The GenScope Tour

... don't go home without it.

http://genscope.concord.org

See the new tool that enables students to investigate scientific and mathematical concepts through direct manipulation and experimentation.

Funded by the National Science Foundation

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About GenScope™

GenScope ™ is a learning environment that uses the computer to provide an alternative to text-based science education.

Paying particular attention to student populations that are under-represented in science, our objective is to help students think like scientists — to grasp not only scientific explanations of phenomena, but also the nature of the scientific process itself.

We designed *GenScope*, a computer-based manipulative, to help students learn about genetics. *GenScope* is a new tool that enables students to investigate scientific and mathematical concepts through direct manipulation and experimentation. Using *GenScope*, students and teachers can manipulate the processes of inheritance on six different, but related, levels: DNA, chromosome, cell, organism, pedigree, and population. As a complement to text-based instruction, the computer allows students not only to read about genetics, but actually observe and manipulate processes at one biological level that affect life at another.

How do students do this? They enter the world of an imaginary species of dragons. For instance, they see what happens if they were at the chromosome level and alter the gene that codes for a specific trait, such as having wings. They can observe the effects of this alteration reflected at all the interrelated levels. At the organism level they see if the dragon has wings. Perhaps it even has a double set. Perhaps it has none. At the cell level they can initiate and observe meiosis. Which gametes have the dominant allele? Can they follow the allele through the process of crossover? What happens at the pedigree level? When a winged father has babies with a non-winged mother, do the babies have wings? What percentage doesn't? At the DNA level students can see how the dominant and recessive alleles differ. Is one base pair affected or several?

GenScope gives students the ability to create dynamic models for manipulating a number of species characteristics such as horns, wings, legs, color, sex, scales, plates and the ability to breath fire. The program offers a new educational technology that uses the computer to bridge the gap between the "facts and figures" of science and the mental models we construct to explain them — the gap between information and knowledge.

Download our demo version for Macintosh from The Concord Consortium Web site at http://genscope.concord.org. The Concord Consortium has a non-exclusive license from BBN, Inc., where the program was first developed, to use it for research purposes. GenScope version .926 is the latest demo of our software. It does everything the fully functional version does with the exception of printing and saving files.

If you would like to participate in our research, please email us at gsinfo@concord.org.

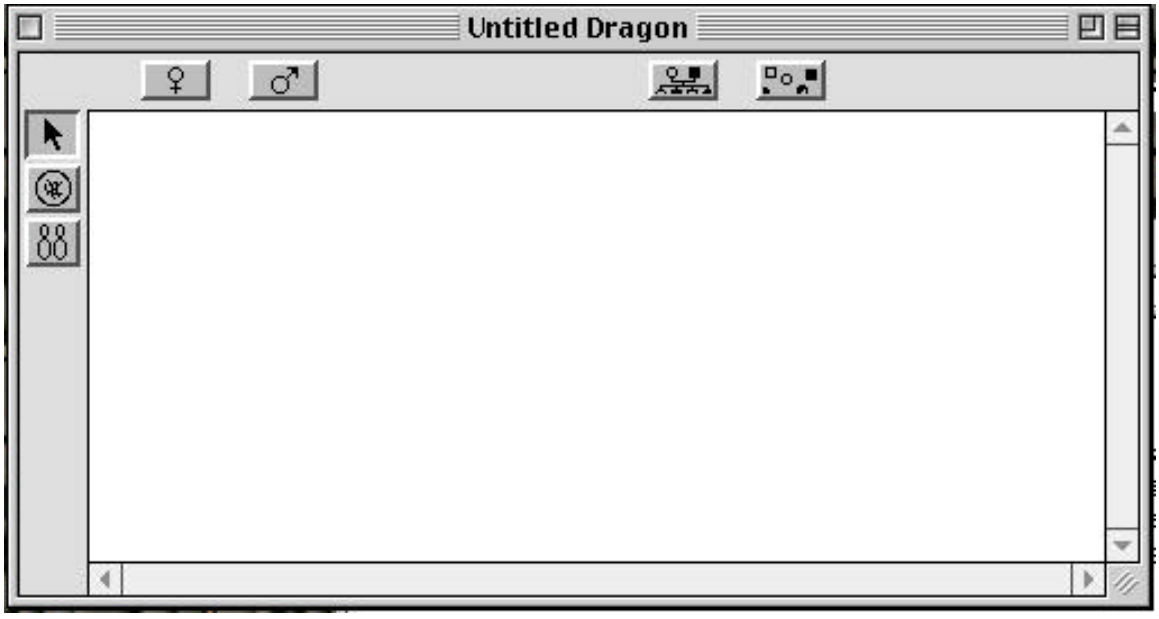
GenScope™ Tour

1. Welcome to GenScope. We'd like you to join us on a software tour, and get to know GenScope, a computer model that explores the world of genetics. We have a variety of tools you can use, a number of levels in our world to explore, and several species to learn about as well.

2. Let's start by introducing you to a species of dragon, letting you use some of our software tools and leading you through the six, interrelated levels of GenScope.

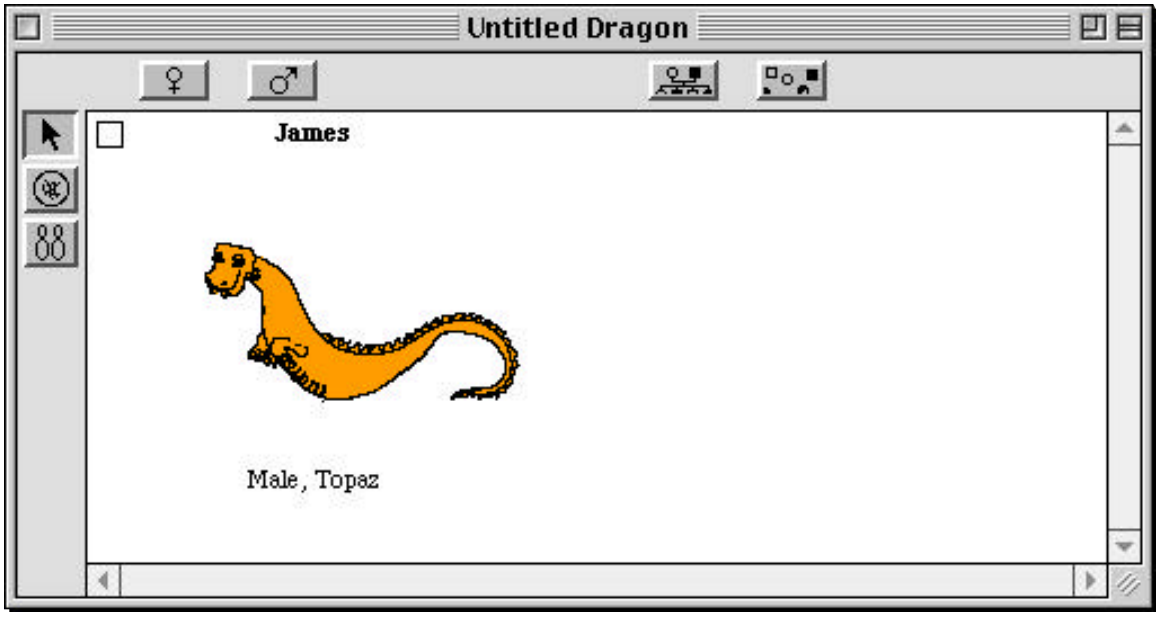
The Organism Level

3. We begin in the Organism Level.
Click on the ♀ (female) or the ♂ (male) to get a dragon which is the sex of your choice. Name it if you like and then click OK or hit return.



4. The characteristics you see on your new dragon are chosen at random by GenScope. Whether you've chosen to make a male or female, you see may be one of a variety of colors - azure, gold, topaz, bronze, emerald, or amethyst. It could be winged or

wingless, fire-breathing or not, horned or hornless, 0-, 2- or 4-legged, fancy- or plain-tailed.



5. Take a moment to look at some of the other tools.

On the left side of the window,

 is the selection tool.

 is the cell tool.

 is the chromosome tool.

On the top,

 brings you to the Pedigree Level.

 brings you to the Population Level.

Seem like a lot to remember? Don't worry. If you hold your mouse over the buttons for a second and a half, a yellow sticky will come up that tells you what the button does.

Let's proceed to Chromosome Level and design dragons.

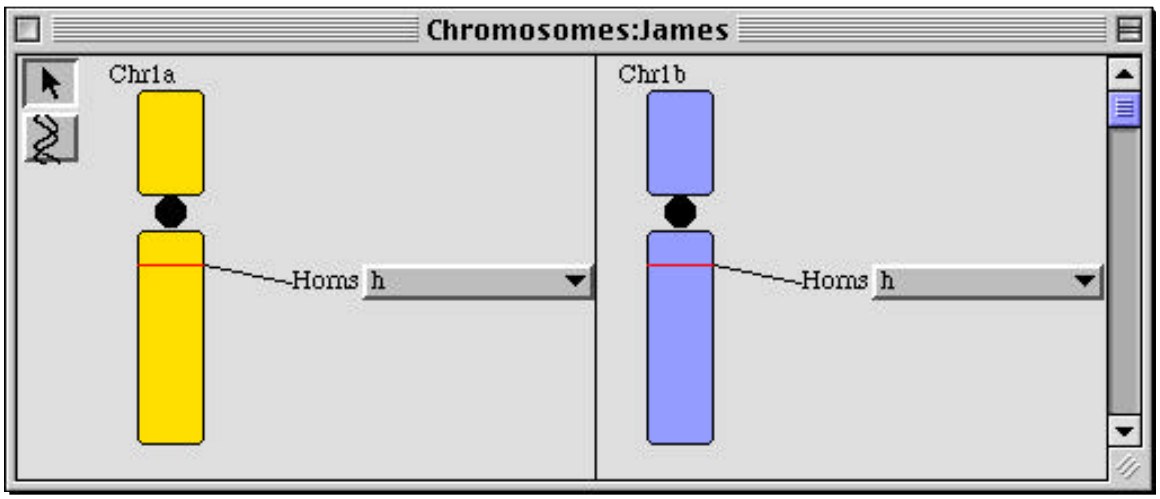
The Chromosome Level

1. This level allows you to see your dragon's chromosomes and the alleles on its chromosomes. You can see the connection between genotype and phenotype: if you change your dragon's alleles, its appearance (in the Organism Window) will change to reflect the changed genetic information.

2. Dragons have three pairs of chromosomes. Using  , the chromosome tool, you can view the three chromosome pairs and modify their alleles.

3. Press,  . Now place your cursor over your dragon. The cursor changes shape to denote it is active. Hold down the mouse button. You'll see a pull-down menu listing your dragon's three chromosome pairs. Drag your cursor over them. Stop on one, let's say the top one, Chr. 1, and release the mouse.

4. You now see a window that displays Chromosome 1, (a and b), with alleles for a horned or a hornless dragon.



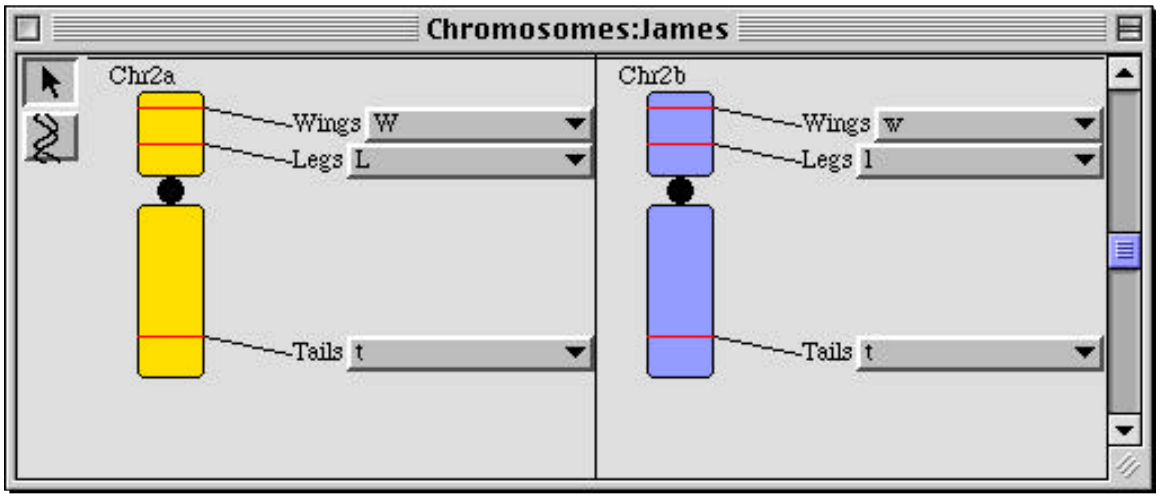
How about modifying your dragon? Look at Chromosome 1a. Click and hold on the button beside Horns, 

.

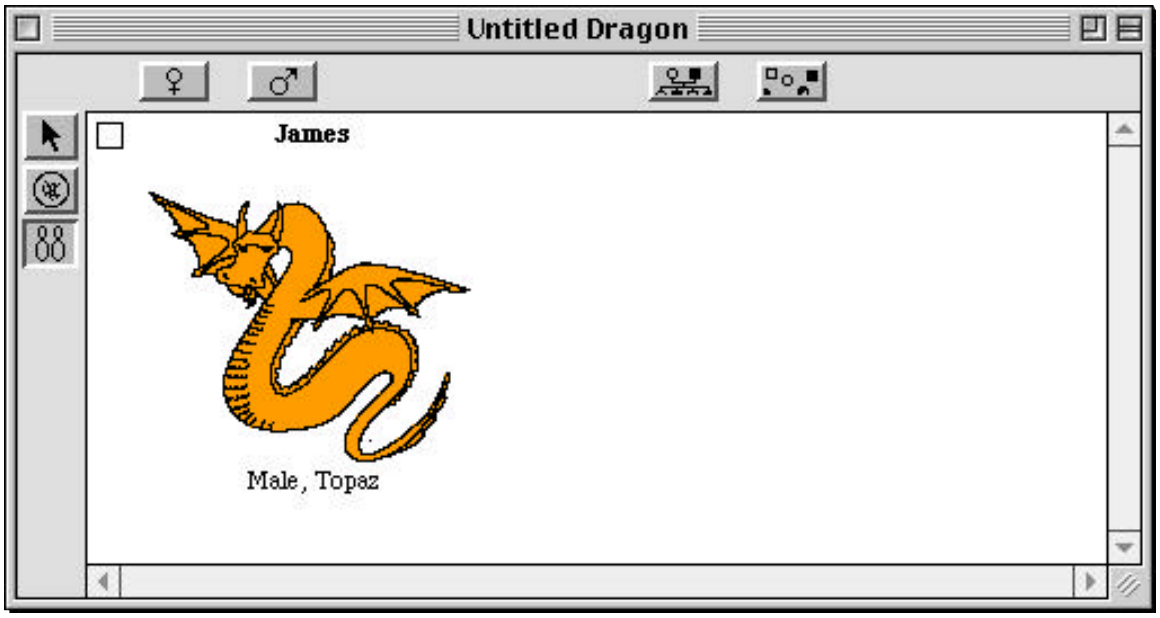
5. You'll see a pull down menu with two possible allele choices, **H** or **h.**

Drag and release your mouse to select one of them. Experiment with Chromosomes 1a and 1b, changing the dragon's appearance between horned and hornless - a simple dominant/recessive gene pattern.

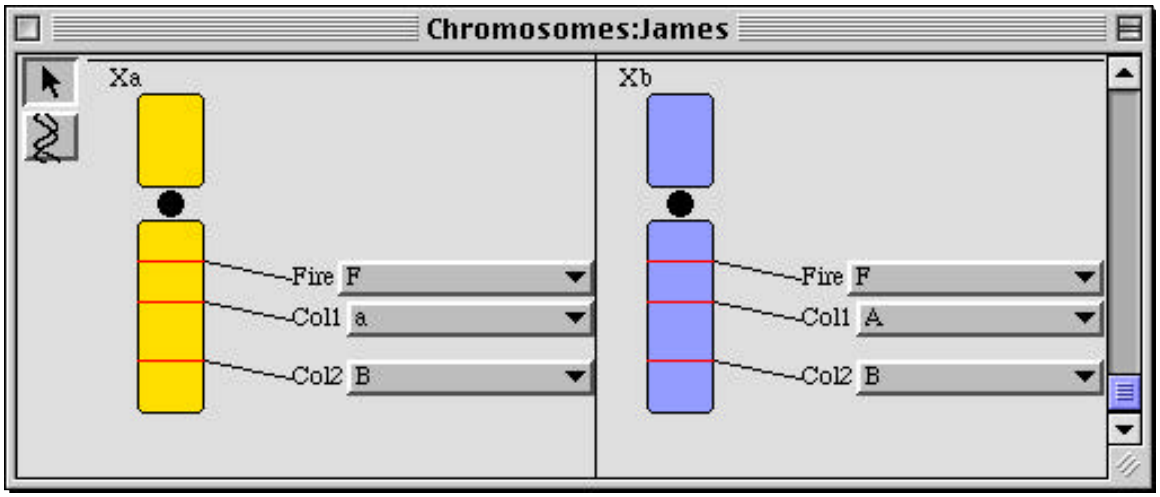
6. Use the scroll bar on the right side of the chromosome window to scroll down and see Chromosomes 2a and 2b. You'll find genes for wings, legs, and type of tail.



7. Experiment with 2a and 2b changing the legs on your dragon. Most of these alleles offer simple dominant/recessive patterns. You can have 0-, 2-, and 4-legged dragons. As you change the genotype, appropriate changes will appear in your dragon's phenotype.



8. Scroll down the chromosome window to Chromosome 3. This carries alleles for color and fire-breathing, which you can also modify. Color is complex: it's an X-linked, polygenic trait. And beware - the absence of the B allele is lethal to your dragon. However, GenScope is a model and you have options that aren't available in real life - you may revive the poor beast by manipulating the alleles.



9. Note: Female dragons have XY chromosomes; males have XX chromosomes. Many animals, such as birds, display this pattern. We don't want students to think that the XY pattern always means male, as it does in humans.

10. Now that you've experimented a bit, how about a couple of challenges? Can you make a different colored dragon? Can you make a dead dragon and revive it?

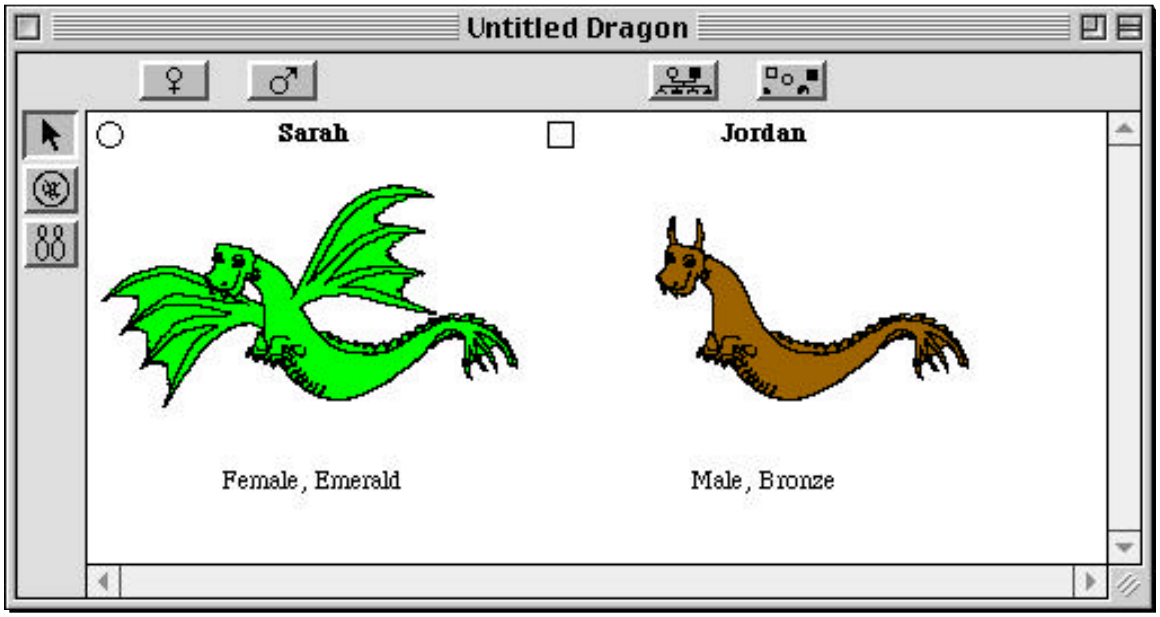
11. You may have noticed another button,  , on the left side of the window when you went to the Chromosome Level. This is the DNA tool. We won't use it yet, but we'll get to it later.

The Cell Level

Let's go to the Cell Level now. This level allows you to see a representative cell of any dragon and learn about meiosis and fertilization. You can produce offspring from two parent dragons. Later, you can design offspring with different traits by controlling alignment and crossover.

Ready to start?

1. First you need a male and a female dragon. Use the  and  buttons. These are your parent dragons. Name them.

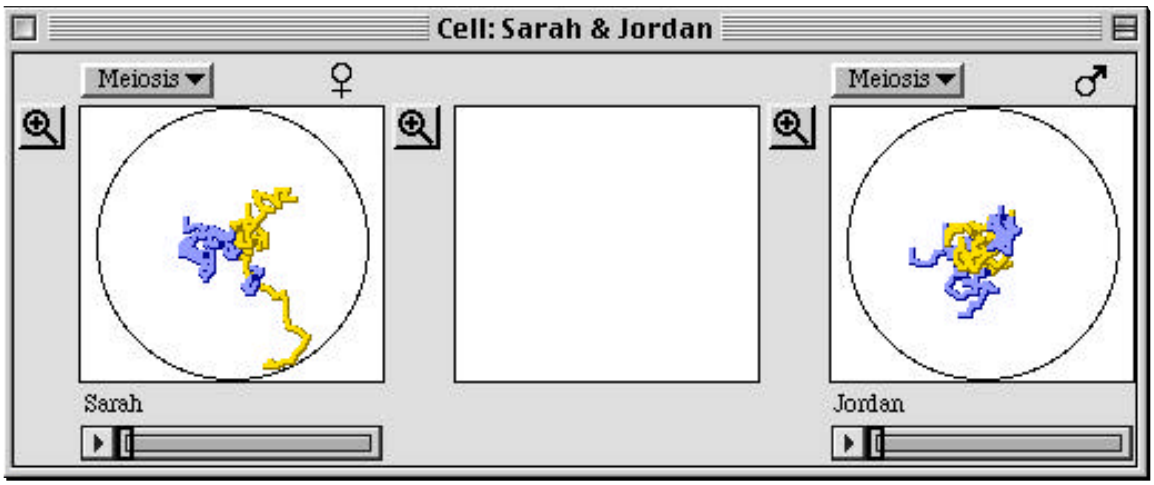


2. Choose the cell tool,  . The squiggly stuff inside the circle represents the chromosomes inside the nucleus of a cell.

3. Drag the tool over one of the dragons and click.

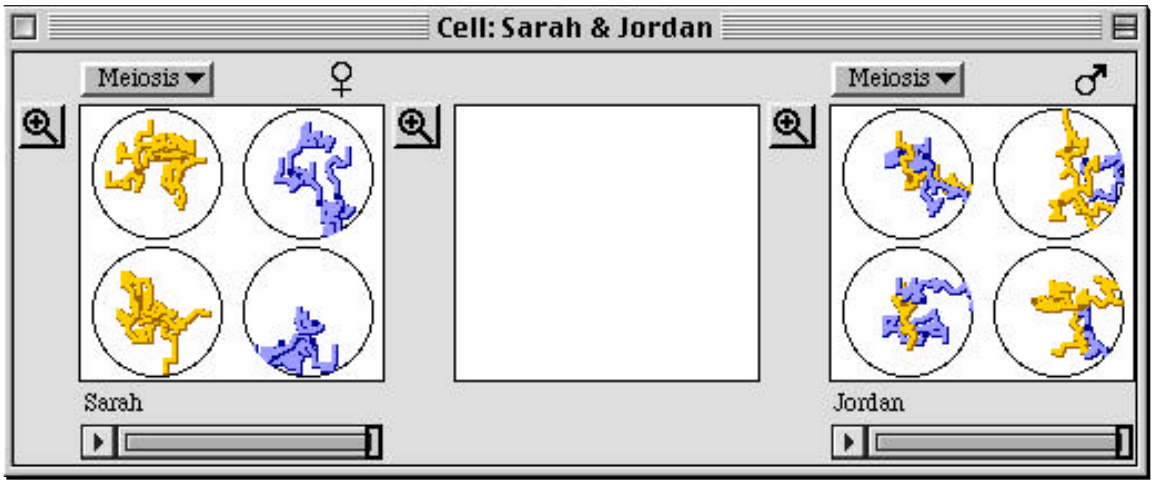
4. You now see a cell window that displays a representative cell from that dragon.

5. Do the same for the second and display that dragon's cell.

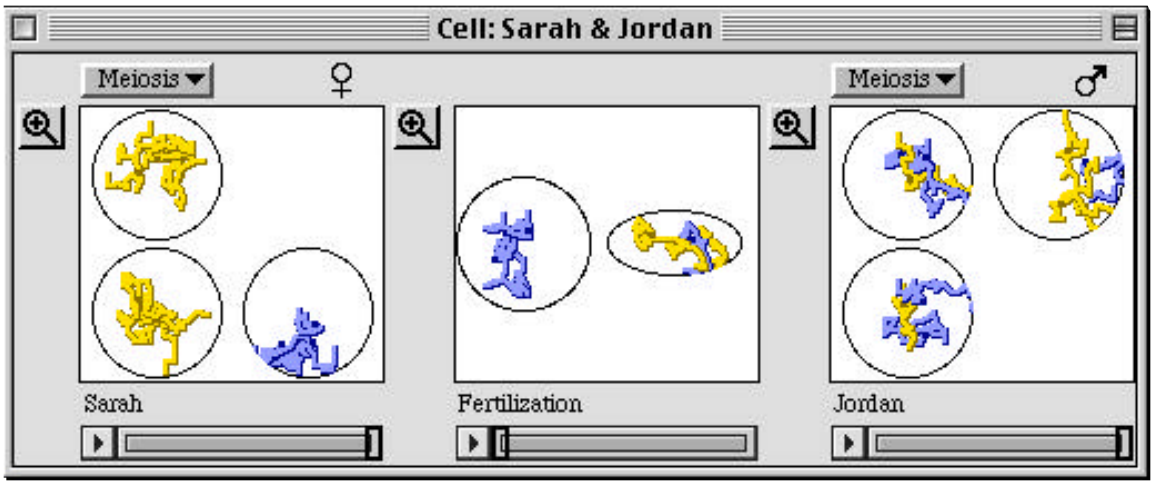


6. Click on the female's right facing arrow,  . You will see an animation of meiosis and end up with four gametes. The animation is random - the chromosomes segregate differently each time you run it.

7. Do the same for the male. If you want to get the gametes without watching the animation, just click anywhere on the gray bar.



8. Make sure you can see the gametes of both dragons. Select a gamete from your female dragon, and drag it to the middle, empty, fertilization window. Now do the same with a gamete from your male dragon.



9. Click on the arrow under Fertilization, 

. When fertilization is complete, name your new dragon and click OK or press return. Your new dragon will appear in the organism window.

10. This new dragon's characteristics are inherited from its parents in accordance with Mendelian principles. You can look at its chromosomes to see how its phenotype arises from its genotype.

Now you can work with GenScope to control the characteristics of the offspring that you create. You can do this by manipulating selection, alignment, and crossover.

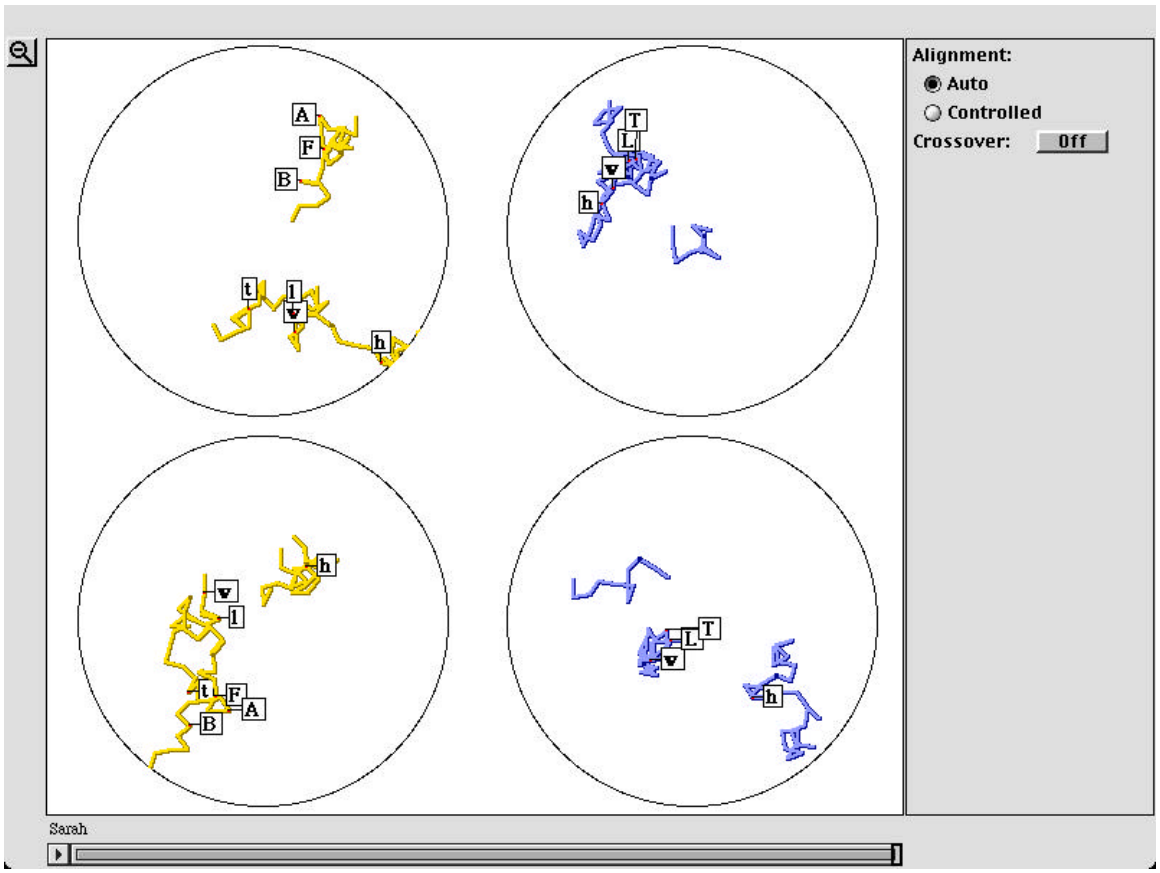
Here's an overview of what happens. First make sure the parents carry the right alleles. Use the chromosome window to view and if necessary, modify the alleles. (For example, if you want a legless dragon, each parent must carry at least one "l" allele on Chromosome 2. Once you're sure the parents carry the right genetic material, you can use any of the following three methods, each allowing progressively more control over meiosis, to ensure you get the baby with the characteristics you want.

Method 1: Run meiosis and choose exactly which gametes to fertilize. Here we go.

1. If you still have the baby showing that you made in the organism window, scroll up to the parents.

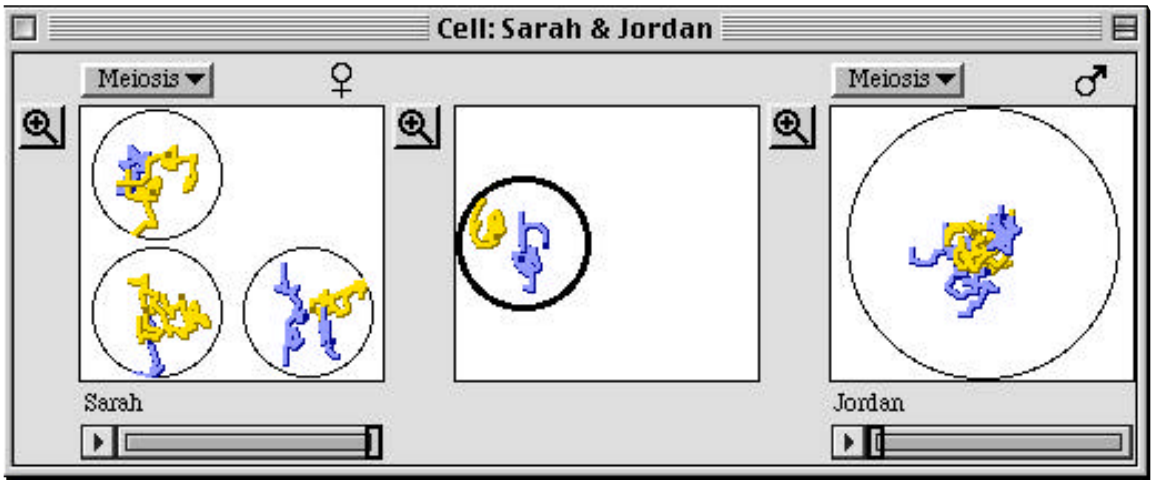
2.  Use the cell tool to open the cell window. Run meiosis for each parent dragon.

3.  Click the magnifying glass to see an enlarged view of the female dragon's gametes. Examine the alleles. You can separate the chromosomes from each other by dragging on them. If the labels are still stacked and hard to read, drag them apart, too. Now you can see exactly which alleles each gamete carries.



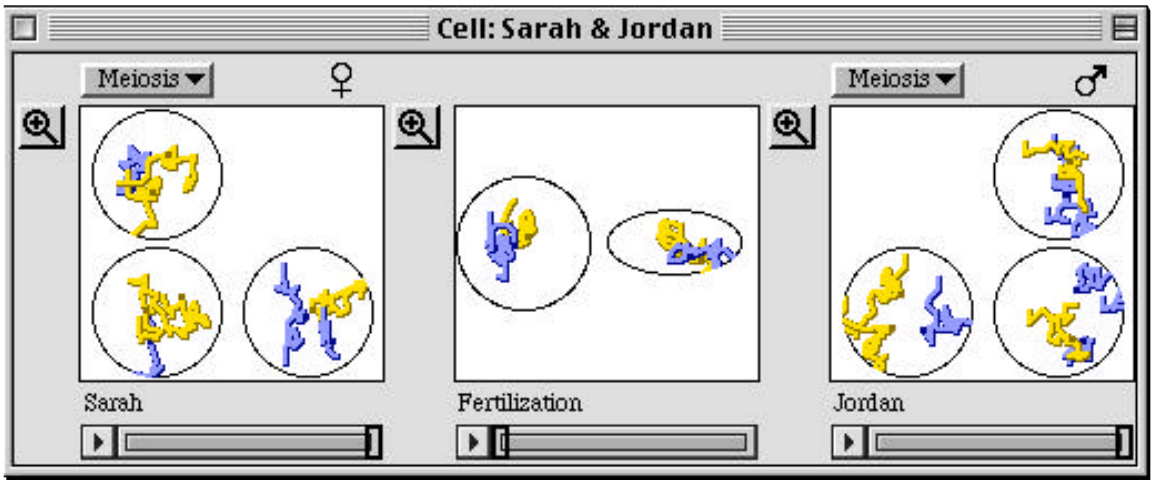
4. Choose the gamete with the alleles you want to pass on to the baby by clicking on it. Do you see the circle outlining the chromosomes become bold?

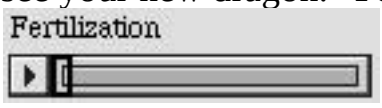
5.  Go back to the partial screen view. You should see the chosen gamete with the bold outline. Drag the chosen gamete into the middle, empty, fertilization window.



6.  Now click the magnifying glass on the right side of the cell window for a full screen view of the male dragon's gametes. Once again, examine the alleles and choose the gamete which carries the alleles you want. Either remember the location of the chosen gamete, or click on the one you want to highlight it.

7.  Return to the partial screen view. Drag the chosen gamete into the fertilization window.



8. Fertilize to see your new dragon. You may name it. You can use the  and then 

to see fertilization in full screen view, or use 

in the partial screen view.

Method 2: Control alignment to create desirable gametes.

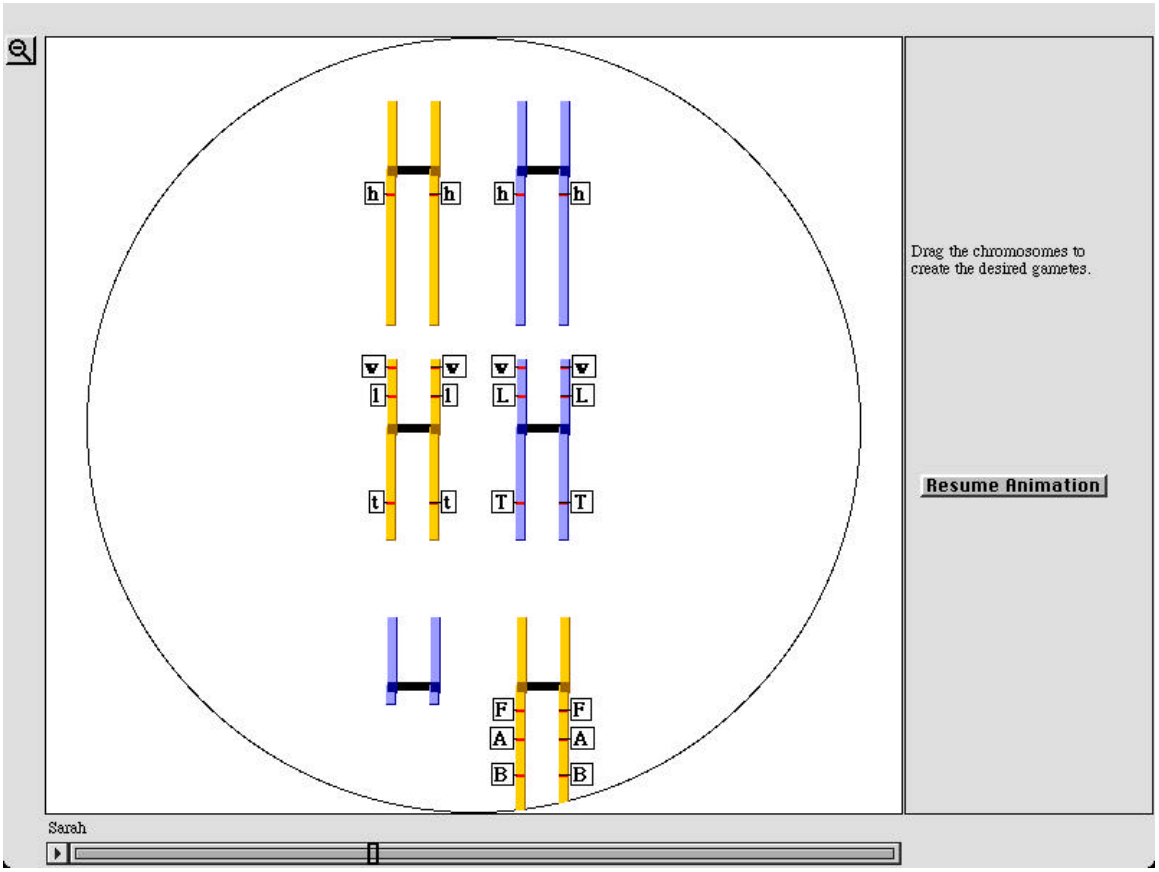
1.  Open the cell window if it's not open, or scroll to the top of the organism window to see the parent dragons.

2.  Choose full-screen view for one of the dragon's cells.

3. Check the circle labeled "Controlled" under alignment.

4. Click on the bar to run meiosis.

5. You'll see a new display. The chromosomes have already replicated during interphase. The three chromosome pairs are aligned, with the alleles neatly labeled. Study the pairs. Those on the right will segregate together, and those on the left will do likewise.



6. Align the chromosomes to get the gametes you want. Make the chromosomes switch sides (alignment) if necessary.

 Place the arrow over the chromosome you want to move. Drag it left or right to its new position. The member of the chromosome pair will switch sides. Click 

or on the horizontal bar when you're satisfied with the alignment of the chromosomes.

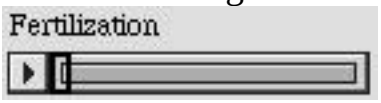
7. Choose the gamete you want.

 Return to partial view.

8. Drag the chosen gamete into the fertilization window.

9. Do the same for the other parent dragon. (The alignment settings will remain as you set them earlier.)

When the 2nd gamete is dragged into the fertilization window, use



to bring your new dragon into the world.

Method 3: Control crossover to design gametes allele by allele.

1.  Look at the cell window for the parent dragons again.

 Choose the full screen view for one of them.

2. Check the circle labeled "Controlled" under alignment.

3. 

Click on the "Crossover: Off" button.

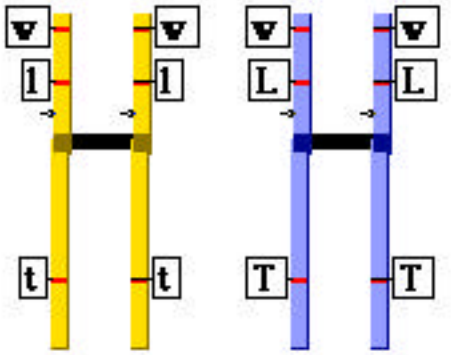
4. It will automatically toggle "On." Click in the circle labeled "Controlled." Now you can control crossover as well as alignment.

4. Click on the bar to run meiosis.

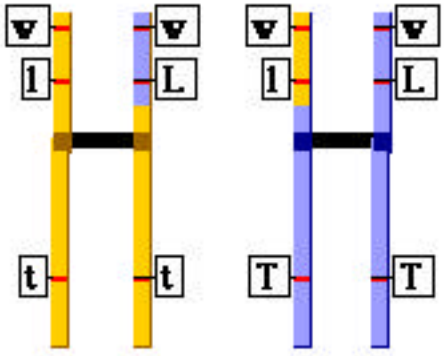
Meiosis will pause at the first alignment/crossover point.

5. Drag paired chromosomes left or right to realign them as you wish (controlling alignment.)

6.  Use the scissors tool to move individual alleles from one chromatid to another (controlling crossover). Click at the point on a chromatid where you would like crossover to occur. A small arrow will appear where you've clicked. Flashing arrows appear on the other three chromatids to tell you which other points you may choose to complete the crossover.



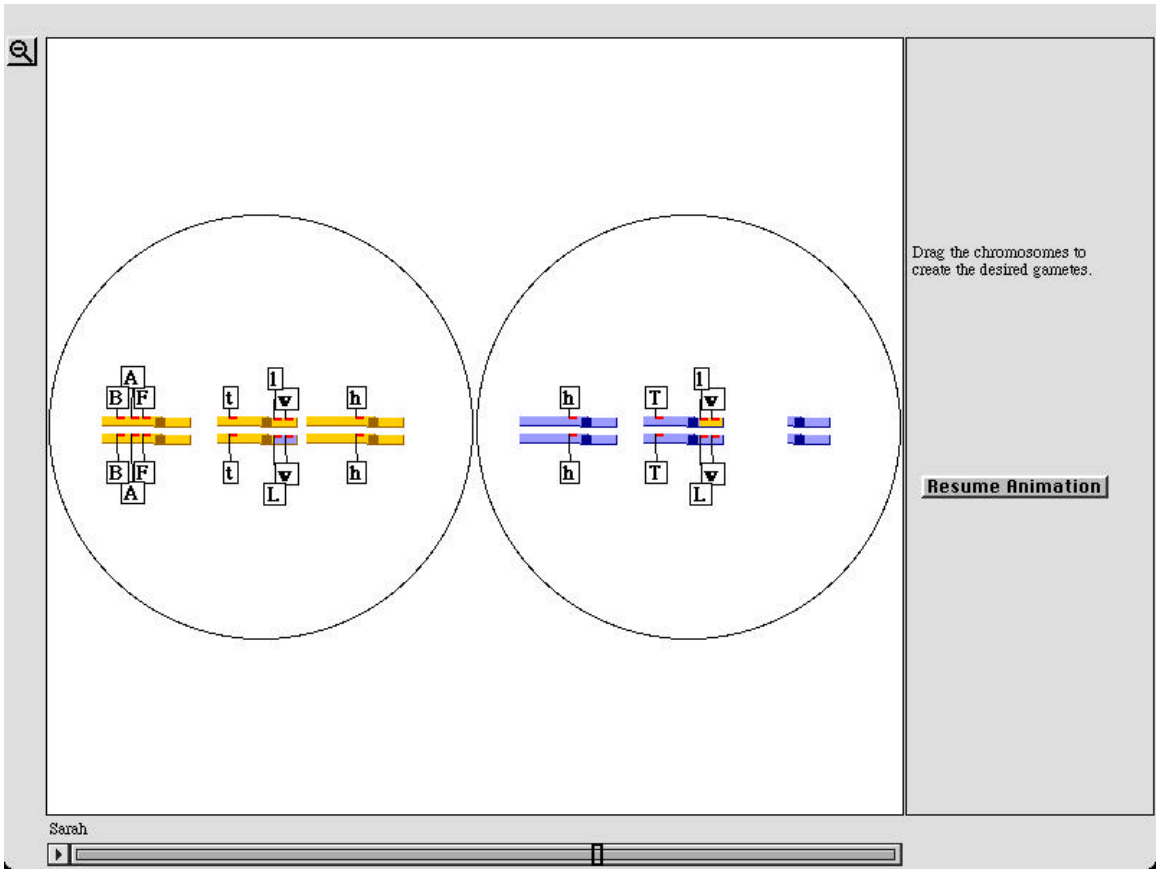
7. Click on one of the flashing arrows. The stretches of DNA beyond the crossover point will exchange places, taking their alleles with them. You can detect crossover by changes in color blocks on the chromosomes as well as by the movement of the allele labels.



8. If you're moving alleles above the centromere, (the point on the chromosome represented by the black bar) click right beneath the alleles you want to see cross over. Below the centromere, click just above the alleles you want to move.

9. Once your alleles are placed as you wish, click Resume Animation. To skip the animation, click on the gray bar to the right of the control bar slider.

10. The cells segregate again, the chromatids lining up horizontally. The top chromatids will move off together (segregate), and the bottom ones will too.  You can make them trade places with the arrow tool.



11. Resume Animation You can click to resume animation or click on the slider to complete meiosis. 

12. You've made gametes. Decide which one you want to use. Then go back to the partial screen view. Drag your chosen gamete into the fertilization window.

13. Do the same thing for the other parent dragon.

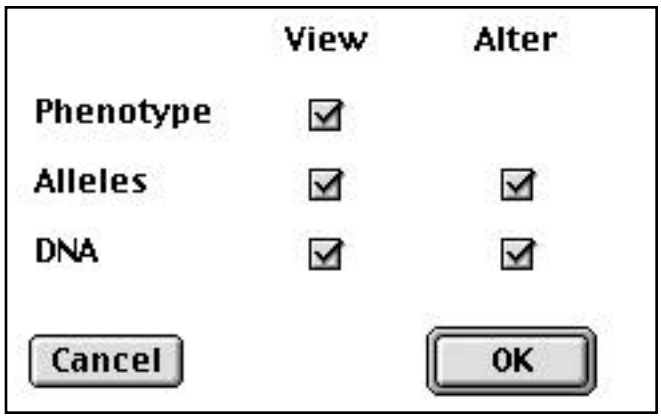
14. Now fertilize. Voila! Your own Designer dragon.

Congratulations. You have mastered the basic tools of the organism level, cell level, and the chromosome levels. Onward, upward and smallward to the DNA level.

The DNA Level

This level allows you to view and change the DNA sequences of your dragon's alleles. Changes you make at this level will be reflected at the organism, chromosome, and cell levels. Your dragon's genotype and phenotype will always correspond correctly to the DNA sequences.

1. You now have only the organism window open. Make sure  is selected, then double-click on one of the dragons. Check to see that the settings in the box allow you to both view and alter the DNA, or change them so you can.



Then click 

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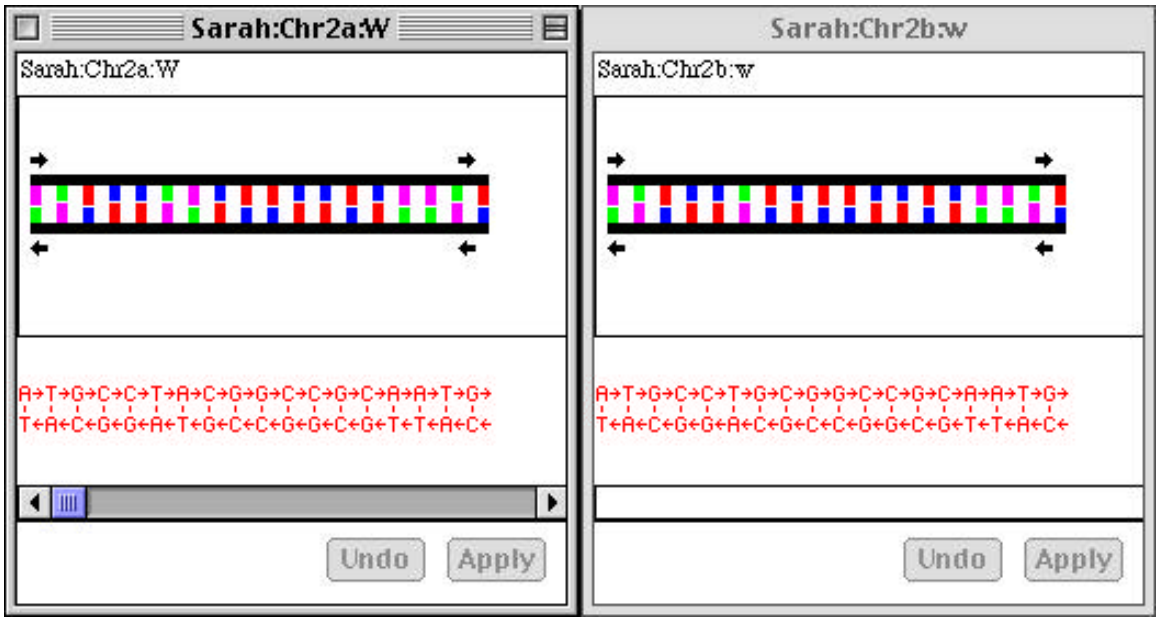
2.  Select the chromosome tool and look at the wing alleles on Chromosome 2 of that dragon. Change the alleles if necessary so your dragon is heterozygous for wings. Do you remember how? If you don't, see pp. 3-4.

3.  Select the DNA tool and place the cursor over one of the genes for wings - not over the letter identifying the allele, but over the

line that represents the gene itself. Your arrow will change to a magnifying glass. Click.

4. You are looking at the DNA window. Use the magnifying glass to open the DNA window for the other wing allele. You now see the DNA sequence for both W and w.



5. Examine the sequences, represented by letters and colors, to see the difference between the W and w alleles.

6. Try changing the sequences. If you change the W allele to conform to the w, your dragon will grow wings. To do this, position the cursor just to the right of the letters you want to change. (If you need a hint ... it's the 7th pair of letters from the left.) Use the delete key to delete the A-T pair. Then type in G to make the G-C base pair of the w allele. 

Click apply.

7. The wings can have a mutation: an entirely new allele. (This can only be done in the DNA window - you can't bring it about from the organism, chromosome, or cell windows.) This allele produces a dramatic effect on the dragon who has it.

8. To see this effect, first make sure your dragon has two w alleles (homozygous recessive; has wings). Create the new allele by

changing one of the w alleles in the DNA window at random to something new.

Click Apply. Do you see your double-winged dragon?

If not, try modifying the other allele.

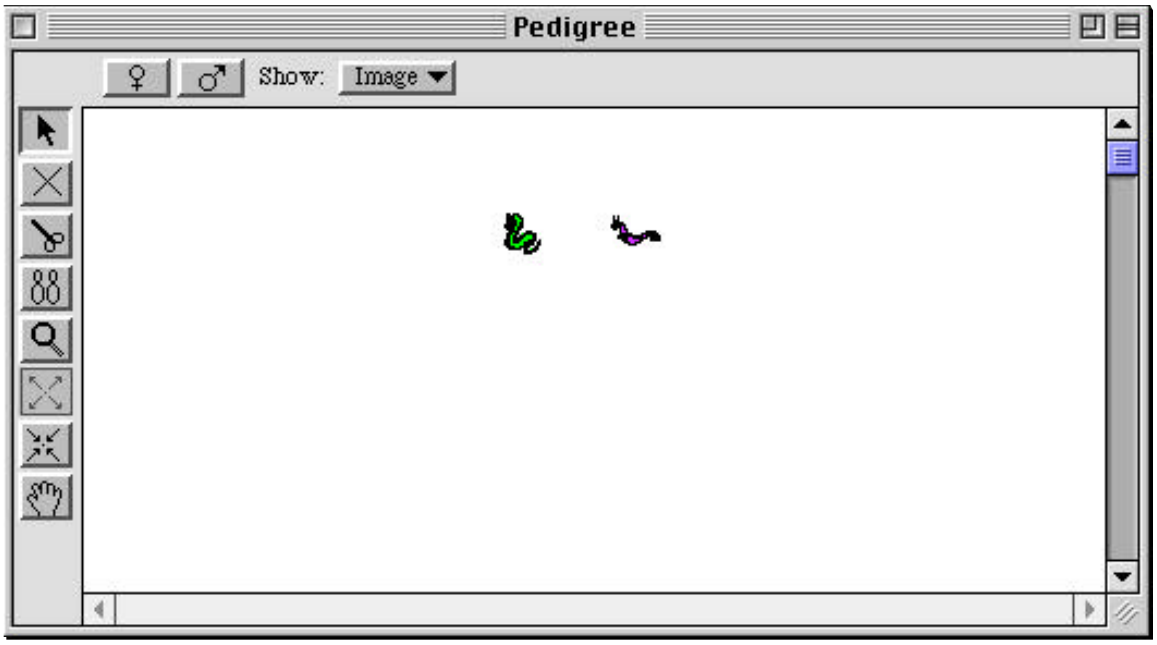
9. The new allele is now part of the dragon gene pool and will show up on all the chromosome menus. Experiment. Try to find all the possible combinations and notice what effect they have on the dragon. Did you find one that may explain why the mutation is not prevalent in the population?

Let's go to the Pedigree Level now.  Click on the pedigree button.

The Pedigree Level

This level allows you to see many offspring of one dragon pair at a time, to create family trees, and to observe inheritance patterns across several generations. So far we've been looking at bits and pieces of genetics - alleles, individual offspring, DNA sequences. In this level we'll get a chance to see how inheritance patterns work in families.

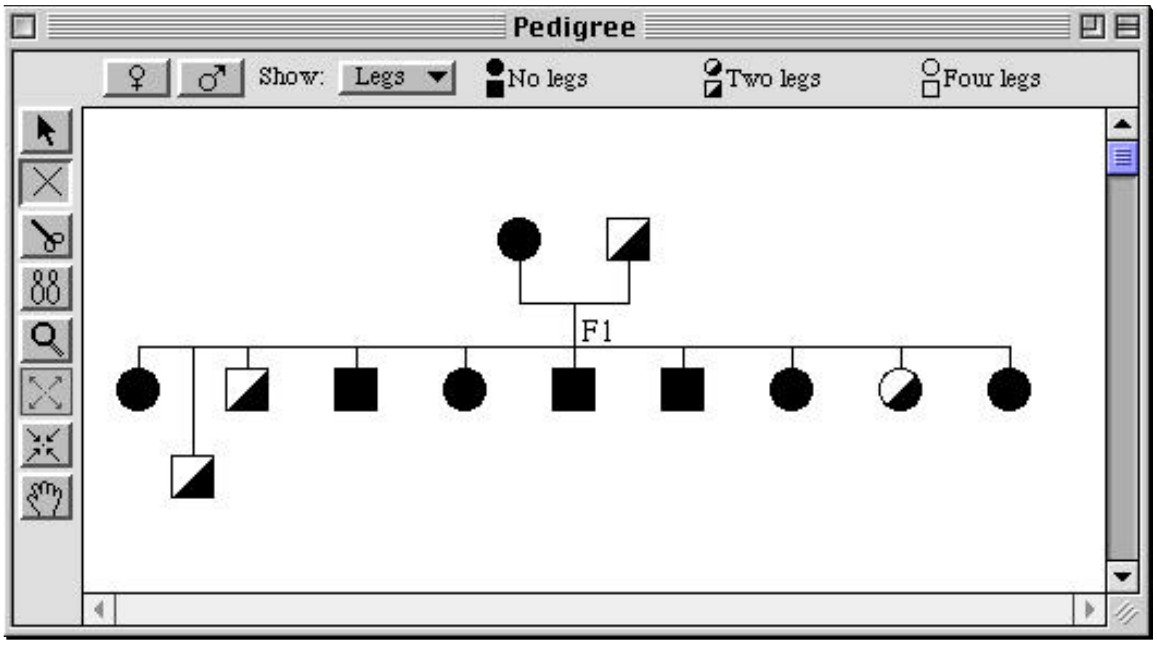
1. Create a male and female dragon as progenitors for your first pedigree. Name them if you like.



2. At the top of the pedigree window, you can see a way to display the traits you choose to study from generation to generation.

If you depress the Image button, you'll see a menu for wings, horns, legs, tail, fire, color, scales and plates. See what happens when you select different characteristics to display. The circle (female) and square (male) will be white, black, black and white, or colored. Read the key and compare the symbols to the dragons in the organism window.

3.  Choose the Crossing tool. Place it on one of the dragons (circle, square, or small image), click, move it over the other dragon, and click again. Ten offspring will appear, giving you a dragon family pedigree.



4. Note that you can no longer use the chromosome tool to change the parent dragons' alleles. Even though you can change your parent dragons' alleles in the pedigree window with the chromosome tool before they have produced offspring, after they produce offspring, you can view their alleles but not change them.

   That's so you can't inadvertently change one of the dragons so the family no longer conforms to Mendelian logic. You can design dragons, but you can't design your own idiosyncratic principles of inheritance!

To study the pedigree, you can use two methods.

Method 1.
Use the Show menu you used earlier to display the inheritance of the chosen characteristic through multiple generations.

Method 2.

 Choose the Select tool. You can make a selection by either dragging a marquee around all the organisms you wish to choose in the pedigree window; or holding down the shift key, select each organism with the mouse. Drag the dragons up into the organism window. You'll see them in full phenotypic splendor.

There are other tools in the pedigree window.

 Cutting tool: Deletes parts of the pedigree.

 Chromosome tool: Allows you to study the alleles of family members.

 Magnifying Glass: Allows you to see the phenotype.

 Zoom-In tool: Enlarges the display.

 Zoom-Out tool: Reduces the display.

 Dragging tool: Allows you to move the display.

You can set various parameters for your pedigrees, such as number of offspring or inbreeding.

1. Click to make sure you're in the pedigree window. (you have to do this to set Pedigree options.)

2. Pull down the Options menu and choose Pedigree options.

3. Set your options. The default is set for 10 **offspring**, **Exact**, **Inbreeding**, and **Show Lethal**.

4. You can determine the number of offspring. You can set the number of offspring to **average** or **exact** size. In GenScope, you can have an exact size for every litter, but in nature the litters of a species will be of varying size and generally average a certain number.

☑ **Inbreeding** allows you to cross two siblings to get another pedigree.

☑ **Multiple crosses** allows you to cross a dragon with two or more other dragons.

☑ **Show names** displays the name of the dragon beneath the appropriate circle or square.

☑ **Show Meiosis** displays the meiosis window and allows you to control meiosis when you cross two dragons. (Note that this will allow only one offspring in the pedigree).

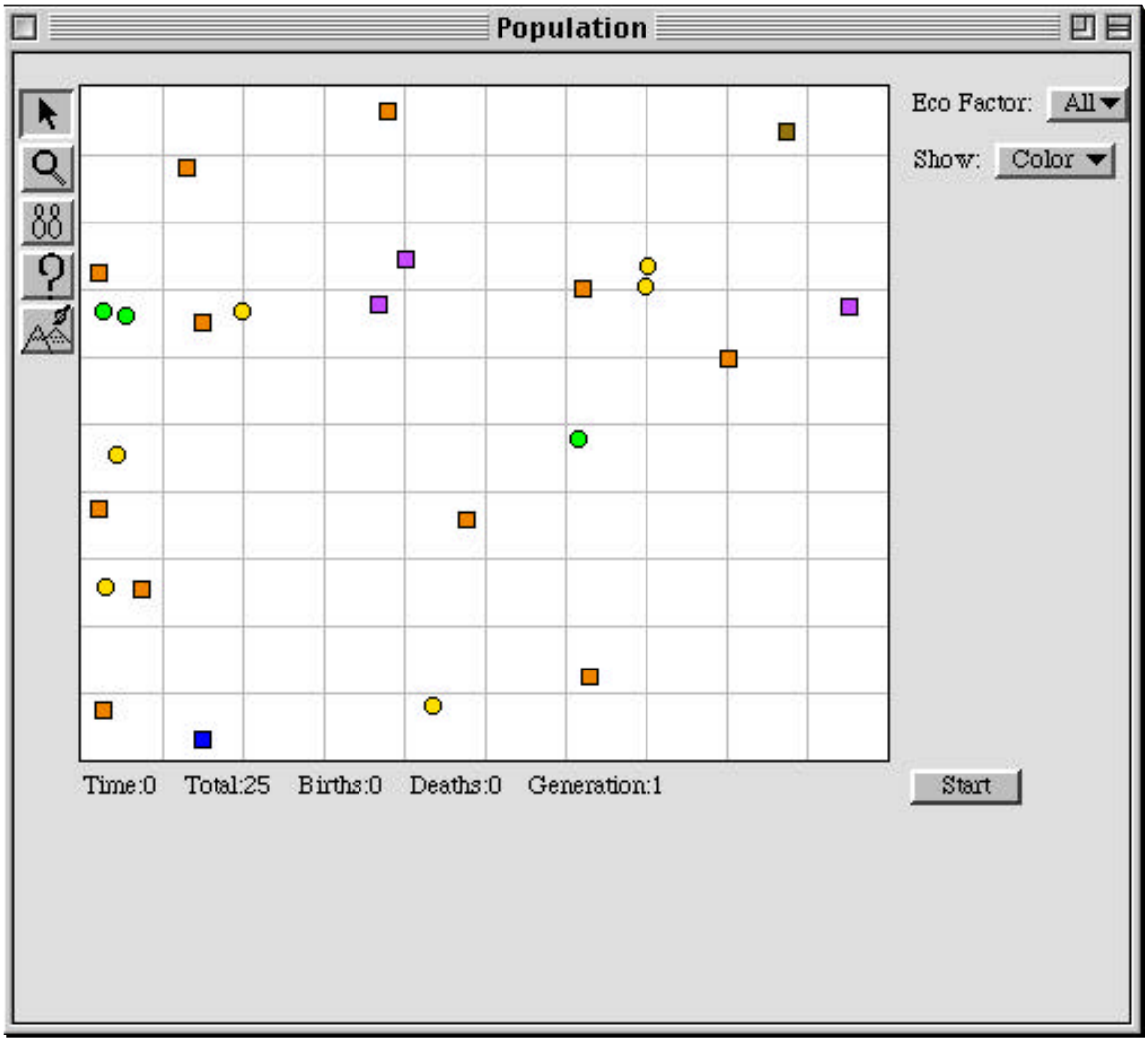
☑ **Show Lethal** displays the dragons in the pedigree which are stillborn. For instance, if your male parent dragon is azure, it's very possible that some of the female offspring will receive two "b" alleles and will not survive. If you check **show lethal,** these dead offspring will be displayed in the pedigree as circles with a line through them.

The Population Level

Let's go to the final level of the tour, the Population Level. This level allows you to work with entire populations and see inheritance patterns and evolutionary factors in a large group of randomly breeding organisms.

1.  Click on the Population button. You can set the number of starting organisms in your population; the default is 25. Press return.

2. This is the population window. The small squares represent male dragons, and the circles represent female dragons, (similar to the ones you saw at the Pedigree Level.)



3. Become familiar with the Population Level tools.

 Select a dragon.

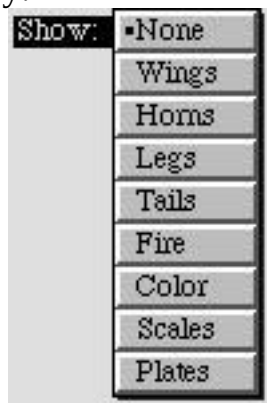
 View a dragon's complete phenotype.

 View or change a dragon's chromosomes. You can determine the characteristics of the first generation of dragons, or accept the random selection of GenScope. Once you press  , however, your dragons will begin mating and you can no longer change any dragon's alleles. Parents and offspring must remain genetically consistent.

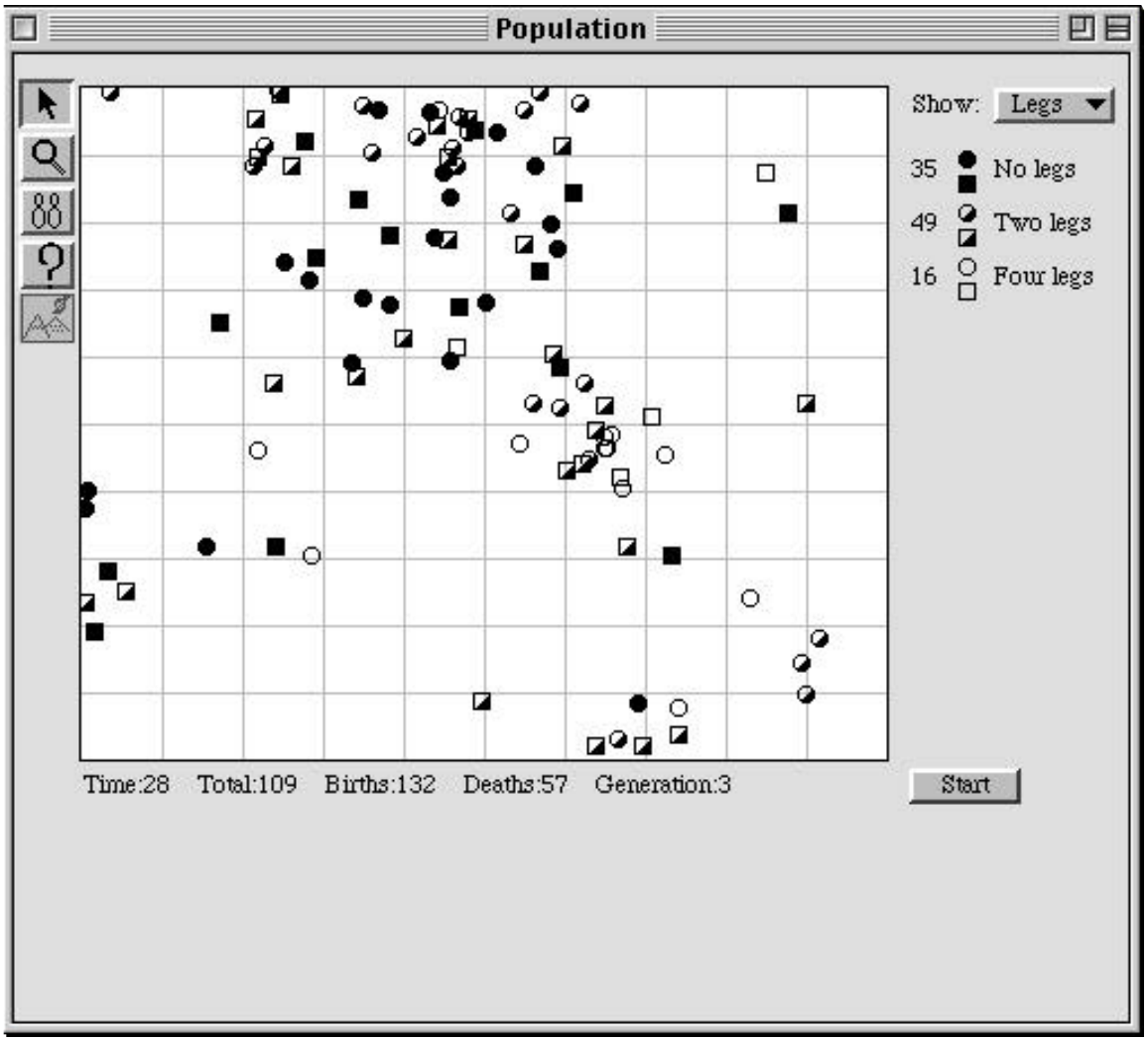
 See information on a dragon's age, generation.

 Assign a chosen eco factor to any square of the population grid.

4. The **Show** menu allows you to see the distributions of specific characteristics in your dragon population. If you depress the button to the right of **Show**, you'll see a menu for wings, horns, legs, tail, fire, color, scales and plates, similar to the one for the Pedigree level. See what happens when you select different characteristics to display.



5. Press  . Your dragons (the tiny circles and squares) will begin to move and the corresponding dynamic population statistics will be displayed at the bottom of the window.



This is the end of your tour ... there's a lot more in GenScope to explore, and we hope you have a chance to return. We're developing more tours and writing more suggestions for how to use it. This really is only the beginning. Thanks for joining us, come back soon.