posterior part and move successively along the follicle. The sections revealed that the nuclei with the heterochromatin labeled are the more advanced ones. Thus, the heterochromatin synthesizes DNA later than does the euchromatin (*3*).

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2. W. L. Hughes, *et al., ibid.* 44, 476 (1958).
3. The animals used in this experiment were raised from eggs obtained from Dr. T. Tahmisian of the Argonne National Laboratory, Lemont, Ill. A detailed report of these experiments is in preparation.
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Ballistics of Dwarf Mistletoe Seeds

Abstract. The explosive fruit of *Arceuthobium* expels the seed for several feet, but the ballistics of seed flight has not been previously investigated. The data reported here for *A. vaginatum* f. *cryptopodum* indicate that the seeds have an initial velocity of about 1370 cm/sec and an initial acceleration of nearly 5000*g*.

The explosive fruit of the dwarf mistletoes (*Arceuthobium* spp.) is one of the most efficient mechanical seed dispersal mechanisms in any of the higher plants (*1*). As far as I know, no calculations have been made of the initial velocity or other ballistic factors of the dwarf mistletoes or any other higher plants with explosive fruits. However, Buller (*2*) studied the ballistics of the glebal masses projected by the fungus *Sphaerobolus stellatus* and found that they were thrown to a height of 14.5 ft; this indicates an initial velocity (when air resistance is disregarded) of at least 30 ft/sec (*3*).

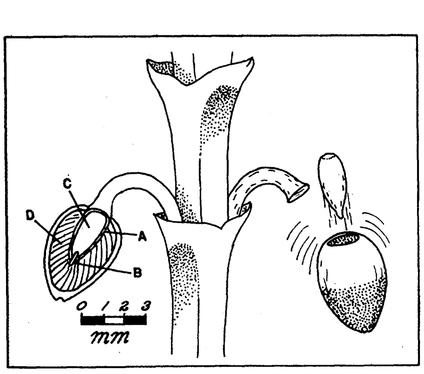

Fig. 1. Semidiagrammatic drawing of a portion of a dwarf-mistletoe shoot bearing mature fruits. Left, a longitudinal section through a fruit showing a seed (*A*), embryo (*B*), endosperm (*C*), and viscin cells (*D*). Right, a fruit immediately after the expulsion of the seed.

Each fruit of *Arceuthobium* contains a single semifusiform seed (Fig. 1). When the fruit is ripe, the pedicel is elongated and recurved so the perianth end points downward. An abscission zone develops between the tip of the pedicel and the base of the fruit. A layer of viscin cells between the seed and the exocarp of the fruit creates a considerable internal pressure, and finally the fruit is sheared from the pedicel and the exocarp contracts rapidly and hurls the seed upward (*4*). The forward end of the seed is rounded and the other end is pointed; thus, their shape approaches the ideal for the most efficient projectile.

The dwarf mistletoe used in this work (*5*) was *Arceuthobium vaginatum* f. *cryptopodum*, which is a widespread and important pathogen of ponderosa pine (*Pinus ponderosa* Laws.) in the southwestern United States. The seeds of this species average 1.1 mm in diameter and 2.9 mm in length. They are expelled for an average horizontal distance of 530 ± 30 cm, with a maximum of about 1280 cm.

The following are the experimental data obtained: Average vertical height of seeds expelled directly upward, 460 cm; terminal velocity of seeds, 750 cm/sec (*6*); average seed weight, 2.4 mg; and seed specific gravity, approximately 1.0. If it is assumed that the forces acting on the seed in flight are the force of gravity and a frictional force proportional to its velocity, then a formula may be derived relating the maximum height to which a seed goes and its initial velocity (*7*). When the data shown above are used in this formula, an average initial velocity of 1370 cm/sec or about 45 ft/sec is indicated. The kinetic energy of the seed as it leaves the fruit is thus $\frac{1}{2}\ mv^2 = 2.3 \times 10^3$ ergs.

From the initial velocity and dimensions of the seed, the time taken for the seed to leave the fruit was calculated as 4.4×10^{-4} second. The computed initial acceleration of the seed was 4.7×10^6 cm/sec^2, or nearly 5000*g*.

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References and Notes

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2. A. H. R. Buller, *Researches on Fungi* (Longmans, London, 1933), vol. 5.
3. This calculation was based on the formula $V_0 = (2gH)^{\frac{1}{2}}$, where V_0 is the initial velocity, g is the acceleration due to gravity, and H is the height of projectile expelled directly upward.
4. L. S. Gill, *Trans. Conn. Acad. Arts Sci.* 32, 111 (1935).
5. I wish to thank R. B. Setlow and W. R. Henson of Yale University for advising me in this work and for reviewing the manuscript, and Dr. Setlow for providing the formula given in reference (*7*).
6. The terminal velocity was determined by passing air upward through a vertical tube containing a dwarf mistletoe seed. The rate of flow necessary to suspend the seed was recorded, and the average value for 24 seeds was taken as the approximate terminal velocity.
7. $$H = \frac{m^2}{c^2} g \ln \left(\frac{g + \frac{c}{m} V_0}{g} \right) - \frac{m}{c} V_0,$$ when H is the maximum height of seed expelled directly upward, m is the mass of seeds, c is the ratio of frictional force (mg) to the terminal velocity (V_t), g is the acceleration due to gravity, and ln is the natural logarithm of V_0, the initial velocity.

26 March 1959

Acetylcholine Effects of γ-Carbomethoxypropyltrimethyl-Ammonium Bromide

Abstract. γ-Butyrobetaine, in comparison with its methyl ester, γ-carbomethoxypropyltrimethyl-ammonium bromide, **is** biologically inert. When injected into mice and insects or assayed on the frog's rectus abdominis muscle, γ-carbomethoxypropyltrimethyl-ammonium bromide has pharmacological properties resembling those of acetylcholine. Although reported to be present in rat brain during the convulsions induced by dieldrin poisoning, γ-butyrobetaine has not been found in the nervous tissue of the roach after treatment with dieldrin.

Burgen and Hobbiger (*1*) reported a similarity in the pharmacological properties of acetylcholine and the methyl ester of γ-crotonic betaine (γ-carboxyallyltrimethyl-ammonium chloride). More recently Hosein (*2*) stated that γ-butyrobetaine (GBB) was found in the brain of rats during convulsions after administration of a large dose of dieldrin. Hosein (*3*) showed that some pharmacological effects of GBB resembled those of acetylcholine. This finding is of importance, since in insects treated with chlorinated hydrocarbons, no explanation has yet been found for the manifestation of convulsions which occur in the central nervous system (*4*). Colhoun (*5, 6*) showed that after treatment of cockroaches with DDT and dieldrin a high titer of acetylcholine was found in the nerve cord at a late stage of prostration. The finding of Hosein (*3*) therefore necessitated a reevaluation of these results.

γ-Butyrobetaine was synthesized and tested for biological activity by intraperitoneal injection into mice. It was inert at the concentrations used by Hosein (*1*) and Linneweh (*7*). Further tests showed that the methyl ester of GBB, γ-carbomethoxypropyltrimethyl-ammonium bromide, had a toxicity for mice comparable to the reported toxicity of GBB injected by Hosein (*1*). Significantly, the ester was the first intermediate product in the synthesis of GBB. γ-Carbomethoxypropyltrimethyl-ammonium bromide was prepared by the reaction of anhydrous trimethylamine with methyl γ-bromobutyrate. On purification, the resulting material melted at 147° to 149°C. The actual bromide con-