

tion and enter at the bottom of the same striation. Midway between two adjacent striae little striae lower than the others tend to form but are soon destroyed by the rotations mentioned above, the dust particles forming these lower striae being pulled away in opposite directions and forced into the two adjacent striae at the bottoms of the same. Thus the dust particles are pulled away from a line approximately midway between adjacent striae in opposite directions and forced into the major striae at their bottoms. When the agitation of the dust particles is violent the striae at the antinodes, especially those extending completely across the tube as disks, do not remain always in one position but very often merge into each other. When the agitation is less violent, as in the case where the striae do not extend completely across the diameter of the tube from top to bottom, there seem to be two orbits of rotation on each side of a striation, one above the other, rotating in opposite directions so that the direction of rotation is from near the middle of the striation, one orbit entering the top of the striation and the other orbit entering the bottom of the striation, somewhat as two meshed cogs, one directly above the other, would rotate.

While there seems to be experimental evidence in the scientific literature for the support of the explanation of the formation of striae in a Kundt's tube as given by Koenig,<sup>1</sup> the author is inclined to believe that the formation of these striae may be satisfactorily explained in a manner similar to the explanation for the formation of ripple-mark in sand as given by Darwin.<sup>2</sup>

In the summer of 1927 the author was able to maintain two paper segments (cut in a shape similar to a dust striation) upright in the tube. When pith dust also was present a violent somewhat elliptically shaped rotation, about an inch long along its major axis parallel to the axis of the tube, was produced. Also a single segment of paper similar to a dust striation has been maintained upright in the tube for a short time by means of the air vibrations.

In the summer of 1927 striae were obtained by the author by allowing puffs of air, produced by interrupting a continuous air stream from a small glass nozzle by a rotating siren disk, to enter a glass tube, one end of which was corked and in which pith dust was distributed along the bottom. These striae were formed when the air jet was interrupted too slowly to produce an audible tone.

The author is continuing his investigation of these striae photographically and is making an effort to

determine the effects produced by forming them in various gases, in tubes of various diameters and lengths, and by sources of various frequencies.

ROLLA V. COOK

BETHANY COLLEGE

### A HYPOTHESIS ON THE CAUSATION OF CANCER<sup>1</sup>

ACCORDING to genetics, all variations in species are due either to mutations of the chromosomes or to recombinations of chromosomes in which mutations have previously occurred. If this mutation occurs in a germ cell, it will result in a hereditary characteristic that will persist until the line is extinct or until a new mutation intervenes, but if this mutation occurs in any other cell of the body except a germ cell, it will persist only as long as the particular individual lives, and will become extinct with the death of this individual, unless the tissue of mutated type cells is transplanted to some other sustaining medium. (All cells other than germ cells are called somatic cells.) This latter type of mutation is called "somatic" mutation. Such mutation may be lethal or beneficial.

*Cancer* is generally regarded as a localized lawless and unrestrained growth of epithelium, the cells (somatic) having become parasitic cells, and attacked the host. The only cure thus far discovered is an early destruction or removal of the abnormal parasitic cells.

The causation of cancer apparently lies in the disturbed balance of the forces of stimulating and restraining growth in the affected cells, and is probably essentially a faulty cellular chemistry.<sup>2</sup>

Unequal distribution of chromosomes in somatic cells may result in abnormal tissue and also a change in the physicochemical components of one or more genes in those cells.

This hypothesis then considers cancer as due primarily to mutation in a somatic cell. That the mutation is *lethal* is borne out by its subsequent course. Its ultimate result is death of the individual, the mutation being of a somatic cell and not of a germ cell. Whether cancer is a heritable factor or not has never been clearly shown, but it is entirely possible that the *lack of resistance* to the same type of mutation reappearing in subsequent generations of the same line could be passed on as an inherited characteristic, as shown by the well-known frequency of cancer as a hereditary taint in such lines.

Therefore, the theory of a bacterial causation of

<sup>1</sup> The authors are deeply indebted to Dr. Herbert Fox, director of the Pepper Laboratory at the University of Pennsylvania, and to Professor W. R. Coe, professor of genetics and biology at Yale University, for their interest, advice and encouragement in the publication of this paper.

<sup>2</sup> Ferris, "Evolution of Earth and Man," p. 213.

<sup>1</sup> *Wied. Ann.*, 42: 353, 549, 1891.

<sup>2</sup> *Proc. Royal Soc.*, 36: 18, October 18, 1883.

cancer seems to be unnecessary, since it can be explained by a physicochemical fault, and if bacteria are found it is probably accidental.

Boveri<sup>3</sup> (1902) suggested that irregular somatic mitosis might well account for the peculiar behavior of these peculiar cells. He did not include other mutations, however.

*Cancer cells* show abnormal metaplasia. Instead of "flattening out" like normal epithelial cells they remain "swollen up." There is also a shift of the nucleus towards the center. They become parasitic and live at the expense of their sister cells.

Now something has happened in such cells to change their normal metaplasia. Bacteria have been held as the causative factor in this "change of stream," but this conviction is growing less and less. *True sarcoma*, however, has been found around tape-worms (Francis C. Wood) and other intestinal worms (Philadelphia Zoo Laboratory). Another factor often advanced has been a genetic factor where cancer is regarded as a true Mendelian recessive.

This hypothesis, it might be argued, would stand or fall on whether the Mendelian law is applicable to cancer families.

However, this hypothesis holds that it is a mutation of a *somatic* cell and not of a *germ* cell, that the mutation itself dies with the individual and is not transmitted directly, that the normal resistance to such imbalance may be weakened and this lowered resistance may be transmitted as a dominant or recessive characteristic or as a multiple factor. This factor would be subject to Mendelian laws.

*Note:* It is a well-known fact, genetically, that mutations experimentally can be speeded up tremendously by exposure to stimulating amounts of radiation and the X-ray effect, where greater doses are destructive. Perhaps the frequently observed "skin-cancers" in Roentgenologists are due to such mutations occurring from *stimulating* exposure to the X-ray effect (the release of the cathode ray).

Would it be possible that some such agency is active in the greatly increased prevalence of cancer? Of course, it is understood that other factors are concerned both in its relative and actual increase.

Evolutionary variations in species, due to mutations in the germ cells, have been very irregular in their intensity. There have been periods of extreme activity in this field, gradually shading down to a comparatively quiescent state. It is held by some that these periods of great evolutionary expansion have coincided with the great crustal revolutions of the earth, and that they may have been due to the influ-

ence of emanations from the radioactive ores that were released in these upheavals.

It is possible that in this intensive electrical age there may be radioactivity and rays that are beyond our present knowledge, which might be sufficient to stimulate mutations in the chromosomes of somatic cells. Again this same electrical influence might be of cosmic origin.

Babcock and Collins<sup>4</sup> performed an experiment with *Drosophila* comparing the rates of occurrence of sex-linked lethal mutations in a street-car tunnel in San Francisco and in their laboratory. A location was discovered in the tunnel where the natural ionization radiation was fully twice as great as the radiation in their laboratory in Berkeley. The difference in rate was 2.5 times the probable error for the flies which had been exposed in the tunnel. In other words, the rate of lethal sex-linked mutation was more than doubled when the flies were transferred to a more highly ionized location.

Hanson and Heys<sup>5</sup> performed independently similar experiments in a carnotite mine in Colorado where the air was strongly ionized. Their results check closely with those of Babcock and Collins.

While these two experiments fall short of being statistically significant, it is clearly shown that ionization plays an important part in the rate of mutation of the germ cells. It would not be too fanciful to assume that such ionization would also affect the rate of mutation of the somatic cells as well.

We admit that such a suggestion would be hard to determine by research, but study of the effects of X-ray radiations of a less intensity than necessary to inhibit all reproductive activity in cells might be of value.

ROBERT S. MCCOMBS  
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#### THE MAGNETIC POLES OF THE EARTH AND THE BIRTH OF THE MOON

DR. OLIVER JUSTIN LEE's article on "The Magnetic Poles of the Earth and the Birth of the Moon" in *SCIENCE* of July 25 interests me greatly.

A number of years ago I was impressed with the same fact, namely, that the magnetic poles are not on the axis of the earth, which would seem to be the logical place for them, nor are they even antipodal to each other. When I found that the shortest distance between them was across the center of the Pacific I immediately began to wonder if the removal

<sup>4</sup> E. B. Babcock and J. L. Collins, "Natural Ionizing Radiation and the Rate of Mutation," *Nature*, 124: 227-228, 1929.

<sup>5</sup> F. B. Hanson and Florence Heys, "A Possible Relation between Natural (Earth) Radiation and Gene Mutation," *SCIENCE*, 71: 43-44, 1930.

<sup>3</sup> Republished, "Origin of Malignant Tumors," Williams and Wilkins Company, Baltimore, 1929.