grain depends for the most part upon division of the cambium and the events that follow. When the cambium divides tangentially, xylem or phloem will be formed from the resulting daughter cells. Circumferential increase of the cambium is accomplished by radial (anticlinal) division; by oblique radial division; or, by oblique transverse division followed by increase in size and accompanied by gliding growth; and, by division of cambium initials to form new ray initials (Bailey).[4] It is in the non-stratified type of cambium, as reported by Bailey, that the oblique transverse wall is more commonly formed. Practically all trees reported to have spiral grain possess this type of cambium. The vertical growth of a tree comes about from activity of apical meristems, while very little or no vertical increase occurs at the base of the tree. Radial increase of the tree follows upon cambial activity, with yearly increments of xylem and phloem. Radial division of the cambium is found less frequently in tangential sections than tangential division, as well as oblique transverse division, which may immediately follow radial division. Fig. 1, accompanying this article, was made from a photomicrograph of a tangential section of cambium cut in celloidin, in which division occurred (1) by a radial cell plate; and (2) transversely by an oblique cell plate. The cell plates which subdivide the mother cell into four daughter cells show no pits. What is the future of these daughter cells? We are faced with the fact that the daughter cells in their vertical increase must be given some space in some way, whether or not we accept it as a manifestation of gliding growth. The oblique transverse wall seems to determine the pitch of the path they take in elongation, since they are held in a sort of straight jacket, which prevents true perpendicular elongation. This path of elongation is diagonally around the tree, or spiral, since it is a path of least resistance. After maturation of the daughter cells has occurred, further divisions are tangential, which causes radial increase. The resulting xylem mother cells and their daughter cells, as well as phloem mother cells and their daughter cells, upon maturation follow in the path of the spirally directed cambium initials. As this process continues from year to year with a further radial enlargement of the stem, the spiral path deviates more from the perpendicular and approaches a closer spiral. However, if the oblique transverse wall changes about and starts a path in the opposite direction, the tier of xylem and phloem which follows upon it balances the spiral in the opposite direction, and no spiral grain is apparent. The present writer appreciates an element of uncertainty in this apparently plausible explanation of the cause of spiral grain in trees.

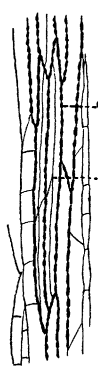

Fig. 1

Knorr[5] suspected that "intensity of the twist" was more pronounced in the later wood of branches, while Herrick[6] observed that pitch of the spiral grain increased with age of the tree, and figures to demonstrate this are recorded. These observations would seem to substantiate somewhat the above explanation. Seifriz[7] interprets spiral grain as a phenomenon based partly on heritable protoplasmic qualities and in part on physiological factors. It is a matter of great uncertainty, whether the cause of the formation of an oblique transverse wall could be attributed to the Liesegang phenomenon. Moreover, the seemingly wide-spread spiral tendency among many plants and animals, which Seifriz believes to be of protoplasmic origin, seems rather remote in its relation to the causal factors of spiral grain. The spiral tendency in trees is fortuitous, but it would seem a natural assumption that parent spiral-grain trees and their progeny should show variations such as occur in all offspring. Consequently, clockwise, counter clockwise and straight grain trees should be expected in any stand of timber trees.

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THE POISONING OF FISH

IN the construction of an artificial lake in Davis County, Iowa, for the Fish and Game Commission, it seemed advisable to destroy the detrimental and infected fish which occupied the creek running through it. The fish deemed undesirable were the black bullhead (*Ameiurus melas*), a runt, the black-striped shiner (*Notropis dorsalis*), and the green sunfish (*Apomotis cyanellus*), the two latter heavily infested with trematode larvae. Carp and gar may also have been present.

On account of the character of the creek bed, sein-

[4] I. W. Bailey, *Amer. Jour. Bot.*, 10: 499–509, 1923.

[5] F. Knorr, *Jour. Heredity*, 23: 49–52, 1932.

[6] E. H. Herrick, SCIENCE (n.s.), 76: 406–407, 1932.

[7] William Seifriz, *loc. cit.*

ing was impractical. It was therefore necessary to find a safe and economical method of poisoning the fish. Since the literature on this subject seems to be quite meager, it is felt that a short note on our experiments might prove helpful to others who may have the same problem.

A solution of copper sulfate in the concentration of 8 pounds per million gallons of water was first tried. Whipple[1] states, in part, that carp are killed in a solution of 2.8 pounds of copper sulfate per million gallons of water, and catfish in 35 pounds of copper sulfate per million gallons of water. In our experiment, we began at the upper end of the stream and constructed a series of small dams, making a number of pools in which the concentration of copper sulfate could be fairly accurately estimated.

In the first of these pools a solution of 8 pounds of copper sulfate per million gallons of water was used. At the end of 55 minutes no fish seemed to be affected. The concentration was then increased up to 7,500 pounds per million gallons; still no lethal effects were observed even after three hours, nor did the fish seem distressed. In other pools where the same dosages were used no dead fish were found after 48 hours of exposure to the solution.

Chlorinated lime with a chloric content of 24 per cent. was next used. In a solution of 1 pound per 2,000 gallons of water, fish were killed in twenty minutes. In quiet water, a solution of chlorinated lime in the ratio of 1 pound per 5,000 gallons of water was effective, but after a longer time. In the running water, a solution of 1 pound per 2,000 gallons of water affected the fish after 10 minutes' exposure, and at the end of 20 minutes respiratory movements ceased. In still waters, a weaker solution was slower in action, but at the end of 48 hours practically all the fish were in a dying condition.

Our experiments show that in out-of-door conditions copper sulfate, even in high concentrations, proved ineffective, while a chlorinated lime solution of 1 pound per 2,000 gallons of water concentration killed the fish tested in 20 minutes or less.

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1 "The Microscopy of Drinking Water," 4th ed., 392, table 94, 1927.

PUNISHMENT AND REWARD IN LEARNING

IN a recent article in SCIENCE[1] and in other papers,[2] Thorndike has called attention to the apparently anomalous influence of punishment on learning. He reports that when punishment follows an act, the underlying connection, instead of being weakened, is either unaffected or strengthened. This is contrary to expectation and to the results of other studies. Thorndike attaches great significance to these results, suggesting that from the psychological point of view, punishment is not the opposite of reward.[3] Thorndike and, later, Lorge[4] suggest that in such cases the connection derives enough strength from just functioning to offset the potential weakening influence of punishment.

It should be pointed out that in Thorndike's experiments and in this discussion "punishment" means merely telling the subject that he has made a wrong choice.

In a series of experiments[5] I find that the weakening influence of punishment is also offset by the strengthening influence of the medium which carries both punishment and reward. To inform a subject that he is right or wrong one must use some physical medium, such as sound or flashes of lights, or the like. I find that the application of the medium itself, (*e.g.*, when it is divorced from all information as to success or failure) has a definite strengthening influence. When the medium is made to carry information of failure, its strengthening influence is reduced, and when it indicates success, its strengthening influence is increased.

The various extents to which a bond is strengthened by the application of different conditions is illustrated graphically below.

O ——— M + P ——— M ——— M + R

Here O represents the extent to which a bond is strengthened when the associated act is followed by nothing whatever, M the amount of strengthening due to the application of the *medium alone,* M + P the amount of strengthening due to the application of the *medium conveying punishment,* and M + R the amount due to the application of the *medium conveying reward.*

From the above illustration it will be seen that with reference to O the gross influences of M + P and of M + R are in the same direction but of different extents, but that with reference to M the net influences of P and R are in opposite directions and may be of equal extent. That is to say, that when punishment and reward are corrected for the influence of the conveying medium they may (in these experiments) be considered as psychological opposites.

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1 SCIENCE, 77: 173, February 10, 1933.

2 "The Fundamentals of Learning," 1932; "Human Learning," 1931; "Comparative Psychology Monographs," 1931–32, 8, no. 4.

3 "The Fundamentals of Learning," p. 313.

4 *Jour. Exper. Psychol.*, 16, 177–207, 1933.

5 The details of this series will appear in a future issue of the *Journal of Experimental Psychology.*