

# Breeding *Drosophila* In the Computer

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ONE OF THE MOST FASCINATING phases of biology is the study of inheritance. Beginning genetics students are enthralled with the application of Mendelian ratios; but lack of time, space, and finances often make it impossible to breed enough *Drosophila* to demonstrate the laws of genetics. However, in this age of computer technology, it is now possible to "breed" several thousand fruit flies in a few minutes to obtain the same kind of statistics that result from weeks of work in breeding flies in the laboratory. Not only can the statistics be obtained quickly, but with a knowledge of programming, you can alter the statistics so that the experiment can be repeated for as many students as necessary, with each obtaining a slightly different set of data with which to work.

In genetics, the familiar monohybrid cross is written  $Aa \times Aa$ . Unfortunately, most computer print-outs do not contain the lower-case letters, so we must represent the monohybrid cross as  $A(1)A(2) \times A(1)A(2)$ . Using this format,  $A(1)$  is the dominant gene, and  $A(2)$  the recessive. When gametes are formed, there are two types— $A(1)$  and  $A(2)$ . Zygotes produced are homozygous dominant  $A(1)A(1)$ , heterozygous  $A(1)A(2)$ , and homozygous recessive  $A(2)A(2)$ . To accomplish a similar type of "mating" in a computer, a random number function is employed.

## Random Number Function

The random number function (see Sage 1969) might be compared to placing numbers in a hat. If, for example, we wish to select numbers at random between 1 and 7, we will write each number on a piece of paper and place the papers in a hat. If we reach into the hat



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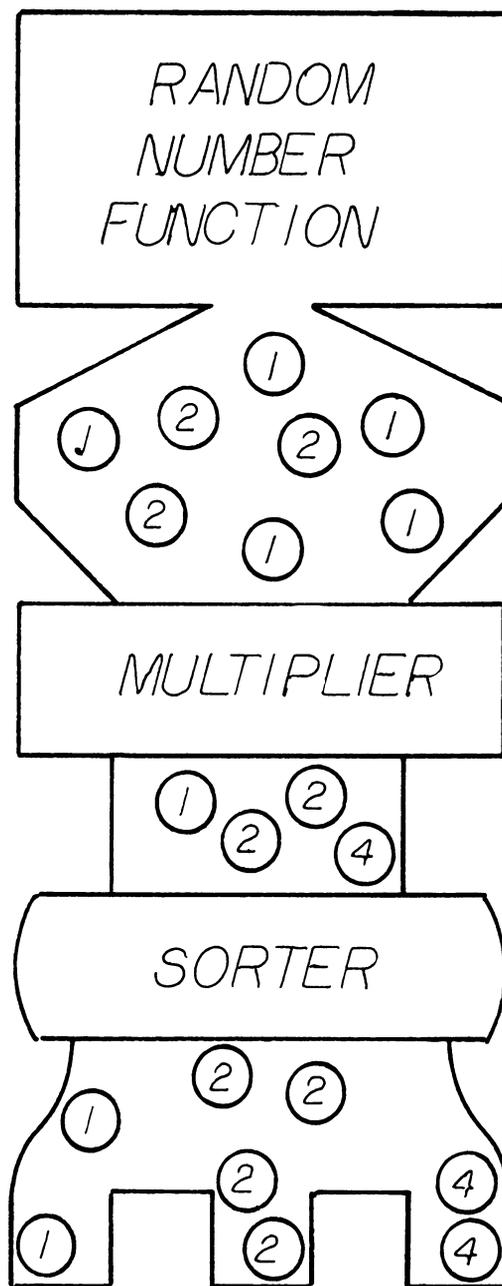


Fig. 1. A simplified flow chart for a monohybrid cross program.

and pick out a number, say the number 3, we will replace the piece of paper with that number on it immediately after selecting it from the hat. The next random number we choose will include the possibility of choosing the number 3 again, since we have returned the paper. Thus, every time we choose a number, we return that piece of paper so that the possibility of choosing that number again still exists.

For a monohybrid cross, our random number function produces the numbers 1 and 2. These numbers are selected by pairs, and then multiplied. The unique products are counted, sorted, and placed in storage bins. The system outlined in fig. 1 is the working computer program we have designed for a monohybrid cross. The full program is given in table 1.

## Simulating a Monohybrid Cross

This program simulates the production of *Drosophila* "by the thousand." To start the program a question must be answered: How many flies do you wish to breed? The response determines the output of the program. We have fixed the program so that it will not run unless a minimal answer of 1,000 is given in response to the question. The program also prints the statistics for each 1,000 samples, and it will stop when the final number in the sample has been generated. In order to save computer working time, the program could be altered to provide statistics for each 100 samples.

Because of its simplicity, and its duplication of the same process that is found in nature, we have selected the monohybrid cross to illustrate the type of computer program that could be written for genetics study. A more complex problem is found in the dihybrid cross. The uniqueness of this computer "mating" can be compared to the Punnett square. For this program, the random number function produces the numbers between 1 and 7. The multiplier selects two random numbers between 1 and 7 as they fall through the number hopper, and it examines the products. If the products are unique, that is, 1, 3, 5, 7, and so on, the products are sorted, counted, and placed in storage bins. Any multiplication by 2, 4, 6, and so on which would not render unique products is discarded from the system.

### Other Options

There are several options available in this program. You may write the program so that only a summary is

**Table 1.** A monohybrid cross computer program.

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5  REM THIS PROGRAM SIMULATES A MONO-HYBRID CROSS
8  REM BREEDING TIME IS 70 SECONDS PER 1000 FLIES
10 PRINT "HOW MANY FLIES DO YOU WISH TO BREED?"
15 INPUT A
16 IF A<1000 THEN 10
17 PRINT
18 PRINT
20 PRINT "GENOTYPE", "NUMBER", "%EXPER", "%THEO", "SAMPLE SIZE"
22 LET N=0
25 LET N[1]=N[2]=N[4]=0
30 LET P[1]=P[2]=P[4]=0
40 LET S=0
45 FOR I=1 TO 2
50 LET X[I]=INT(2*RND(1)+1)
55 NEXT I
60 LET S=X[1]*X[2]
70 LET N=N+1
75 IF S=1 THEN 160
85 IF S=2 THEN 190
95 IF S=4 THEN 220
160 LET N[1]=N[1]+1
165 GOTO 240
190 LET N[2]=N[2]+1
195 GOTO 240
220 LET N[4]=N[4]+1
240 LET P[1]=100*N[1]/N
245 LET P[2]=100*N[2]/N
250 LET P[4]=100*N[4]/N
260 IF INT(N/1000)=N/1000 THEN 270
265 GOTO 40
270 PRINT "A(1)A(1)",N[1],P[1],25
275 PRINT "A(1)A(2)",N[2],P[2],50
280 PRINT "A(2)A(2)",N[4],P[4],25,N
285 PRINT
290 IF N=A THEN 300
295 GOTO 40
300 END

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**Table 2.** A print-out of the monohybrid cross program.

GENOTYPE	NUMBER	%EXPER	%THEO	SAMPLE SIZE
A(1)A(1)	253	25.3	25	
A(1)A(2)	518	51.8	50	
A(2)A(2)	229	22.9	25	1000
A(1)A(1)	513	25.65	25	
A(1)A(2)	1023	51.15	50	
A(2)A(2)	464	23.2	25	2000
A(1)A(1)	807	26.9	25	
A(1)A(2)	1501	50.0333	50	
A(2)A(2)	692	23.0667	25	3000
A(1)A(1)	1051	26.275	25	
A(1)A(2)	2002	50.05	50	
A(2)A(2)	947	23.675	25	4000
A(1)A(1)	1286	25.72	25	
A(1)A(2)	2568	50.16	50	
A(2)A(2)	1286	24.12	25	5000

READY

printed instead of statistics for every 1,000 flies. A print-out for 5,000 *Drosophila* from the monohybrid cross program appears in table 2. In addition to the genotype, the program may be altered slightly to produce a phenotype summary as well at the end of the program. The percentages calculated by this program may be omitted, and the calculations may be assigned as a student project. We have included a print-out for each 1,000 samples in our own program so that a student studying the percentages can see how important it is to have a large number in the samples in order to approach the theoretical statistical probabilities.

Adjustment of the statistics for the dihybrid cross program is accomplished by designing the program to ignore the first 1,000 pairs of numbers produced by the random number function.

Our programs were designed for the Hewlett-Packard 2114B computer using HP Educational Basic (Hewlett-Packard Co., 1971). It may be necessary to adjust your program, depending on the computer available for your use. It might be worth discussing the structure of the program with your students, even if they do not have a background in programming. Setting the counters at zero, starting the random number function, selecting pairs of numbers, multiplying, sorting, and counting are easy to detect and follow in the programs. A much shorter program could be written for each case, but it is advisable to use the longer program to illustrate the logic of the system.

The original programs also contained an optional Punnett square printed on command. A question was used to determine if the square was required, and a series of PRINT statements were utilized to obtain the square. The number of characters in each line and the storage capability of the computer determines your PRINT limitations. The HP 2114B will accept 72 characters per line, thus the Punnett square for a dihybrid cross must be printed in two parts.

Finally, for those who have the energy, interest, and ambition, you can apply the same principles to a trihybrid cross (see Gottlieb 1966). The program is long

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processes for teacher selection and teacher education.

Author: Bruce Tulloch, Schalmont Middle School, Schenectady, N.Y.  
Title: **Strategic grouping in the life sciences**

Heterogeneous classes of early secondary students show wide variance in abilities, interests, and needs. Thus, teaching modes directed at the total class as an intact group are often inappropriate. To facilitate social learning and match instructional tactics with learner characteristics more precisely, classes were broken up into three categories of students, each category composed of one to three groups of four students. Pupils were assigned to a specific categorical group on the basis of similar aptitude, achievement, and motivation. Each group chose a leader who was responsible for transmitting materials and teacher directives to his fellow group members, monitoring their progress, and returning completed work along with status reports to the instruc-

tor. As a result, increased self-control, more immediate feedback to students, and greater teacher time devoted to slower children has been fostered.

Author: Linda Wilson, Shedd Aquarium, Chicago  
Title: **Public aquariums and the schools: a double bond**

Aquatic science is being given increasing attention by schools. However, many schools lack opportunity to visit shore areas, trained staff, equipment needed to maintain large numbers of animals, or time and funding to develop materials. Aquariums are too limited in scope to offer credit and are somewhat isolated from the formal curriculum. Working together, though, schools and aquariums can give students opportunities neither can offer alone. This paper will describe the academic association between Shedd Aquarium and Metro High School, an alternative school which utilizes many community resources. Discussion of

how such a program might be set up will be illustrated by slides and film.

Author: Harold Wiper, Newton High School, Newtonville, Mass.  
Title: **A club model—one that goes!**

This paper will describe the development of a very successful biology club that features a great variety of activities. The club is built around interest sections, each chaired by a student who has a strong interest in that particular field. Each section plans and runs its own program of speakers, field trips, and projects, one of which is to be directed toward benefiting the school or the community. Last year the pre-med section sponsored a bloodmobile, and the marine section presented a "Save Our Whale" program. The club meets as a whole twice a year—once for organizational purposes at the beginning of the year and for a social get-together at the year's end. In between these times the section leaders meet to coordinate the various activities.

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but not involved. The principles we have discussed are the same. The random number function for this program must produce the numbers from 1 to 19. The unique products are formed in the same way as before. These products are examined, sorted, and counted—if acceptable. You will note that some of the unique products formed have the same physical meaning and can be placed in the same storage bins. You might utilize the notation  $A(1)A(2)B(1)B(2)C(1)C(2)$ .

In addition to the speed with which the computer can "produce" the *Drosophila*, the experimenter is spared the problems associated with preparing culture media, the accidental killing of samples, or having the little critters regain consciousness and fly off to their own breeding grounds. It took the HP 2114B about 15 minutes to generate 5,000 samples using the dihybrid cross program and printing the results for each 1,000 samples. The laboratory time for raising such a large sample is much longer by comparison.

Hopefully, these simple programs will aid you and your students in obtaining larger statistics for genetics study; and having mastered the mathematics of unique multiplication, you will see that this same procedure can be applied to a variety of genetics problems (see Crowder 1967). Your imagination is the major limiting factor of any computer program.

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## NSF Chautauqua-Type Short Courses For Secondary School Teachers

The National Science Foundation, which has provided funds to the American Association for the Advancement of Science for short courses for college teachers since 1971, has funded a pilot project extending the program to secondary school teachers. During the 1975-76 academic year, the following two courses will be offered: Water Pollution; and Workshop on Teaching Observational Astronomy.

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