brick walls to a distance of about 100 feet. In 1875 a fundamental invention of his was the three-coil dynamo; another was the electrical magnetic regulator. The Centennial Exposition of 1876 gave him such a stimulus with respect to electric lighting that it led to a large number of his inventions in that field.

Thomson's discoveries and inventions during his high-school career were made in conjunction with Professor Edwin J. Houston, who generally claimed the major credit for his minor part of the work. In 1880 Thomson decided to leave the profession of teaching and to devote himself to a career as inventor. He accepted a call to organize the American Electrical Company at New Britain, Conn., and accompanied by one of his high-school seniors, E. W. Rice, he removed to that place. Amidst great difficulties there he carried out a series of remarkable experiments leading to several important inventions, among them the lightning arrestor and electrical welding. This was a period of breathless haste in patenting inventions. Among the leaders in this race were Edison, Thomson, Brush and Westinghouse. In the rough-and-tumble battle of the patents Thomson proved to be a shrewd business man as well as a great inventor, and when the New Britain Company tried to sell out surreptitiously to a competitor, it was found that Thomson controlled all his patents.

The Thomson-Houston Company was then removed to Lynn, Mass., where under wise business management it grew and expanded into one of the great electrical companies of that period. Many other inventors were added to the staff, many great inventions were patented. The "battle of the currents" was waged between Edison, who stood for direct current, and Thomson, who favored alternating current. Similarly, a battle was fought between Edison's incandescent light and the arc light of Brush and Thomson. In the end the alternating current, with Thomson's protective grounding, and the incandescent light won the larger support.

A partial list of his nearly 700 patents includes the lightning arrestor, electric welding, three-coil dynamo, cream separator, repulsion motor, magnetic blow-out, improved transformers, distributors, trolley-car and train control, improved x-ray tubes, high frequency radio apparatus, etc.

Infringement suits between the Edison General Electric Company and the Thomson-Houston Company led in 1892 to the consolidation of the two in the General Electric Company with one principal branch at Schenectady, N. Y., and the other at Lynn, Mass. Thomson and his associates then turned to the application of his "repulsion motor" to the fruitful field of electric traction; he devised the leading type of electric meter, he experimented with x-rays and wireless.

After 1900 Thomson retired from the race of invention and devoted much attention to consultation and cooperation in many scientific and educational lines. For 37 years and until near his death at the age of 83, he continued to take an active part in the general advancement of science. He had from his earliest youth been greatly interested in astronomy, and in these later years of leisure he cooperated with Percival Lowell and W. H. Pickering and especially with George Hale. He undertook to make of fused quartz the 200-inch mirror for the Mt. Palomar telescope, but after long and costly experiments found that it was impracticable. He served for a time as acting president of the Massachusetts Institute of Technology and for many years on its board of trustees. On March 13, 1937, he died at his home in Swampscott, full of years and honors.

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SPECIAL ARTICLES

RELATION OF DUAL PHENOMENON IN PENICILLIUM NOTATUM TO PENICILLIN PRODUCTION

DIFFICULTIES in penicillin production have been reported recently by a number of those engaged in this work. Foster, Woodruff and MacDaniel[1] state that cultures of *Penicillium notatum* Westling "tend to lose spontaneously their ability to form penicillin either entirely or partially," and that "frequently degenerated cultures show a marked reduction in the tendency to sporulate abundantly." An additional complaint concerns the increase in yellow pigment which accompanies this degeneration.

In view of the nature of the difficulty we have made a single spore analysis of a stock culture of the fungus according to the method of Hansen and Smith.[2] The results have shown that *P. notatum* is a dual fungus, composed of two distinct constituents associated together in culture. This is the dual phenomenon discovered by Hansen[3] in 1938 and which has been found to be characteristic of most if not of all fungi.

The two components of *P. notatum* are a normal conidial or *C* type and an abnormal mycelial or *M* type. The *M* type arises repeatedly as a mutation in physiologically aging colonies of the *C* type, even though the culture be started from a single conidium.

[1] J. W. Foster, H. B. Woodruff and L. E. MacDaniel, *Jour. Bact.*, 46: 421, 1943.

[2] H. N. Hansen and R. E. Smith, *Phytopath.*, 22: 953, 1932.

[3] H. N. Hansen, *Mycologia*, 30: 442, 1938.

This mutation is probably of a genetic nature, and may be associated with sex, as has been shown by the writers[4,5] in another fungus. The *M* type is physiologically as well as morphologically distinct from the *C* type, and where mass transfers of inoculum are employed the *M* type is apt to become predominant. The appearance of the *M* type *de novo* in a *C* type culture is a function of physiological age. Pure cultures of the *C* type which are maintained in a state of youth by frequent transfer (always made by means of conidia) tend to remain free of the *M* type.

Presence of the *M* type in what appears to be a normal culture often remains undetected unless the culture be frequently analyzed by the single spore technique,[2] when some of the single spores will be found to produce the normal sporulating *C* type and others to produce the non-sporulating *M* type with which is associated an increased production of yellow pigment. This *M* type (non-sporulating and pigment-producing) is presumably the form which various workers have reported as being a poor producer of penicillin. The presence of the *M* type in cultures used for inoculum would be expected therefore to result in decreased penicillin production.

If our interpretation is correct, it would appear that the highest yield of penicillin probably could be obtained by frequently making single spore cultures of the fungus and choosing the most productive of these for large-scale operations, whether these be slight variations within the *C* type or even in the *M* type.

If it is desired merely to return the present stock culture to its highest sporulating condition it is suggested that a procedure somewhat as follows be adopted. Gently flush conidia from the agar slant stock culture with sterile water. Flood the surface of an agar medium in a plate or flask with this conidial suspension; pour off the excess suspension and incubate the inoculated medium in diffuse light. Harvest the new crop of conidia soon after they are formed, again using the flushing method to avoid carrying over mycelial fragments into the suspension. This spore suspension from this fresh culture should be pure for the *C* type. Cultures must never be scraped to obtain inoculum if the *M* type is to be avoided.

M types rarely mutate. If an *M* type is found which produces a satisfactory yield of penicillin it probably may be propagated by mass transfer without recourse to the above methods. If it is desired to distribute this inoculum through a liquid to serve in place of a spore suspension the mycelial colony may be cut up by means of a Waring blender.[6]

It should be clear that to maintain penicillin production at maximum levels the highest yielding clone of *P. notatum* should be used and that this clone be kept monotypically pure and free from recurring mutants. It should be evident also that where biological assay of penicillin is practiced, the assay organism too must be perpetuated in a monotypically pure state. Only when this is done is it possible to effectively standardize the processes of penicillin production and assay.

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[4] H. N. Hansen and W. C. Snyder, *Phytopath.*, 30: 787, 1940.

[5] *Idem, Amer. Jour. Bot.*, 30: 419, 1943.

[6] C. F. Andrus, *Phytopath.*, 31: 566, 1941.

AN ANTIBIOTIC SUBSTANCE FROM SPECIES OF GYMNOASCUS AND PENICILLIUM

THE antibiotic substances from three different fungi, namely, *Aspergillus clavatus, Penicillium patulum* and *Penicillium claviforme,* and variously called clavacin, claviformin and patulin have proved to be identical.[1] Raistrick *et al.*[1] have elucidated the chemistry as anhydro-3-hydroxymethylene-tetrahydro-γ-pyrone-2-carboxylic acid (patulin). This substance has now been isolated from two more mold species. The first was an undefined species of *Gymnoascus,* labelled 5070.1, and kindly furnished by Dr. Thom. The second was *Penicillium* sp. freshly isolated from soil in the course of a survey. Cultivated for 7 to 10 days on Czapek-Dox medium containing 3 per cent. corn steep liquor, the *Gymnoascus* filtrate inhibited *Escherichia coli* at 1/100 and *Staphylococcus aureus* at 1/50. The active agent was adsorbed on 1 per cent. norite, eluted with acetone, and the eluate concentrated *in vacuo* to a thin syrup. After standing overnight in a refrigerator, crystals appeared. They were separated by filtration and recrystallized twice from hot 50 per cent. ethanol. The white crystals melted at 109°. A mixed melting point with crystalline clavacin (m. 109.5°), from *Aspergillus clavatus* kindly supplied by Dr. Waksman, showed no depression. The substance analyzed as follows: C, 54.72; H, 3.98 (theoretical: C, 54.53; H, 3.93); molecular weight (cryoscopic in ethylene dibromide), 195. $C_7H_6O_4$ requires 154. The 2,4-dinitrophenylhydrazone derivative began to darken at 190° and did so progressively up to 250° C. without melting. The

[1] I. R. Hooper, H. W. Anderson, P. Skell and H. E. Carter, SCIENCE, 99: 16, 1944; S. A. Waksman, E. S. Horning and E. L. Spencer, SCIENCE, 96: 202–3, 1942; H. Raistrick, J. H. Birkinshaw, S. E. Micheal and A. Bracken, *Lancet,* 245: 625–34, 1943; B. P. Weisner, *Nature,* 149: 356–7, 1942; F. Bergel, A. L. Morrison, A. R. Moss, R. Klein, J. Rinderknecht and J. L. Ward, *Nature,* 152: 750, 1943; E. Chain, H. W. Florey, M. A. Jennings and D. Callow, *Brit. Jour. Exptl. Path.*, 23: 202–5, 1942.