producing the disease and the associated malignant tumor, but rats showed marked strain and family differences in the proportion of individuals which developed both the disease and the complication.

Early in the experiments it was noted that the duration of the irritation (that is, the residence of the parasite in the liver) before the appearance of the malignant phase of the *Cysticercus* disease varied over a period of 19 months, which is half the maximum life span of our laboratory rats. Furthermore, the proportion of tumor bearers increased directly from the eighth to the twentieth month of infestation. It was also noted that usually only one cyst and in some of the early tumors only a small area of the cyst wall showed the malignant transformation, although the host might have had one to one hundred other cysts which were benign. Occasionally two or more apparently independent *Cysticercus* tumors occurred in the same host.

The clue to the explanation of the strain and family differences and to the variations in the duration of infestation appeared in the present analysis, when it was observed that in the 3,669 bearers of

[3] The detailed results for all the experiments will be published at an early date.