out in a centrifugal direction away from the piece of tissue implanted; thus a more or less radial and often tree-like branching arrangement of the outgrowing cell strands is produced. We have discussed above the stereotropic response. The centrifugal arrangement can be conveniently studied in amœbocyte tissue. Several years ago we tested experimentally the possible significance of the galvanic current and differences in electric potential in the centrifugal direction of cell migration. Our results were negative, neither did the direction of light rays influence the movements. It is very probable that the centrifugal growth depends upon the following two factors, (1) the tendency of the cells adhering to each other to separate, to send out pseudopodia and to move in such a direction that two or more cells forming a clump become isolated, (2) the tendency of a healthy cell to continue for a certain time to form pseudopods at the same part of the cell at which this process has been induced. These two factors, the existence of which observation of the moving cells verifies, would be sufficient to produce the centrifugal movement, which would thus partly represent a statistical chance phenomenon. Inasmuch as the isolated cells and the cell clumps become less frequent with increasing distance from the central piece, this would insure a centrifugal, more or less net-like growth, or in other cases a tree-like growth, such as we found under various conditions. We may assume that the same factors play a role during the growth within the organism.

Tissue formation depends upon a combination of cell movements and cell divisions. We have seen that contact with a solid base is a prerequisite for the outgrowth of tissues; but in addition we found more recently that in various tissues growing in vitro, a very active mitotic cell division may be induced in favorable liquid culture media supplied with a sufficient amount of oxygen, even under conditions which do not permit an active outgrowth because of the lack of a solid surface along which the cells would be able to migrate.[10]

While it is thus possible to separate experimentally mitotic cell proliferation and migration of cells in tissue cultures, the same stimulus usually tends to produce both of these reactions together. A suitable change in environmental conditions usually brings about alterations in the cells, which lead to both mitotic cell division and migration in tissues, provided they are capable of both of these activities. The difference in actual response on the part of different tissues depends upon the structure of the tissue, which enables certain kinds of cells to migrate very readily and to divide only with difficulty or not at all, and other tissues to divide much more readily than to make amœboid movements.

The stereotropic reaction of tissue cells to an environmental change consists of two component parts, (a) of amœboid movement and (b) of alterations in the consistency of the outer layer of the tissue cells; the latter change may vary very much in different cases. In some cases a previously non-sticky surface may become sticky as the result of the environmental change (as in amœbocytes, the free surface of endothelial cells, perhaps in lymphocytes and certain other cells), while in other cases a certain degree of usually circumscribed adhesiveness pre-existed, but became more general or stronger as the result of the environmental change.

These changes in motility and adhesiveness are responses of a living organism to a stimulus. This is quite apparent in the case of the amœbocytes and in the reactions of the experimental amœbocyte tissue, where a mechanical stimulus leads to that far going alteration in cell consistency, which makes possible both stereotropic reactivity and tissue formation; but in principle, conditions are similar also in the case of other tissues.

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[10]Leo Loeb and Moyer S. Fleisher, *Journ. Med. Research*, 1919, XL, 509.

THE SHENANDOAH CAVERNS

THE exhibition of caverns to the traveling public is noted by the United States Geological Survey as a growing industry in the Shenandoah Valley of Virginia. The famous Valley Pike, now a link in the New York to Atlanta highway, is traversed yearly by thousands of automobile tourists, and no one has adequately

seen America who has not visited one or more of the caverns in the Shenandoah Valley. Until recently the only caverns that were accessible to the public were the celebrated Luray Caverns, in Page County, and Weyer's Caves, in northern Augusta County, near Grottoes. However, within twelve months, the Endless Caverns, near New Market, in Shenandoah County, have been opened, and on May 31 another cavern near Mount Jackson, also in Shenandoah County, made its first bid for public favor.

The latest-opened caves have been named Shenandoah Caverns. They are about three miles south of Mount Jackson and two miles west of the Valley Pike, with which they are connected by a macadamized road. The visitor descends into these caverns by a concrete stairway and soon sees the first stalactites, which appear as stout daggers of crystallized lime carbonate, hanging like icicles from points where surface water drips from the limestone roof. At the foot of the stairs is the spacious anteroom to a long chain of high-vaulted chambers connected by narrow passageways, forming in general plan a gigantic letter S, all illuminated by cleverly concealed lights. Attractive natural decorations are found in every room. Here the side walls are covered by fluted veneer done in crystal stucco, there in graceful drapery hang creamy lambrequins in ruddy-tinted stripes. From place to place, singly or in groups, are pendent stalactites and uprising stalagmites—the first inverted narrow cones fed by trickling films of lime-bearing water; the second pillars or columns fed by spattering drops of the water. In one room midway down the chain the show piece is a narrow 30-foot cascade of white glittering crystal flanked by twin falls of pale translucent ocher. At the base and to the rear of this diamond cascade, visible by peering between slender columns of oriental alabaster, is the "Fairy's Secret," a tiny pool illuminated in due season by animated torches, presumably carried by a brood of phosphorescent larvæ of some insect, perhaps a small fly that is commonly present in such caverns. At the end of the developed portion of the cavern a chamber of high vaulted roof suddenly gives place to a low-ceiled room containing a lakelet in which are mirrored a multitude of delicate stalactites—a pool of a thousand crystal pendants.

According to A. C. Spencer, of the United States Geological Survey, the caverns of the Shenandoah Valley are far more numerous than the casual visitor would be likely to imagine. The rocks in which the broad trench-like valley has been excavated by water are mainly limestone, and wherever these rocks occur the existence of caverns is indicated by two unfailing signs—the presence of innumerable water sinks and the absence of brooks tributary to the rather regularly spaced creeks. The brookless tracts receive a due share of rainfall and must obviously contribute water to maintain the flow of the creeks and rivers, but their contributions are not delivered by way of the surface drains, but through underground channels that supply copious springs in the deep valleys. The sinks are rude funnels, by means of which surface waters are diverted to the subterranean waterways.

The development of extensive underground waterways in limestone formations like those of the Shenandoah Valley hinges upon the two geologic facts that large masses of rock are always cut by joints and that limestone is dissolved by rainwater, which always contains more or less carbon dioxide. Surface water entering fissures, joint cracks and bedding planes attacks the limestone walls and thus by a process of etching converts close fractures and joints into relatively open crevices. As this process of solution goes on lateral connections will be made from crevice to crevice, and the downward etching of the linked openings will be halted only when the subsurface water channels have become closely adjusted to the water table controlled by surface streams. Thus it is that the caverns of the Shenandoah Valley are formed.

THE SALT LAKE CITY MEETING

THE sixth annual meeting of the Pacific Division, American Association for the Advancement of Science, held at Salt Lake City, June 22 to 24, 1922, in conjunction with a summer session of the national association, was