CROWDING AND ASEXUAL REPRODUCTION OF THE PLANARIA, DUGESIA DOROTOCEPHALA

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Crowding clearly reduces the fissioning rate of the planaria, Dugesia dorotocephala. This reduction seems to be the result of some water soluble substance and is not the result of slime, oxygen depletion, or carbon dioxide increase. At densities below 2.0 planaria per 100 ml. of water, reproduction is not affected by crowding. If planaria do not reproduce at their maximum rate all the time, but only reproduce to replace losses, then the effect of intraspecific competition and natural selection is reduced. Supposedly, without natural selection there would have been no evolution. If planaria living today in a protected environment can turn their reproduction off when a certain maximum but healthy density is reached; then it is quite conceivable that in the perfect creation before the Fall these animals could regulate their own numbers without the necessity of outside predation, starvation or disease.

Introduction

With regards to the regulation of animal numbers two possibilities exist: The individual may reproduce maximally near its physiological limit with the population density being regulated by negative outside forces. Or, alternately, the individual may in some way influence its own recruitment rate and maintain some form of density homeostasis.

Evolutionists have generally taken the former view with natural selection always favoring the individual or genotype that can leave the most reproducing progeny.[1, 2] Competition between too many offspring is thought to be the "directing" force of evolution. Without an excess of offspring there would be no competition, no natural selection, and no evolution.[3] Creationists should find the alternate view more acceptable.

Population Control Before the Fall

The original creation was good, complete, and not lacking in any aspects. The phrase, "And God saw that it was good," appears seven times in the first chapter of Genesis[4] and refers to the things God created. Verses 21 and 25 refer specifically to the animal kingdom, and verse 31 summarizes God's opinion of the things that He had willed into existence, "and God saw everything He had made, and behold, it was very good. . . ." Certainly an all wise Creator would not have called something good if it contained errors or inadequacies. In addition, Gen. 2:1 states, "Thus the heavens and the earth were finished, and all of the host of them," emphasizing again the idea of a fully functioning and complete world.

Implied in the teaching of a perfect creation is the concept of a deathless creation; no starvation, disease or predation. Only after sin entered into the newly created world did predation and death appear. Consider the argument by Whitcomb and Morris:

> One of the clearest texts in the Old Testament on the transformation of animal characteristics after the Fall is that which describes the diet which God ordained for animals before the Fall. Before the Edenic curse, this was God's provision for the food of animals: "to every beast of the earth, and to every bird of the heavens, and to every thing that creepeth upon the earth, wherein is life, *I have given every green herb for food:* and it was so" (Gen. 1:30). Under such conditions, there could have been no carnivorous beasts on earth before the Fall; for the animals to which God gave "every green herb for food" included "every beast of the field" and "everything that creepeth upon the earth, wherein is life."[5] (Emphasis added)

This is in direct contrast to the conditions described after the Fall immediately following the Flood:

> And the fear of you and the dread of you shall be upon every beast of the earth, and upon every fowl of the air, upon all that moveth upon the earth, and upon all the fishes of the sea; into your hand are they delivered. Every moving thing that liveth shall be meat for you; even as the green herb have I given you all things.[6]

If a great span of time separated the Creation from the Fall, or if Adam and Eve had not sinned, what would have kept the population of the many herbivore animals in check? Without predators would the rodents soon have destroyed God's "good" and "finished" work? Of course not. Inside each animal was a mechanism for regulating its own population.

Immediately following Creation in response to God's command to "Be fruitful and multiply,"[7] "fill the waters,"[8] and "replenish the earth"[9] all animals would have reproduced at a very high rate, probably near their physiological limits. After a while (a short time for highly fecundant forms, longer for others) the earth would have been filled. In order to avoid overpopulation and consequent destruction of the newly created world, reproduction had to drop to zero. All

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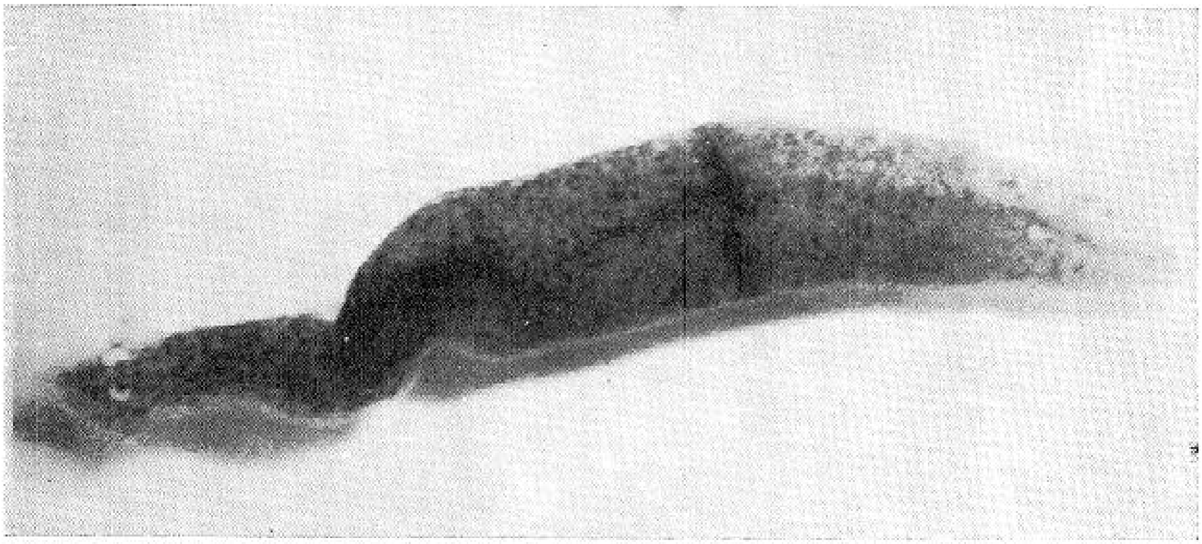

Figure 1. Flatworm reproduction. The flatworm photographed here has begun to attach itself to the substrate at two points (note two lines, or darkened regions, across its body near midpoint). By means of each attachment, the flatworm pulls itself apart and produces two new worms by a kind of asexual reproduction. Photography by Richard Lund.

animals must have had a built-in mechanism for controlling their reproductive rates. The command was to fill the earth not to reproduce at the highest rate possible indefinitely.

Population Control Today

The paradise did not last. Sin entered into the world and because of sin the Curse. This curse was not limited to the Serpent and Adam and Eve, but to the entire created world. "Cursed is the ground for thy sake; in toil shalt thou eat of it all the days of thy life; thorns also and thistles shall it bring forth to thee; and thou shalt eat the herb of the field; in sweat of thy face shalt thou eat bread, till thou return unto the ground. . . ."[10] The New Testament teaches that this fallen state still exists for the entire world. "For we know that the whole creation groaneth and travaileth in pain until now."[11]

The Fall certainly brought about modifications to the living world. Animals began to prey upon one another. Death, fear, and disease entered into the world but the Fall and Curse do not imply a re-creation. If animals were created with the ability to regulate their own numbers, it is only logical that they still retain that ability. Woman's curse, in part, was increased pain in child birth, not a new mode of reproduction.[12]

It appears that two truths are evident from the Scripture concerning the regulation of animal numbers :

(1) A perfect creation prior to the Fall would necessitate animals capable of limiting their own rates of reproduction; and,

(2) This mechanism may be working today, perhaps partly masked by other consequences of the Edenic Curse, which include predation, disease, and starvation.

For animals living today it is also logical to look for an intrinsic mechanism for the regulation of numbers. Man has discovered (often too late) that the maximum harvest of any renewable resource can increase to a point where increased effort results in diminishing returns. To avoid over kill (with possible irreversible damage to the environment or species), countries have set limits as to the number of individuals (fish, whales, or game) that can be annually harvested. Only by this method can the maximum sustainable harvest be maintained.

Animals in their natural environment face the very same problem. Whether carnivore or herbivore the problem remains the same; unlimited reproduction results in over exploitation of the food supply.

V. C. Wynne-Edwards[13,14] has proposed the theory that animal numbers are regulated from within, not by the traditional population checks (predation, disease, and starvation) that Darwin advanced. He proposed that the individuals of a population regulate their own recruitment rate, and has amassed great support of his theory from mammals, birds, and insects.

The fresh water planaris, *Dugesia dorotocephala*, might offer a method of testing a portion of Wynne-Edwards hypothesis. The planaria is easily kept in the laboratory, reproduces asexually, and its fissioning rate is known to be inversely related to density.[15] In fissioning the posterior region clings tightly to the substrate, and the anterior portion crawls away causing the two ends to break apart. Each fission fragment regenerates the appropriate missing part to produce two complete worms. No morphologically differentiated plane of fracture has been observed.

The purpose of this study was to attempt to determine what consequences of crowding reduce fissioning.

Materials and Methods

Three separate groups of planaria were used in this study. The first group was collected from a small stream in Red Rock Canyon State Park, Hinton, Oklahoma, in the fall of 1968. About 30 individuals were collected and kept until May, 1969, when the study was initiated.

The second group (36 animals) was collected June 9, 1969, at the Wichita Mountain Wildlife Refuge, Oklahoma.

The third group (80 animals) was collected from Red Rock Canyon State Park, Hinton, Oklahoma, on January 13, 1972 and was maintained at Baylor University under conditions of constant (20± 1.0°C) temperature and a twelve hour photoperiod (centered at 12:00 noon, Central Standard Time).

In order to measure quantitatively the effects of crowding on the rate of fissioning the planaria were kept in identical containers. Different densities of planaria were kept in each container; that is, in any one experiment one worm was kept in one container, two worms in another identical container and so on.

In each of the following experiments the worms were fed beef liver twice weekly. They were allowed to feed for two hours (during which time most worms had gorged themselves and crawled off the meat). The meat then was removed. The water was changed twice and any daughter fragments counted and removed, thereby maintaining each container of worms at the starting density throughout the experiment. Only aged aerated tap water was used and only large (12-15 mm), active animals were used.

Experiment 1

The first experiment consisted of 24 planaria from the first group in five identical 4¾ oz. glass jars. Each jar contained 10 ml of water. No aeration was used and the experiment lasted 64 days. The 24 planaria were distributed as follows: 1, 2, 4, 7, and 10 per jar.

The experiment was conducted in a basement with a temperature of 21°C ± 1°C. Except for the days the worms were fed and counted, they were kept in darkness.

Experiment 2

The second experiment consisted of 25 worms from the second group. Six 4¾ oz. glass jars were again used, each with 10 ml of water. The planaria were distributed as follows: 1, 2, 3, 4, 6, and 9 planaria per jar. Again the temperature was 21°C ± 1°C with no light. This experiment was run for 45 days. Again no aeration was used.

Experiment 3

The third experiment was conducted at Baylor University. Thirty-eight worms from the third group were used and the containers with the smaller numbers were repeated to minimize the effects of genetic variation of fissioning rate in the small sample sizes. Ten ml of water was used in each container. Eight plastic shell vials (3 cm diameter) each containing 10 ml of water were used. The planaria were distributed as follows: 1, 1, 2, 2, 4, 4, 8, and 16 per vial. No aeration was used and the experiment was run for 57 days.

In this experiment, and each of the following, the temperature was 20°C ± 1°C with a twelve hour photoperiod centered at 12:00 noon Central Standard Time.

Experiment 4

The fourth experiment, lasting 34 days, included eight plastic vials and 38 planaria from the third group. Again low density vials were repeated. In this experiment aeration was used in each vial by introducing a chain of bubbles from a small capillary tube placed below the water level in each vial. The air was "scrubbed" by first letting it bubble through a one liter flask of distilled water. The planaria were distributed as follows: 1, 1, 2, 2, 4, 4, 8, and 16 per vial.

Experiment 5

The fifth experiment included 31 planaria from group 3 and, instead of impervious containers, the planaria were enclosed in a small mesh cloth bag of about 10 ml capacity. The small bags were then suspended in a one liter container of water. The bag kept the planaria captive but allowed water to freely pass in and out. Planaria were distributed as follows: 1, 2, 4, 8, and 16 per bag. The experiment was conducted for 31 days. No aeration was used.

Experiment 6

The sixth experiment was conducted for 34 days. Sixty-three animals were used in six glass jars (4¾ oz.). One hundred ml of water was placed in each jar. Planaria were distributed as follows: 1, 2, 4, 8, 16, and 32 per jar. No aeration was used.

Results of Experiments

Table 1 represents data from experiment 3 and may be used as an example of how the data were collected and used to prepare the graphs. Twice each week when the animals were fed the asexually reproduced progeny (daughter fragments) were removed from their respective containers and counted. At the end of the experiment the total for each container was recorded as the total number of fragments per container. The day column simply represents the range of days during which the worms in a particular jar may have reproduced. Since the worms were observed only twice each week the exact day of fissioning was not known.

The total number of fragments in each jar was divided by the number of worms in that jar (this number remains the same for the duration of the experiment since any daughter fragments are removed twice weekly). This gave the number of fragments produced per worm for the different densities. Since the different experiments did not all last for the same duration it was then necessary to divide the number of fragments per worm by the total number of days the experiment was conducted. This gave the number of fragments per worm per day and the results of the various experiments were compared. Since the rate of asexual reproduction changed by almost threefold it was necessary to plot it on a logarithmic scale to avoid crowding.

The density is expressed in planaria per 100 ml of water. Since experiments 1 thru 5 were conducted in only 10 ml of water the densities (per 10 ml) were multiplied by 10 and expressed as density per 100 ml of water. This facilitated comparison of all of the experiments. The volume of water used in each experiment (and not just the density) should be kept in mind however as it no doubt affected the results.

In Table 1 notice especially the apparent synchrony with which both of the planaria in jar 3 and both the planaria in jar 4 reproduced.

Table 2 is a summary of the results of all six experiments.

Figures 2 thru 7 represent graphically the results of experiments 1 thru 6 respectively.

TABLE 1
FISSIONING FRAGMENTS FROM EXPERIMENT 3

Jar Number	1	2	3	4	5	6	7	8
Planaria/Jar	1	1	2	2	4	4	8	16
OCCURANCE OF FRAGMENTS								
DAY								
0 - 2	0	1	0	0	0	1	1	0
3 - 6	1	0	2	2	1	1	1	0
7 - 9	0	1	0	0	0	1	0	1
10 - 13	1	0	0	0	1	0	0	0
14 - 16	0	0	0	0	1	0	0	0
17 - 20	0	1	2	0	0	1	1	0
21 - 23	1	0	0	0	0	0	0	0
24 - 27	0	1	0	2	0	1	0	0
28 - 30	0	0	0	0	0	2	0	0
31 - 34	1	0	2	0	0	0	0	0
35 - 37	0	1	0	0	0	0	0	0
38 - 41	0	0	0	0	1	0	0	0
42 - 43	0	0	0	0	0	0	0	0
44 - 47	0	1	0	0	0	0	2	0
48 - 50	0	0	0	1	0	2	0	0
51 - 54	1	0	0	1	1	2	2	0
55 - 57	0	1	2	0	0	0	0	2
Total Fragments	5	7	8	6	5	11	7	3
Fragments/Planaria/ 57 days	5	7	4	3	1.25	2.75	0.875	0.1875
Fragments/Planaria/ day	0.088	0.12	0.070	0.053	0.022	0.048	0.015	0.0033

Discussion

Only limited work has been done with fissioning rates in the planaria as a function of crowding. Best, *et. al.*[16] found that reduced population densities lead to increased fragmentation rates and concluded that, "In the presence of other planarians, the brain exerts an influence (probably neurohormonal) to suppress fissioning." They felt that the functional significance of this reduction in fragmentation rate by the brain was part of a population density "feedback control system for adjusting the rate of reproduction to population density."

Results of this study verify the conclusions of Best, *et. al.* in that increased crowding reduced fissioning rate. The effect is best seen in Figures 2, 3, 4, and 5 where only 10 ml of water was used. The same result is apparent, however, in Figures 6 and 7 as well. It appears certain that some consequence of crowding inhibits fissioning. Possible factors might be: 1) increased antimetabolite concentration resulting from crowding (such as NH_3 or CO_2). 2) Some density dependent, planarian produced, inhibitor (such as slime or some "neurohormonal" substance. (3) A neural response to planaria-meeting-planaria, or 4) the depletion of some metabolite such as oxygen.

It would seem likely that depletion of oxygen or carbon dioxide build-up could be limiting under high density conditions. This is plausible since after each feeding the planaria in the crowded containers would be found clinging to the surface film at the top of the water.

Experiment 4 was designed to test the effect of the depletion of oxygen or the build-up of carbon dioxide (or any other volatile metabolite). Aeration maintained dissolved oxygen at saturation and removal of soluble volatile metabolites. Instead of decreasing the effect of crowding, it was exaggerated (Figure 5). Although 16 planaria were started in one vial (16 planaria survived in 10 ml of water in experiment 3), after three days they began to break up. By the ninth day the pieces were dead. Increased oxygen and removal of volatile wastes clearly did not decrease inhibition associated with crowding.

The planaria's life history reveals that lack of oxygen is probably not a limiting factor. Planaria are found under rocks in slow moving water, and deep in the mud below a stream, where dissolved oxygen is well below saturation.

It would appear that inhibition is not the result of oxygen depletion of volatile metabolite

TABLE 2
SUMMARY OF EXPERIMENTAL RESULTS

Experiment 1: 10 ml, no aeration, 64 days								
Jar number	1	2	3	4	5			
Quantity planaria	1	2	4	7	10			
Total fragments	5	6	9	7	1			
Fragments/planaria	5	3	2.25	1.0	0.1			
Fragments/planaria/day	.078	.047	.035	.016	.0016			
Experiment 2: 10 ml, no aeration, 45 days								
Jar number	1	2	3	4	5	6		
Quantity planaria	1	2	3	4	6	9		
Total fragments	2	0	4	2	1	1		
Fragments/planaria	2	0	1.3	0.5	0.167	0.111		
Fragments/planaria/day	.044	0	0.030	.011	.0037	.0025		
Experiment 3: 10 ml, no aeration, 57 days								
Vial number	1	2	3	4	5	6	7	8
Quantity planaria	1	1	2	2	4	4	8	16
Total fragments	5	7	8	6	5	11	7	3
Fragments/planaria	5	7	4	3	1.25	2.75	.0875	.1875
Fragments/planaria/day	.088	.12	.070	.053	.022	.048	.015	.0033
Experiment 4: 10 ml, aeration, 34 days								
Vial number	1	2	3	4	5	6	7	8
Quantity planaria	1	1	2	2	4	4	8	16
Total fragments	4	4	5	4	1	1	1	–
Fragments/planaria	4	4	2.5	2	.25	.25	.125	–
Fragments/planaria/day	.12	.12	.074	.059	.0074	.0074	.0037	–
Experiment 5: approx. 10 ml (see text), no aeration, 31 days								
Bag number	1	2	3	4	5			
Quantity planaria	1	2	4	8	16			
Total fragments	3	6	6	10	20			
Fragments/planaria	3	3	1.5	1.25	1.25			
Fragments/planaria/day	.097	.097	.048	.040	.040			
Experiment 6: 100 ml, no aeration, 34 days								
Jar number	1	2	3	4	5	6		
Quantity planaria	1	2	4	8	16	32		
Total fragments	3	6	11	16	24	15		
Fragments/planaria	3	3	2.75	2	1.5	.469		
Fragments/planaria/day	.088	.088	.081	.059	.044	.014		

build-up. Best, *et. al.*[17] eliminated slime as the prime factor. Perhaps it is a result of the increased concentration of some large molecular weight substance produced by the planaria.

Experiment 5 was designed to test this possibility and the results are suggestive if not conclusive. In previous experiments the rate of fragmentation changes were more than one order of magnitude. In experiment 5 the water diffused away from the high concentration of planaria and the rate dropped only from .097 (1 planaria/bag) down to .040 (16 planaria/bag) fragments/planaria/day. This would tend to indicate that whatever reduces fissioning can diffuse freely in the water. That slime is not the factor is shown. Slime build-up was apparent in the bags with the high density of worms. Yet, the rate of reproduction was not inhibited as drastically as it was in previous experiments.

If the density of planaria is reduced (by the addition of water), eventually one would expect to find a point beyond which additional living space does not increase reproduction. Experiment 6 was an attempt to find this point. It appears that crowding up to a density of about 2 planaria per 100 ml of water does not inhibit fissioning. Beyond this density, reproduction is reduced. The reduction, however, is not simply a function of planaria per volume of water. The rate of fissioning at identical densities was found to be different relative to water volume (compare experiment 6 with 1, 2, and 3). Perhaps it is partly controlled by the surface to volume ratio of the container or by the surface area of the substrate which provides "crawling space."

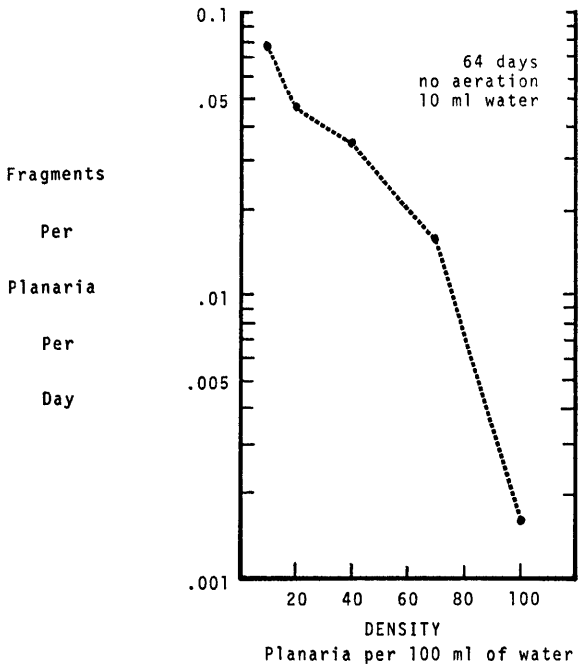

Figure 2. Results of Experiment 1. Planaria from Red Rock Canyon State Park, Hinton, Oklahoma. Twenty-four planaria were distributed 1, 2, 4, 7, and 10 to each jar.

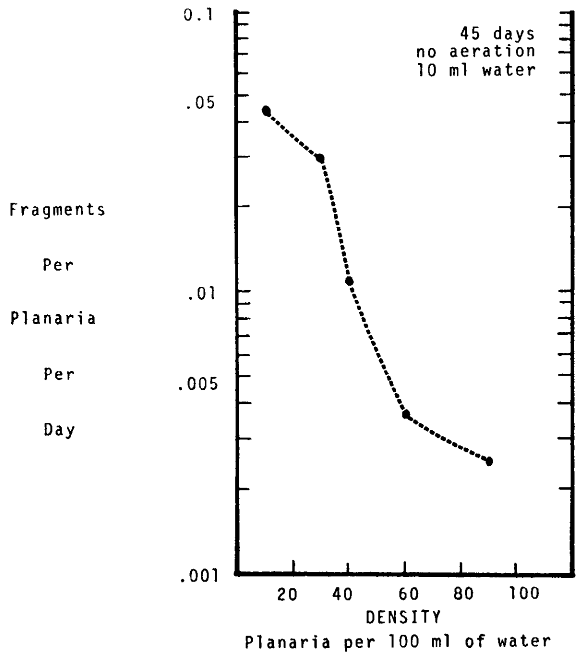

Figure 3. Results of Experiment 2. Planaria from Wichita Mountain Refuge, Oklahoma. Twenty-five planaria were distributed 1, 2, 3, 4, 6, and 9 per jar.

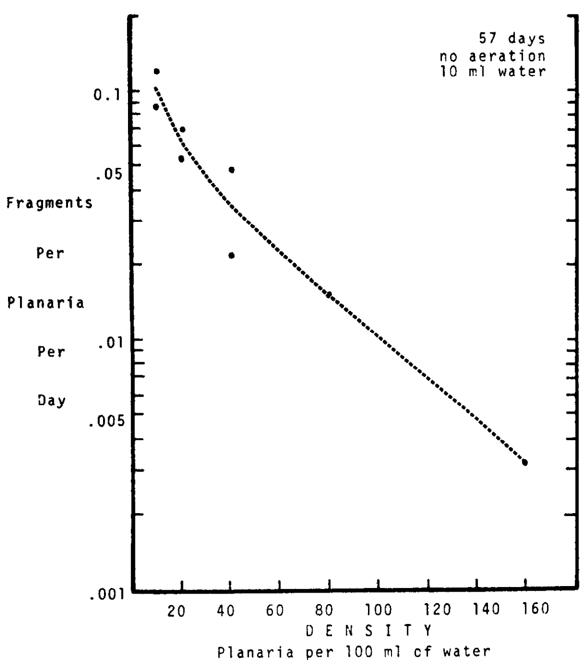

Figure 4. Results of Experiment 3. Planaria from Red Rock Canyon State Park, Hinton, Oklahoma. Thirty-eight planaria were distributed among eight vials as follows: 1, 1, 2, 2, 4, 4, 8, and 16.

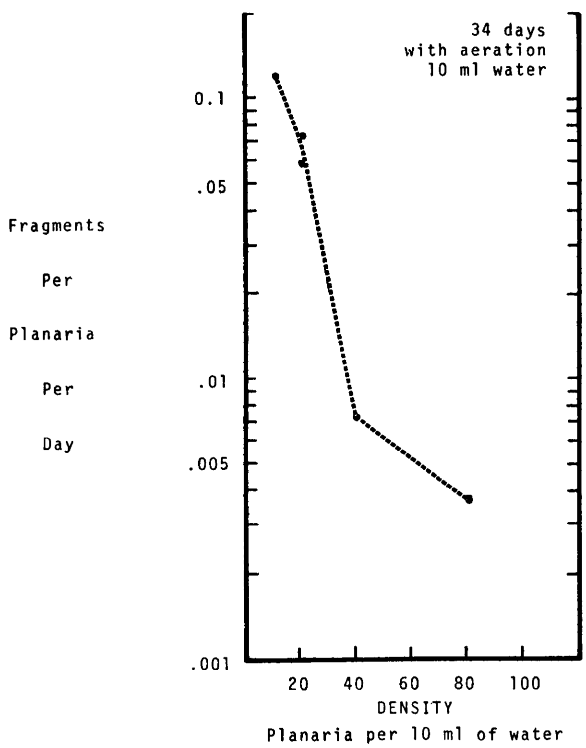

Figure 5. Results of Experiment 4. Planaria from Red Rock Canyon State Park, Hinton, Oklahoma. Thirty-eight planaria were distributed among eight vials as follows: 1, 1, 2, 2, 4, 4, 8, and 16.

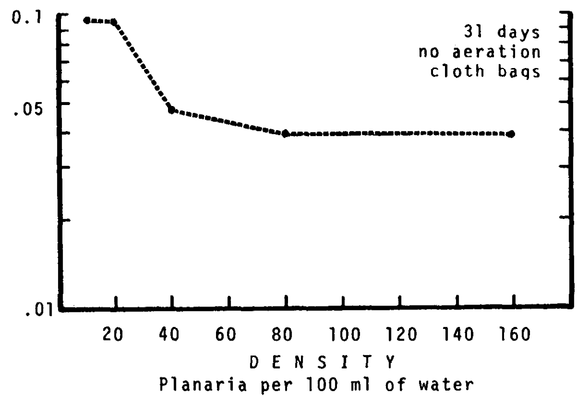

Figure 6. Results of Experiment 5. Planaria from Red Rock Canyon State Park, Hinton, Oklahoma. Planaria were confined in cloth bags suspended in a 1 liter pan of water. Thirty-one planaria were distributed among five cloth bags as follows: 1, 2, 4, 8, and 16.

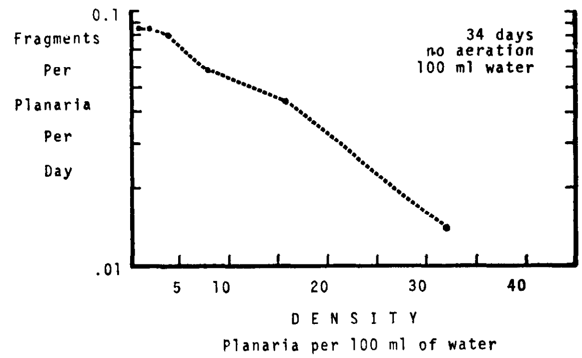

Figure 7. Results of Experiment 6. Planaria from Red Rock Canyon State Park, Hinton, Oklahoma. Sixty-three animals were distributed among six jars as follows: 1, 2, 4, 8, 16, and 32.

Licht[18] found that some substance (probably thyroxine) produced by metamorphosising tadpoles induced premature metamorphosis in younger tadpoles that were kept in the same water. An anologous situation seems to occur in planaria with regard to fissioning. Table 1 illustrates that when two planaria share 10 ml of water their fissioning is usually synchronized. Notice that for jar 3 each time one planaria divided so did the other. A similar thing occurred in jar 4 with exceptions on days 48-50 and 51-54. Could it be that the neurohormal substance postulated by Best, *et. al.*[19] as suppressing fissioning is diffusable throughout the water and brings about synchrony in reproduction? This effect was negated under higher crowding and apparently diluted in the 100 ml of water used in experiment 6.

Conclusion

This study indicates a decrease in asexual reproduction of the planaria, *Dugesia dorotocephala,* under conditions of crowding. The inhibition of reproduction is not due to depletion of oxygen or the build-up of carbon dioxide (or other volatile metabolites). It would appear that the reduction in fissioning is the result of some water soluable substance produced by the planaria and not the result of slime formation. At densities below 2 planaria per 100 ml of water, reproduction is not affected by crowding. With a density of 2 planaria per 10 ml of water, the reproduction of both individuals is sometimes locked together, perhaps by some water soluble neurohormal substance.

The planaria should provide a good model for further work. These experiments should be repeated with clonal colonies[20] to minimize genetic variability. Further laboratory work needs to be done to isolate the "crowding inhibition factor," and more clearly elucidate the entire fissioning control mechanism.

Finally, and most important in terms of its bearing on Creation or Evolution, field studies must be undertaken to determine if the same or different factors of crowding in nature do indeed tend to regulate the natural population density.

Once again the facts of nature seem to point not to evolution (with its necessity of wide open reproduction) but to a divine creation. Built-in density-dependent reproduction rates were mandatory in the beginning and are quite possibly at work today. Perhaps planaria in an artificial, protected universe is a demonstration of pre-fall ecology. Certainly the study of post-fall population ecology deserves a fresh approach. "It is better to trust in the Lord than to put confidence —in man."[21]

Acknowledgments

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[19]Best, *Op. Cit.*
[20]I will be happy to provide in small quantity, free of charge, clonal descendants from group three used in this study.
[21]Psalms 118:8. This verse is also the center verse in the Bible and in a very real sense man's view of life pivots on his interpretation of this passage.

GENETIC ENGINEERING: A BIOLOGICAL TIME BOMB?

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Claims are being made that man will be able to eliminate genetic defects and eventually "control his own evolution" by a combination of eugenics and specific alterations in his genetic material.

While eugenics, or controlled human breeding, is possible, its beneficial effects would be limited or doubtful, and its practice would be socially unacceptable by the majority of the population.

In vitro fertilization with subsequent in utero implantation of the resultant blastocyst may some day be possible, but success may be limited, and the method most likely would be fraught with many dangers for the developing embryo.

Insertion of healthy genetic material into cells that are genetically defective would have limited benefit even if successful, and the results would more likely be disastrous rather than beneficial. While correction of faulty genes by "genetic surgery" may be theoretically possible, insurmountable technical difficulties will almost certainly forever prevent its use.

The idea that man may someday be able to alter specific human characteristics and thus "control his own evolution" is seen as science fiction rather than as serious science.

Introduction

In an editorial entitled, "Will Society Be Prepared?" in *Science,* 11 August, 1967, Marshall Nirenberg, Nobel Prize-winning scientist, stated that, "Cells will be programmed with synthetic messages within 25 years."

George W. Beadle, another Nobel Prize winner, in his book, *Genetics and Modern Biology,* said that "our knowledge is such that we could, if we chose to do so, direct our own evolutionary future."[1]

Immediately after a press conference called by Harvard biologists to announce that they had isolated a gene, the *Evening Standard* in London carried the headlines, "Genetic 'Bomb' Fears Grow." On that same day, another London paper, the *Daily Mail,* headlined a story, "The Frightening Facts of Life. Scientists find secret of human heredity and it scares them."

Gordon R. Taylor, a science journalist, has authored a book published in 1968 entitled *The Biological Time Bomb.*[2] Mr. Taylor attempts to answer the question, where are the biologists taking us? He apparently based much of his material on reports similar to the highly speculative predictions and scare stories quoted earlier. Taylor characterizes new discoveries of biologists "as earth-shaking as the atom bomb."

He indicates that the results of these discoveries are not going to explode in some distant future, but during the lifetime of many who are living today (some of whom, he claims, may live to be 150 years old!). He anticipates the early possibility of a child being born 100 years after his father's death; human beings conceived and nurtured into life by processes in which sex plays no part; elimination of diseases caused by genetic defects; and even control of human intelligence through genetic engineering.

There is real cause for alarm, of course, if indeed it will be possible at some time in the future to control human intelligence, emotions, and personality via genetic engineering. The biological, psychological, political, ethical, and moral problems generated would be immense in scope, and perhaps insoluble. The possibility that such developments would be used to advance the public good rather than as a means to acquire power and control over one's fellow men

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