Mitotic Disturbances Induced in Yeast by Chemicals, and their Significance for the Interpretation of the Normal Chromosome Conditions of Yeast

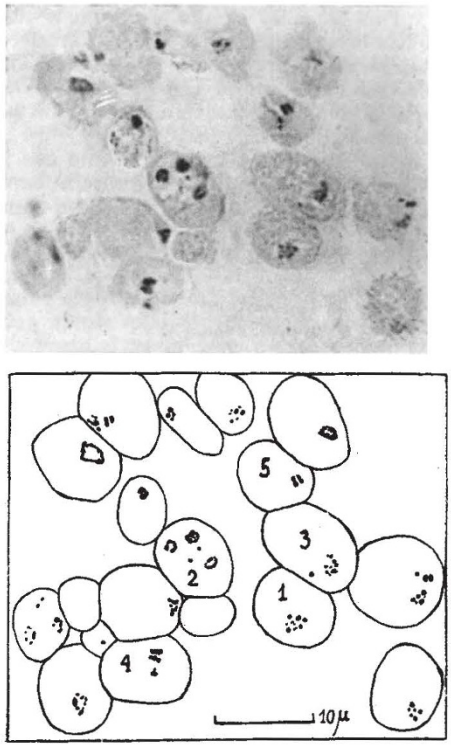
THE camphor reaction of yeast, described by Bauch[1], was interpreted by me[2] as a narcosis affecting the normal growth of the yeast cell. Instead of budding normally, the yeast, under the influence of many chemicals of the same type as the narcotics, grows out into associations of cells, which show an irregular, tube-like, bottle-shaped or vesicular form. Their cell volume is often enlarged. In 1938 and 1939, Segal[3] induced this reaction by treatment with the higher aliphatic alcohols and fusel oil. The so-called involution forms of yeast, often observed in ageing cultures in connexion with the autolysis, seems to be a phenomenon of the same nature, the yeast cells narcotizing themselves with their own metabolic products.

Segal noticed the occurrence of abnormal nuclei in yeast cells treated with the higher alcohols. No detailed study of the nuclear conditions of the 'camphor cells' has been made, however, although supposed chromosome-doubled types of yeast have been produced by chemical treatments several times[1,4,5]. In the present communication a few data will be given concerning the nuclear behaviour of 'camphor cells' induced by camphor, butyric alcohol and benzene.

During the first days of treatment, most nuclei in the 'camphor cells' divide normally, each daughter cell obtaining one normally shaped nucleus. After a somewhat longer treatment, certain mitotic disturbances appear, and after a fortnight there may be a large number in some slides. The accompanying photomicrograph, which has been made from a Feulgen-stained slide of cells treated for sixteen days with 0·012 mol. benzene, shows some typical deviations from normal mitosis. In cell 1 a fairly normal metaphase is seen in polar view. About ten separate bodies may be counted, six of them being larger. In cell 2 three nuclei are present, and in addition two solitary bodies which I interpret as single chromosomes. This configuration is suggestive of the action of a multipolar spindle. 3 and 4 show instances of one larger nucleus and one small body outside the nucleus, presumably one vagabond chromosome. In other cases I have found pairs of chromosomes lying free in the plasma, single chromosomes having evidently divided in their abnormal position.

The mitotic disturbances here described are of special interest, since they furnish an opportunity to estimate the size of single yeast chromosomes, which is seldom possible in untreated cells, where the chromosomes usually appear in dense groups; and it is found that the chromosome size varies from 0·1 μ to, perhaps, 0·5 μ. Thus, the chromosome size lies near the limit of what can be seen in the microscope.

In my best fixations of untreated yeast I have found the nuclei to contain a number of distinct bodies of a size similar to that of single chromosomes of these treated cells. At metaphase these bodies may be seen clearly and have the same appearance as cell 1 of the present picture. They are often distributed on a hollow spindle. At normal anaphase their tendency to stick together may easily give an impression of one or two bodies, just as has happened in cell 5 of the reproduction. In my opinion this is the cause



Saccharomyces cerevisiæ TREATED FOR SIXTEEN DAYS WITH 0·012 MOL. BENZENE, 1, NORMAL METAPHASE; 2, EFFECT OF MULTIPOLAR SPINDLE; 3, 4, VAGABOND CHROMOSOMES; 5, LUMPING OF CHROMOSOMES INTO TWO BODIES. × 1,200

both of the assumption of amitosis in yeast and of the low chromosome number reported by many workers (for example, Badian[6], Sinoto and Yuasa[7]). After having been able to study the size of single chromosomes in treated yeast, I do not doubt that the normal chromosome number of yeast is higher. Ten separate elements are often counted in untreated material, and it is quite probable that several very small chromosomes are then concealed. I accordingly consider ten a minimum number. Neither can I agree with Lindegren[8] that the Feulgen-positive constituent of the yeast cell is a centriole without further interior organisation.

The nuclear disturbances of the 'camphor cells' of yeast are evidently not identical with full colchicine-mitosis of higher plants. Even after long treatment, the spindle apparatus functions at least partially. The disturbances observed may very well give rise to cells with altered chromosome number; in fact, cells with doubled number have been actually seen in my slides. If a similar condition occurs also in the normally occurring involution forms of ageing cultures, it may be important not to use old cultures as mother cultures in practical brewery.

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[1] *Naturwiss.*, **29** (1941).
[2] *Hereditas*, **30** (1944).
[3] *Microbiologija*, **7** (1938), **8** (1939).
[4] *Nature*, **152** (1945).
[5] *Curr. Sci.*, **14** (1945).
[6] *Bull. Int. Acad. Polon.*, B, **61** (1937).
[7] *Cytologia*, **11** (1941).
[8] *Mykologia*, **37** (1945).