

Teacher Worksheet: Build-your-own Hardy Weinberg Calculator

Subject: Biology

Grades levels: 8 - college

Description: Using this lesson worksheet, computers and a simple programming interface, students step through and build a simple program to sequentially calculate all of the variables in the Hardy Weinberg equations. By building the program in sequence it is hoped that students will learn the sequence to solve a Hardy Weinberg problem and appreciate the value and power of computer number crunching capabilities as well as sequential programming considerations.

- Uses [Python](#) 2.7 programming language which needs to be installed on computers. [Python Download and Install Instructions](#). [Python intro](#).
- Program [example file](#) link.



This icon is used for teacher suggestions throughout the lesson. Answers to the questions will be inline in **red**.

The Hardy Weinberg equation – is used to calculate frequencies (percentages) of the three genotypes for a gene in a population. It will also calculate the frequencies for each of the two types of alleles for that gene in a population. Note: The Hardy Weinberg equation only applies (is valid for) large populations that mate randomly and natural selection is not acting on the trait.

Here it is:

$$p + q = 1$$


AND

$$p^2 + 2pq + q^2 = 1$$

One of these two equation components is used to calculate the frequencies for the alleles of a gene (in a population) and one is for calculating the frequencies of genotypes.



1. Can you guess which one is for calculating genotype frequencies? **bottom**
2. Allele frequencies? **top**
3. When you look at individuals in a population, can you identify individuals who definitely are homozygous dominant (HH)? **No**
4. What about heterozygous individuals (Hh)? **No**
5. What about homozygous recessive individuals (hh)? **Yes**

Whenever you see a , partners should write out answers **together**. If you don't know the answer, ask another group for help before moving on.

6. Why can you definitely see/know the genotype of ONLY one of the above?
All homozygous recessive individuals will show the recessive trait. Individuals showing the dominant trait could be HH or Hh.

7. Can you definitely identify the number of alleles in a population? No

For this lab we will be creating a computer program to do all the Hardy Weinberg calculations automatically. As we work through a Hardy Weinberg problem on the board, we will also write code in the program to do the calculations for us. After we finish writing all the code and save our program, all we need do is run it and enter the value for q^2 , the program will do the rest! The programming language we will be using is Python. Don't be scared, it won't bite!

What is Python?

Python is a programming language. It is used to make programs. The programs make the computer do stuff. Computers are stupid, but follow directions very well and ...fast. Everything that one does with/on a computer or the internet, happens within some kind of program that someone created.

Python commands to create an interactive program:

- = sets or resets the value for a variable. For example, "x = 5" sets a value for the variable x as 5.
- print** This is needed in a programming window so that the computer will display whatever comes after. For example, "print eval('35+24')" tells Python to display the answer to 35 + 24.
- input** allows the program to ask a question of the user and record the answer. For





Prior to conducting exercise with a class:

1. The (free) python programming interface needs to be installed on all the computers. It's available at <http://python.org/download/>
2. The instructor should work through the worksheet to become familiar with the IDLE shell window and the program writing window.


example, "c=input('How many pets do you have?')" will ask the user for his or her number of pets and store the number entered as the variable c.


Procedure:

 The first thing we need to do is open up the programming "shell" window. Your teacher will tell you where to find the icon for the application called

Whenever you see a , one partner should be working on the computer.

IDLE. Click to open IDLE also known as the "shell" window. *The "shell" window is where we eventually see our program run.*

 The next thing we want to do is open up a new programming window. Go to the *File* menu and drag down to *New window*. The "programming" window is where we will be writing our code. NOTE: the way to easily tell the difference between the shell and program window is the shell will have the symbol `>>>` that precedes the blinking cursor.

 In the new program window type *from math import **. This just tells python to load some math logic from a folder it is stored in. Don't you wish you could have your brain load some math logic from a storage area!

Now let's look at a problem:

Purple wings is a recessive trait for the Indonesian Moonbeam Butterfly (red is the dominant trait). 1 out of every 500 butterflies are purple.

Remember:

$$p + q = 1$$

AND

$$p^2 + 2pq + q^2 = 1$$

In ALL Hardy Weinberg equations:

p^2 - represents the frequency for homozygous dominant (HH) individuals in the population.

$2pq$ - represents the frequency for heterozygous dominant (Hh) individuals in the population.

q^2 - represents the frequency for homozygous recessive (hh) individuals in the population.

p - represents the frequency for the dominant allele (H) in the population.

q - represents the frequency for recessive allele (h) in the population.

As we determined before, the **ONLY** value we can observe in a population is the number of individuals showing the recessive trait, whom (we know) **must** all be homozygous recessive. In the example above 1 out of 500 butterflies exhibit the recessive trait. To figure out the frequency (percentage) for that count of 1 in this population of 500 we would divide 1 by 500..... = .002 which is **q^2**

Let's write it in our program in the new program window (not the shell that shows `>>>`).



Make sure they are in the program window

📖 Since we want our program to be a calculator that can use ANY value/number for q^2 , let's make it ask for this value by typing this code in the new programming window

```
freqhh = input("What is the frequency or percent of individuals displaying the recessive trait? which, BTW, must be homozygous recessive")
```

What this does:

It asks the user for input (usually a number), which it will store in a named variable *freqhh*

📖 The value will be stored in that variable (holder) and could be used by other equations or it can be displayed by.....this code: *print freqhh* Let's code it and try it.

📖 Now let's save our program as HardyWeinbergCalc and then go to the *Run* menu and choose *run module*. NOTE: The program cannot be run until it is saved first. When it asks you "What is the frequency or percent of individuals displaying the recessive trait? which, BTW, must be homozygous recessive" (AKA q^2) type in .002 and let it do its work.



8. Now that we know q^2 , can we calculate anything else? q

9. How? **find the square root of q^2**

📖 Let's code it! In the programming window delete *print freqhh* and type $q = \text{sqrt}(\text{freqhh})$ As you may have guessed sqrt is a square root function. It was loaded by the *from math import* code we entered at the beginning.

📖 To have the program display q , push return and code this on the next line: *print q, "is the frequency of the recessive allele"*

What this does:

It will display whatever value is currently in q AND whatever is in quotations. We added the quoted text so that when the value in q is spit out we will know what it is for.



10. Now that we know q , can we calculate anything else? p

11. How? **$1 - q$**

📖 Let's code it! In the programming window, and on the next line, type: $p = 1 - q$

📖 To have the program display p , code this on the next line: *print p, "is the frequency of the dominant allele"*



12. Now that we know p , can we calculate anything else? p^2

13. How? **$p \times p$**

📖 Let's code it! In the programming window, and on the next line, type: `freqHH=p*p`
Note: We used the name freqHH instead of p^2 because the ² superscript is not possible in the programming window, we could just have easily named that variable Fred.

📖 To have the program display p^2 code this on the next line: `print freqHH, "is the frequency of the homozygous dominant individuals "`



14. Now that we know p^2 , can we calculate anything else? $2pq$

15. How? $2 \times p \times q$

📖 Let's code it! In the programming window and on the next line, type: `freqHh=2*p*q`

📖 To have the program display $2pq$, code this on the next line: `print freqHh, "is the frequency of the heterozygous dominant individuals"`

📖 Now save our program and run it. When it asks you "What is the frequency or percent of individuals displaying the recessive trait? which, BTW, must be homozygous recessive" (AKA q^2) type in .002 and let it do its work.

📖 Run it again and give it a different decimal number for q^2

Now let's figure out the values for another Hardy Weinberg equation. This time do it all by hand.... And then use your program to check your work.

Albinism is a recessive trait for humans. 1 out of every 20000 humans is albino.

0.00707106781187 is the frequency of the recessive allele

0.992928932188 is the frequency of the dominant allele

0.985907864376 is the frequency of the homozygous dominant individuals

0.0140421356237 is the frequency of the heterozygous dominant individuals



16. When you do it by hand, what would happen if you made a mistake in an early calculation.... Say for q or p ? every calculation following would be incorrect

17. What would happen if we made a coding mistake in some early lines of code?
every calculation following would be incorrect

Most computers process information in sequence. If something is not working correctly then computer programmers have to trace back through the lines of code to try to locate the mistake – sometimes through thousands of lines of code - this is called debugging. Thankfully, our program is fairly short as well as being very useful. If you want, you can email the file to yourself, so you can use it to check any Hardy Weinberg equations you

practice at home. To use your program, you'll need the Python shell (IDLE comes in the bundle) which you can download for free here: <http://python.org/download/>

CA 9 – 12 Science standards

Evolution 7. The frequency of an allele in a gene pool of a population depends on many factors and may be stable or unstable over time. As a basis for understanding this concept:

- a. Students know the conditions for Hardy-Weinberg equilibrium in a population and why these conditions are not likely to appear in nature.
- b. Students know how to solve the Hardy-Weinberg equation to predict the frequency of genotypes in a population, given the frequency of phenotypes.

National Board standards

3. Research and Information Fluency.

- Students apply digital tools to gather, evaluate, and use information. Students:
 - a. plan strategies to guide inquiry

The ISTE - National Educational Technology Standards (NETS•S)

1. Creativity and Innovation

Students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology. Students:

- a. apply existing knowledge to generate new ideas, products, or processes.

3. Research and Information Fluency

Students apply digital tools to gather, evaluate, and use information. Students:

- d. process data and report results.

6. Technology Operations and Concepts

Students demonstrate a sound understanding of technology concepts, systems, and operations. Students:

- a. understand and use technology systems.
- b. select and use applications effectively and productively.
- c. troubleshoot systems and applications.



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