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The effect of conjugation.

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A single individual (ex-conjugant) of *Uroleptus mobilis* was isolated November 20, 1917. Five lines of the series were maintained by the usual daily isolation culture method used with infusoria. The relative metabolic activity is indicated by the average division rate of all five lines of the series for ten-day unit periods extending throughout the life cycle. Once a week, the excess individuals, after the isolations are made, are placed in larger culture dishes for a conjugation test. Here they multiply by division, until, in a week or ten days, thousands of individuals are present. With increasing scarcity of food they will conjugate, provided the protoplasm is sexually mature. From time to time, ex-conjugants, obtained from such conjugation tests, are isolated to form the beginnings of filial series. These are similarly maintained in daily isolation cultures, five lines to each series, and all fed at the same times and on the same standardized culture medium as the individuals of the parent series. This method furnishes the possibility of comparing the vitality of a filial series with that of the parent series. The protoplasm of 16 such series has been studied, each series represented by five lines; seven series have

died and nine are still under observation in different stages of vitality.

The process of parthenogenesis ("endomixis" of Woodruff and Erdmann) occurs in *Uroleptus* while encysted. These cysts require drying before the individuals will emerge. Parthenogenesis, therefore, is too clearly advertised to be overlooked, and the effects of such asexual reorganization cannot confuse the results obtained by the isolation cultures, for, while parthenogenesis occurs in the conjugation tests, it never has occurred in the isolation cultures.

In these experiments we deal with one protoplasm originally contained in the single-celled ex-conjugant of the A series. Some of this protoplasm has been maintained in isolation cultures where conjugation and pathenogenesis have been prevented; some is represented by protoplasm that has passed through processes of conjugation, both closely-related individuals in all cases being of the same age and having had the same identical treatment daily and with the same standardized food as the protoplasm of the parent isolation cultures; and some is represented by individuals that have passed through the processes of encystment and parthenogenesis.

The problems presented are: (1) Does the protoplasm of an ex-conjugant and its progeny by division, undergo progressive weakening of metabolic vigor ending in natural death? (2) Does conjugation between two individuals of the same age and each composed of similar, weakened protoplasm, result in the restoration of metabolic vigor to an optimum? The results of the experiments prove clearly, that both questions, so far as *Uroleptus* is concerned, are answered in the affirmative.

First, as regards physiological weakening and natural death. The original A series died in the 313th generation. The B series (obtained from a cyst) died in the 258th generation. The C series (from A 78) died in the 349th. The D series (from A137) died in the 271st. The F series (from C 86) died in the 317th. The G series (from B 115) died in the 291st, and the H series (from A 237) died in the 268th generation. All of the other series are still living, although two of them (I and J) will be dead within a month.

Using a longer unit period of 60 days to avoid the minor fluctuations of the 10-day periods, we find that all ex-conjugant series show a remarkable uniformity in corresponding periods. The standardized diet was not used until the 50th day of the parent A series so the rate for the first 60 days of the A series is not computed. The mean division rate, computed biometrically, for the first 60 days of the C series was $8.6333 \pm .2185$, or a rate of 17.26 divisions in 10 days; for the first 60 days of the D series, it was $8.5833 \pm .1349$ or 17.16 in 10 days; for the F series it was $8.600 \pm .2320$ or 17.2 in 10 days; for the H series it was $8.666 \pm .1892$ or 17.33; for the I series (from F143) it was $8.5833 \pm .2468$, or 17.16; for the J. series (from A 311) it was $8.966 \pm .2252$ or 17.93 and for the first 60 days of the L series (from I 199) it was $8.7000 \pm .2986$ or 17.4 divisions in 10 days. All ex-conjugant series, therefore, start with an initial optimum average division rate of $17. \pm$ divisions in 10 days. In the second 60-day period for each series, the rate falls to $15. \pm$ divisions in 10 days. In the third 60-day period the rate falls again to from 8 to 12 divisions in ten days while the variations become more marked. In the fourth 60-day period, the average division rate falls still lower, and all series, thus far, have died before the end of the fifth period. This decreasing vitality and death, cannot be due to food or other environmental factors, for, while one series is dying, a filial series whose protoplasm has been under identical conditions for the same length of time, is in full metabolic vigor. The cause of depression and death is endogenous, not exogenous.

Second, as regards the effect of conjugation on vitality. This question obviously is already answered by the results given above. In every case conjugation results in restoring the lagging activities to optimum metabolic vigor, indicated by the rate of $17 +$ divisions in 10 days, for the first 60-day period. It is still more obvious if we compare the metabolic activity of this protoplasm after it has conjugated, with a portion of the same protoplasm which has not conjugated. Thus the J series was derived from an ex-conjugant of the A series when the latter was in the 311th generation and nearly exhausted. The mean division rate of the offspring (J) was 17.9 divisions in 10 days while that of the parent (A) for the same calendar period, was only 0.25 divisions

in 10 days, a difference in vigor amounting to more than 17 divisions in ten days. In other words, if the two individuals, one of which formed the J series, had not conjugated, they would have had only enough metabolic vigor to divide at the rate of one division in 40 days, but, having conjugated, their metabolic vigor was such that they actually divided at the rate of 71.6 divisions in 40 days. This is an extreme case; if conjugation occurs before vitality runs so low, the difference between parent and offspring is less. Thus, the C, D and H series came directly from this same A series, C from individuals in the 78th generation, D from the 137th and H from the 237th generation, of the parent series. For the first 60 days of each filial series the mean division rates for ten days of offspring and parent were: C 17.26, A 15.73; D 17.16, A 14.13; and H 17.33, A 12.53, the differences being 1.53, 3.03 and 4.80.

Exactly similar results were obtained with the F₂, F₃ and F₄ generations of the original A series, some of which are dividing today with the optimum vigor of 17 + divisions in ten days.

Directing attention again to the fact that all series are treated in the same identical way as regards food and environmental conditions, and that conjugations were invariably between two individuals of the same age, the conclusion is incontestable that one fundamental effect of conjugation is the renewal of vitality, or rejuvenescence, of the protoplasm.

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Endomixis and size variations in pure lines of *Paramecium aurelia*.

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Jennings¹ considers the mean size of a pure line as strictly hereditary throughout the pure line; it belongs to one of the fundamental characteristics of this individual pure line. Eight years

¹ Jennings, H. S., *Proc. Amer. Philos. Soc.*, 47, 393-546.