and his coworkers,[6] demonstrated that the two metabolic processes, anoxidative-fermentative-splitting and oxidative-salvaging of the split carbohydrate, were characteristics of animal tissue cells other than muscle, and especially of growing tissues, such as mucous membrane, skin and glandular tissues, and curiously enough also of retinal tissue. All embryonic tissue showed a high rate of both the fermentative splitting and the oxidative salvaging processes.

When pathologic cells, such as carcinoma cells, were studied by Warburg and his associates, the remarkable facts were revealed that these cells exhibited an excessively high rate of fermentation, causing a vastly greater amount of sugar to be split to lactic acid than normal cells do, but on the other hand a greatly diminished power of utilizing oxygen. Indeed it was found that cancer cells could live and continue to split sugar in a nutrient solution in which the pressure of the oxygen had been reduced to 1/100000 vol. per cent.; the cells could live and recover completely if asphyxiated thus as long as forty-eight hours. Longer asphyxiation, however, proved to be fatal. It was shown that they utilized oxygen in small amount independently of high tension of the gas. That is, the oxygen utilization as in normal cells appears to be determined only by the physiological capacity to breathe. The high rate at which tumor cells are capable of splitting dextrose to lactic acid is shown by the fact that *in vitro,* in an hour, they can produce an amount of lactic acid equal to 10 per cent. of their own weight. It is emphasized that in these quantitative studies the weight of tumor cells always refers to masses of pure tumor cells and not the usual mixtures of tumor and non-pathological cells that are removed by the excisions of the surgeon. Experiments testing the blood passing into and that passing out of a tumor in the living animal supports the results obtained *in vitro.* The blood from a tumor vein is found in rats to have two to three times as much lactic acid as that from an artery.

These physiological experiments with normal and pathologic animal cells when compared with those on muscle and yeast show, as the authors point out,[4,6] that there is a striking similarity in the physiological transformation that tissue cells must undergo to become tumor cells on the one hand, and that the aerobic yeasts must undergo to become the anaerobic type on the other. That normal embryonic cells may be transformed into cancer cells by injury *in vitro* (arsenic and other poisons) has been shown by Carrel and by A. Fischer. The cells so injured when injected into chickens developed sarcomas. The injury in these cases consisted first in damaging the respiratory function of the cells, but being embryonic cells they already had their fermentation capacity highly developed. When injected into normal animals the cells were able to thrive by continuing their anaerobic fermentation, their supply of sugar being furnished by the host. That they could utilize little oxygen was rather an advantage than a disadvantage to them. Warburg points out that these results confirm the view long held that cancers are the result of injury to normally growing cells and that the injurious agent may be of manifold variety.

It would seem that the next step in the field of cancer research is to find out if possible how the cancer cell can be transformed back to the normal cell; how it may most easily be trained to improve its breathing capacity, and if possible to reduce its fermentative capacity. If such retransformation can be effected metastases would be rendered much more unlikely, for during the early stages of fixation comparative oxygen-want and diminished ability to get energy from anaerobic fermentative carbohydrate splitting would more likely lead to the death of the cells. Surgical removal of parent tumors then would mean more certain the removal of all the tumor-producing tissue, and in cases of the inoperable kind one could still hope to check the growth.

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[6] Warburg, Posener, u. Negelein, "Über den Stoffwechsel der Carcinomzelle," *Biochem. Zeitschr., 152*: 309, 1924; Warburg, "Über den heutigen Stand des Carcinomproblems," *Die Naturwissenschaften,* Jahrg. 15, p. 1 (Jan. 7), 1927.

SPECIAL ARTICLES

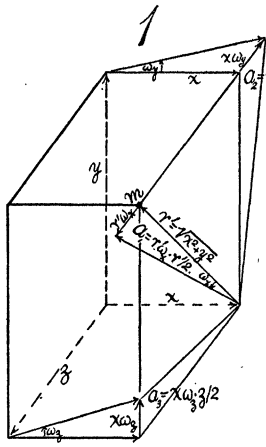
GRAPHIC TREATMENT OF EULER'S EQUATIONS

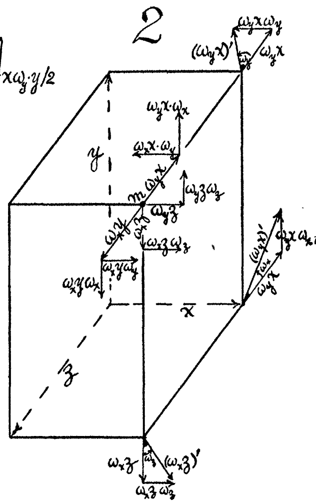
I WAS struck, some time ago, with the ease with which the familiar Eulerian tensor ($A = \Sigma m(y^2 + z^2)$, etc., $D = \Sigma myz$, etc.)

$$\begin{matrix} A & -F & -E \\ -F & B & -D \\ -E & -D & C \end{matrix}$$

usually reached analytically, can be written down from the mere inspection of an orthogonal volume. The angular momentum (H), the kinetic energy (T) and the torque of centrifugal forces (C) of a rotating rigid body are all in question, the last two taking the vector form $2T = \mathrm{H.w}$ and $\mathrm{C} = \mathrm{H} \times \mathrm{w}$, w being the vector angular velocity.

H.—In Figure 1 let m be any molecule of the body rotating clockwise about the x, y, z axes and for convenience let the unit of time be infinitely small so that w may be infinitesimal. The figure shows the component angular velocities ω_x, ω_y, ω_z, the corresponding tangential velocities $\omega_x r'$, $\omega_y x$, $\omega_z x$ and the





momentum couples per unit of m $2a_1 = r' \omega_x \cdot r'$, $2a_2 = -x\omega_y \cdot y$, $2a_3 = -x\omega_z \cdot z$, where $r' = \sqrt{y^2 + z^2}$ so far as displacements in a plane normal to x are concerned. If therefore we make the summation for all the mass points m of the body, w being constant, we obtain the coefficients $A - F - E$ of the first row of the tensor and the component moment of momentum about the x axis, $A\omega_x - F\omega_y - E\omega_z$. The forces normal to y and normal to z contribute the other two, in turn.

H.W.—If this angular momentum about x be construed as linear momentum relative to a radius 1 and if it be multiplied by the angular velocity ω_x also regarded as linear for the same unit radius, the product $(A\omega_x - F\omega_y - E\omega_z)\omega_x$ is twice the kinetic energy of the body, so far as rotation about x is concerned. The other two axes make the corresponding contributions. The expression is interesting in showing how square product terms arise in the equation for kinetic energy.

H × w—In contrast to the preceding, the equation for the torque of the centrifugal forces is astonishingly complicated. I have analyzed it in Figure 2, to be interpreted in the same way as Figure 1, but referring to the torque about the z axis. Centripetal force is generated by the rotation of a tangential velocity about a non-parallel axis (a few examples at the corners of Figure 2) and acts at m with the appropriate lever arm here either x or y. The tangential velocities $\omega_z y$ and $\omega_z x$ may be discarded; for either they are not rotated ($\omega_z y \cdot \omega_x$, $\omega_z x \cdot \omega_y$), or they generate pulls along z, $\omega_z y \cdot \omega_y$, $\omega_z x \cdot \omega_x$), while the torques $\omega_z x \cdot \omega_z \cdot y$ and $- \omega_z y \cdot \omega_z \cdot x$ balance. Since $\omega_x x$, $\omega_y y$, $\omega_z z$ have no meaning, there remain so far as m alone is concerned, the tangential velocities (see Figure 2)

$$\omega_y x, \ \omega_x y, \ \omega_y z, \ \omega_x z$$

The per second rotation of these produce the centripetal forces per gram of m (see figure)

$$-\omega_y x \cdot \omega_x + \omega_x y \cdot \omega_x - \omega_y z \cdot \omega_z$$
$$-\omega_y x \cdot \omega_y + \omega_x y \cdot \omega_y + \omega_x z \cdot \omega_z$$

which operate respectively with the lever arms x and y, so that the full torque about z is

$$m\,(-\omega_y x \cdot \omega_x + \omega_x y \cdot \omega_x - \omega_y z \cdot \omega_z)\,x - m\,(-\omega_y x \cdot \omega_y + \omega_x y \cdot \omega_y + \omega_x z \cdot \omega_z)\,y$$

To convert it into torque of centrifugal forces, these must be reversed. For symmetry $m\omega_y \omega_x z^2$ is to be added and subtracted, to match the terms in x^2 and y^2. Finally the summation is to be made for all the points m of the body. The result (after arrangement) is for the axis z,

$$(A - B)\omega_x\omega_y + F(\omega_x^2 - \omega_y^2) + (D\omega_x - E\omega_y)\omega_z$$

with corresponding expressions for the x and y axis. Altogether therefore there are 18 deputy torturers engaged in their nefarious practices. Naturally if D, E, F, vanish, the treatment by the same method is simple.

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THE SEAT OF FORMATION OF AMINO ACIDS IN PYRUS MALUS L.[1]

ALTHOUGH it has been established that nitrates can be reduced to nitrites in the roots and stems of plants, the possibility that the reduction of nitrites to form α-amino acids as an intermediate stage in the synthesis of proteins in plants could also take place in the cells of the roots and stems has not generally been accepted. Emmerling[2] indicated that in certain soils amino acids might be formed from nitrates in the roots and stems of some plants. However, Sachs (1865), Sorokin (1870), Pagnourd (1879) and Schimper[3] (1885) supported the photochemical theory of the formation of amino acids and proteins. They considered the chloroplast of the cells of the leaves maintained with a continuous supply of carbohydrates as being specially adapted to carry on the synthesis of proteins from ammonium salts and nitrates supplied to them by the conducting cells. Moreover, the rapid consumption of nitrates in the leaves is offered as the reason for the lower nitrate content in these tissues than in the roots and stems of some plants.

[1] Published by permission of the Director of the Agricultural Experiment Station as Technical Paper No. 425. Contribution No. 28 of the Department of Agricultural and Biological Chemistry.

[2] Emmerling, A., numerous papers in Landw. Ver. Stat. (1880–1898).

[3] See Czapek, F., Biochem. der Pflanzen 2: pp. 296–301 (1920) for a résumé.