"A Conjugating 'Yeast.'" By B. T. P. BARKER, B.A., Gonville and Caius College, Cambridge. Communicated by Professor MARSHALL WARD, F.R.S. Received May 4,—Read June 6, 1901.

(Abstract.)

At the outset, the idea of a true yeast (*Saccharomyces*) which conjugates may appear anomalous in the extreme, but it is not improbable that such an event has been observed before in such organisms, though the phenomena have been misinterpreted.

The yeast which is the subject of this communication was obtained from commercial ginger, pieces of this substance being placed in sterile saccharose-Mayer solution and kept at 25° C. until the organisms situated on the surface of the ginger had attained vigorous growth. These were separated by means of fractional plate-cultures of beer-wort gelatine.

The colonies of the yeast-form, as seen on beer-wort gelatine plate-cultures, appeared to the naked eye as small rounded white dots, about the size of a pin's head. Under the low power of the microscope colonies on the surface of the gelatine had regular edges, while submerged colonies had a woolly appearance, due to numerous radiating branches.

A pure culture was obtained from a colony developed from a single cell kept under observation in a hanging drop of beer-wort gelatine.

Streak cultures on beer-wort gelatine and beer-wort agar are of a milky-looking brownish-white colour, and have well-marked regular crenate edges. Streak cultures on potato and bread are milky-white when moist, and chalky-looking when dry; on pieces of moist ginger their colour is darker.

A yeast-ring is formed in old cultures on many liquid media, but no films are produced. In tubes of beer-wort, which have been actively fermenting, the ring makes its appearance in 10—14 days at 25° C. It is milky-white in colour, and looks like a layer of cream, deposited around the edges of the liquid. Such rings are also formed on dextrose-Mayer, lævulose-Mayer, saccharose-Mayer, and maltose-Mayer solutions, being particularly well developed on those liquids which have undergone an active fermentation.

The vegetation of the cultures described consists of typical ovoid and round yeast cells, and in the older cultures a few sausage-shaped and many irregular cells also, some of the latter containing spores.

Reproduction by budding in a typical yeast-like manner is the usual method of growth, taking place best at 25—30° C., the maximum and minimum limits being 37—38° C. and 10—13° C. respectively.

Reproduction by spores occurs under the usual conditions of spore-

formation for the Saccharomycetes. The gypsum-block method gives a plentiful supply, while spore-containing cells are frequently found in old cultures on nutrient media, whether solid or liquid. The spore-containing cells differ from those of most other Saccharomycetes in being compound cells, *i.e.*, they consist of two ordinary ovoid or round cells which have conjugated by means of a beak developed from each, the tips of the beaks fusing, the process thus resembling the well-known case of conjugation of many Algæ and Fungi. The compound cells are thus made up of two ordinary yeast-like cells joined together by a narrow neck, the length of which varies according to the circumstances under which spore formation has taken place.

Details of the process have been observed in hanging-drops of distilled water, in which have been placed a number of vigorously growing cells, the temperature being kept about 25° C. The cells, originally clear and homogeneous, in a few hours began to grow vacuolated, and numerous bright-looking granules made their appearance. In twelve or more hours after sowing, a beak-like tubular process was put forth by many of the cells. The beaks of two neighbouring cells grew towards each other until their tips were in contact. Fusion of the walls then took place at the point of contact, being followed by the fusion of the protoplasmic contents of the beaks, which were clearer and brighter than the rest of the protoplasm in the cells. In a few hours after fusion, the protoplasm began to contract in the cells, and small round masses were formed: these eventually developed into the spores.

The bright granules in the cells arranged themselves into groups in connection with the above masses and formed a network around them, the final differentiation of the spores being completed by the formation of a cell-wall around each mass. The size of the ripe spore is 4—5 μ; and the number in each compartment of the mature cell varies from one to four, the most common arrangement being two in each.

The spores germinate in a normal manner. After swelling they bud like ordinary yeast-cells. Fusion of spores in some cases seems to occur before germination. The optimum temperature for spore formation lies between 25° C. and 30° C., the first signs of spores appearing in 16—24 hours. At 34° C., 32—36 hours are required, and at 36—37° C., 2—3 days. Above 38° C. no spores are formed. At 13—15° C., 10—14 days are required, and below 13° C. practically no spores are produced.

When heated for 10 minutes in beer-wort the spores are generally killed at 60° C., but some withstand an exposure of 5 minutes to a temperature of 65° C.

In old cultures on nutrient media, and in spore cultures where the conditions were not of the most favourable character for the formation of spores, many cells of exceedingly irregular shape are found. These

are apparently produced from the ordinary ovoid or round cells during efforts at spore-formation. Beaks are formed at different points of the cell, but no conjugation takes place ; or, if it does occur, no spore formation follows. Consequently cells of great irregularity in shape result, and such may be considered as cells which have made attempts at spore-formation, but have failed owing either to lack of energy or substance in themselves, or to unfavourable external conditions.

The behaviour of the nuclear contents during conjugation and spore-formation is suggestive. Stained preparations of cells in different stages of these processes show that the tips of the beaks are occupied by a deeply stained mass, which on conjugation fuses with a similar mass in the beak of the other cell which takes part in the process. The fused mass then divides into two, one portion withdrawing into each compartment of the compound cell ; there division again takes place, in such a way as to provide the basis of each spore about to be formed. Previous to the latter division a deeply stained and prominent granular network becomes arranged around each mass, and this separates into groups when the final division occurs, the number of groups corresponding with the number of masses.

By this time each mass is rounded off into a spherical body—the young spore—and around each spore a group of granules is arranged and eventually a wall is formed. The spores then ripen. Lack of knowledge as to the exact nature of the yeast nucleus prevents a complete interpretation of the histological facts observed, but it seems certain that the deeply stained masses are nuclear in nature, and that consequently a kind of nuclear fusion takes place. If so the process must be looked upon as a simple sexual act, somewhat similar to that occurring in the process of spore-formation of *Schizo-saccharomyces octosporus*.

Alcoholic fermentation is produced in beer-wort by this yeast. It also ferments lævulose vigorously, and dextrose and saccharose slightly. Maltose, lactose, and dextrin are not fermented. A mixture of dextrose with maltose and dextrin is fermented more freely than dextrose alone. Long-continued cultivation in beer-wort seems to have increased its fermentative activity for that medium.

In conclusion, there seem to be three possible views regarding the nature of the fusion-process, viz. : (1) It is an abnormal or pathological phenomenon due to the conditions of culture ; (2) it is a mere cell-fusion, such as frequently occurs between contiguous cells in fungi ; or (3) it is a true sexual process, such as is now known to occur in many fungi.

The first view seems unlikely, since the result of the process is the production of normal healthy spores, and the conditions are exactly such as are generally efficacious in the production of spores in yeast of all kinds.

The second view receives a certain amount of support from the fact that such fusions are known in other yeasts, *e.g.*, *Saccharomyces Ludwigii* (Hans), but in these cases growth is active, and there does not seem to be any nuclear fusion.

Having regard to the behaviour of the nuclear contents and the subsequent formation of spores, the third view seems most likely. Looking upon the process then as a sexual act of the simplest kind, and in view of the fact that, while all its other characters accord with those of Saccharomyces, it differs from the latter in the manner of its spore-formation, it is proposed to place it in a new genus, *Zygo-saccharomyces*, on the analogy of the genus Schizo-saccharomyces, suggested by Beyerinck for the fission-yeasts.

"The Measurement of Magnetic Hysteresis." By G. F. C. Searle, M.A., and T. G. Bedford, M.A. Communicated by Professor J. J. Thomson, F.R.S. Received May 2,—Read June 6, 1901.

(Abstract.)

§ 1. In 1895 one of the authors described* a method of measuring hysteresis by observation of the throw of a ballistic electro-dynamometer. The method in its most elementary form is very simple. An iron ring of section A and mean circumference l is uniformly wound with Nl turns of primary winding, and the primary current C passes also round the fixed coils of an electro-dynamometer. A secondary coil of n turns wound on the ring is connected in series with the suspended coil of the dynamometer and an earth inductor, the total resistance of the circuit being S.

The effects of self-induction in the secondary circuit being neglected, the secondary current c is

$$c = \frac{An}{S}\frac{dB}{dt}.$$

If the couple acting on the suspended coil due to the currents C, c be qCc, then at any instant

$$\text{Couple} = qCc = q\,\frac{An}{4\pi NS}\,H\,\frac{dB}{dt},$$

since $H = 4\pi NC$, when the magnetic force due to c is neglected.

If the instrument be used ballistically, the angular momentum acquired by the coil while C changes from C_0 to $-C_0$, is

$$K\omega = q\int Cc\,dt = q\,\frac{An}{4\pi NS}\int H\,dB.$$

* G. F. C. Searle, "A Method of Measuring the Loss of Energy in Hysteresis," 'Camb. Phil. Soc., Proc.,' vol. 9, Part I, 11th November, 1895.