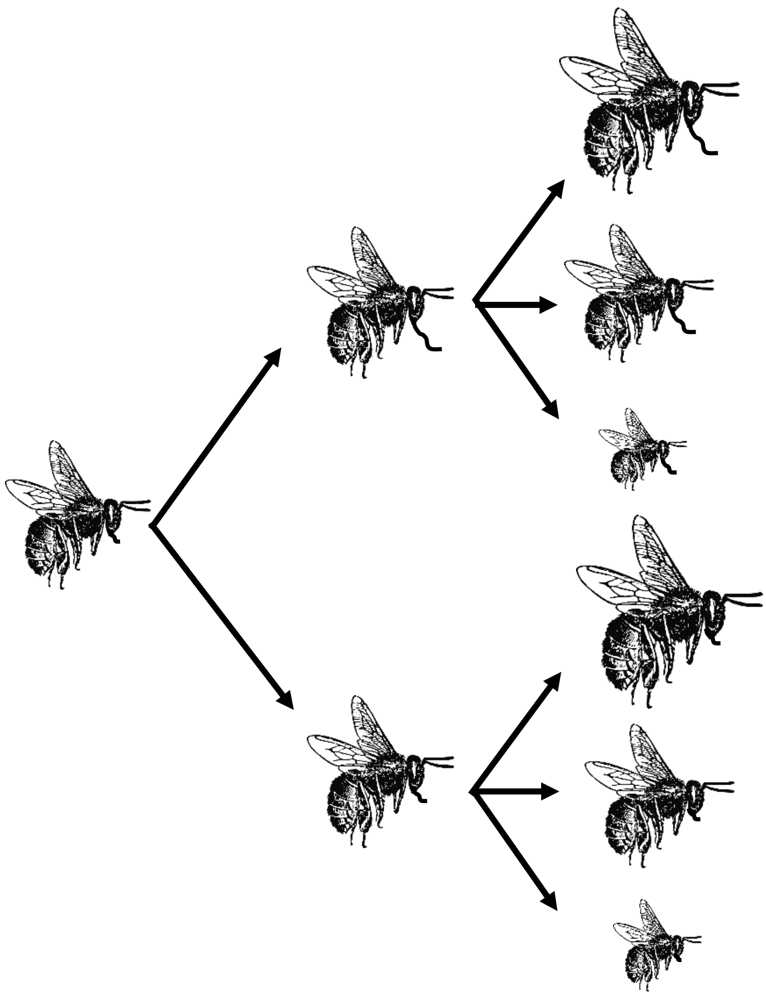
Adaptive Speciation of Honey Bees:



Some Multiplicative and Algebraic Thinking

Adaptive Speciation of Honey Bees: Some Multiplicative and Algebraic Thinking

A. Introduction – Honey Bee Adaptations

Have you ever wondered about the huge variety and diversity of living things in the world? It's mind-boggling, isn't it?

Let's take bees, for example. There are some 25 000 described species of bees in the world – and more are discovered and added to the list of species recognised by scientists each year[1]. (Remember, a 'species' is a group of similar living organisms who are capable of 'exchanging their genes', or breeding with one another to produce offspring.)

Like all living things, bees **adapt** to their environment. New species are created when a group of organisms develop adaptations (changes) to their environment and pass these adaptations on to their offspring through their genes (DNA). Over time, these changes establish a new breeding group of organisms who all have the new adaptive features. These changed features could be physical, size or colour-related, behavioural (how they behave) or dietary features (what they eat). This process is known as **speciation**.

Some of the different adaptive *physical* features developed by bees are listed below. As you read through this list, discuss with a friend how changes in each of these features might help a species of bee to survive to changes in their environment:

Tongue length - Short Tongue or Long Tongue

Size - Small (less than 5mm); Medium (5-9mm) and Large (greater than 9mm)

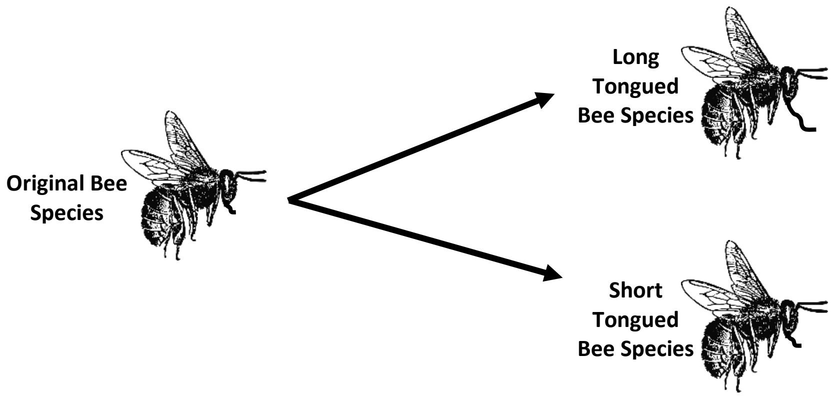
Pollen Carrying Hairs – Simple (straight) Hairs or Plumose (branched) Hairs

Type of pollen collected - Monolectic (only use only species of plant); Oligolectic (use a restricted group of plants eg. Eucalyptus); or Polylectic (use multiple types of flowering plants).

Let's imagine we have a species of bees who live in a hive. Over time, new hives for these bees are established and the species of bees spreads over a fairly large area. Now let's imagine that due to some changes in weather or climate, one of the main groups of flowers from which the bees get their pollen dies out and the only type of nectar-bearing plants left are those with deep cup-shaped flowers.

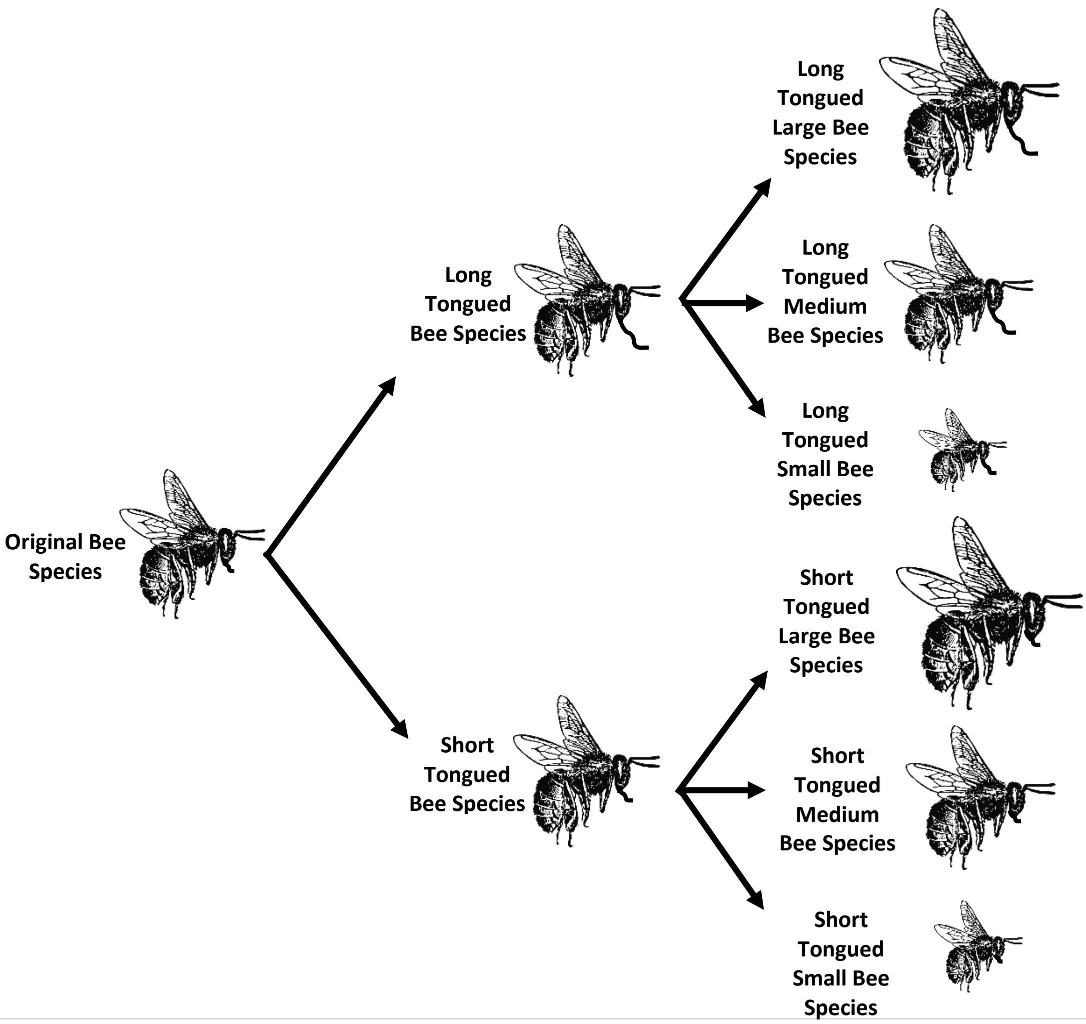
The only bees in this particular area who are now able to get to the nectar – and therefore the only ones that survive – are bees who tend to have long tongues. Over time, there are **two different species** of bees: those with short tongues (in the old hives) and those with long tongues (in the newer hives):

[1] Milner, A. (2011), *'An Introduction to Understanding Honey Bees, Their Origins, Evolution and Diversity'* (online article). Accessed on Bee Improvement and Breeders Association (URL: http://bibba.com/honeybee-origins/). Accessed 22/10/2015.



Now, again over a long time, let's imagine that both the long-tongued bees and the short-tongued bees move into new areas. In some new areas there are lots of bird and insect predators who feed off the bees and in others there are fewer predators. In the areas with lots of bird predators, the bees which survive the best are the smaller bees as they are harder for birds to see. In other areas the bees that survive are larger as they are harder for the many insect predators to attack and kill. In still other areas, the bees stay the same size. Now, we end up developing three separate bee sizes and the bees end up speciating according to their size – small, medium or large.

Let's have a look at what happens now to the number of bee species due to these two adaptive changes:



Wow! Due to just 2 genetic variations – one with 2 variations (Short tongue length / Long tongue length) and one with 3 variations (Large body, Medium body, Small body) – we now have 2 x 3 = **6 species** of honey bee!

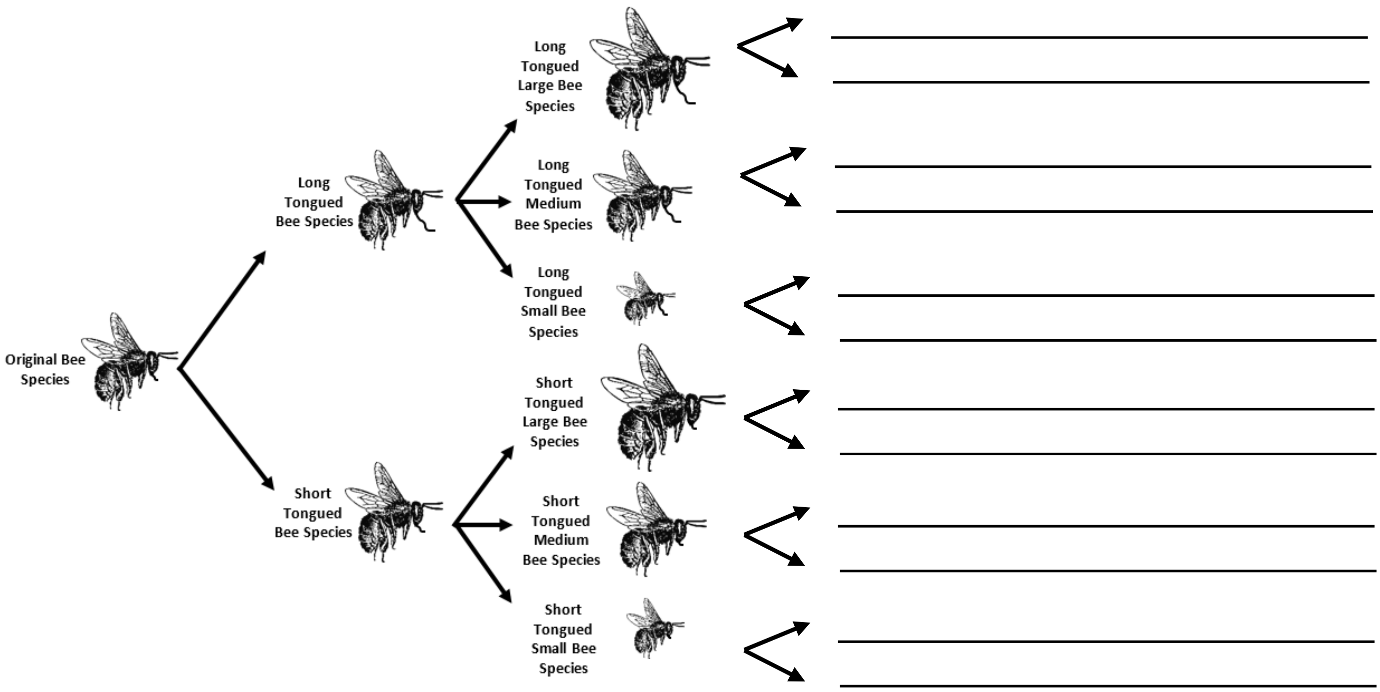
Now things can really get interesting!

Have a look back on the first page at the two other types of adaptive variations mentioned: pollen carrying hairs (2 outcomes – straight hairs or branched ('plumose') hairs); and type of pollen collected (3 outcomes – monolectic, oligolectic and polylectic).

Take the pollen-carrying hair variations first.

Using the diagram, **how many species of bee would we have after each of the above bees further speciated into either straight-haired bees or plumose-haired bees?**

See if you can describe each of them!



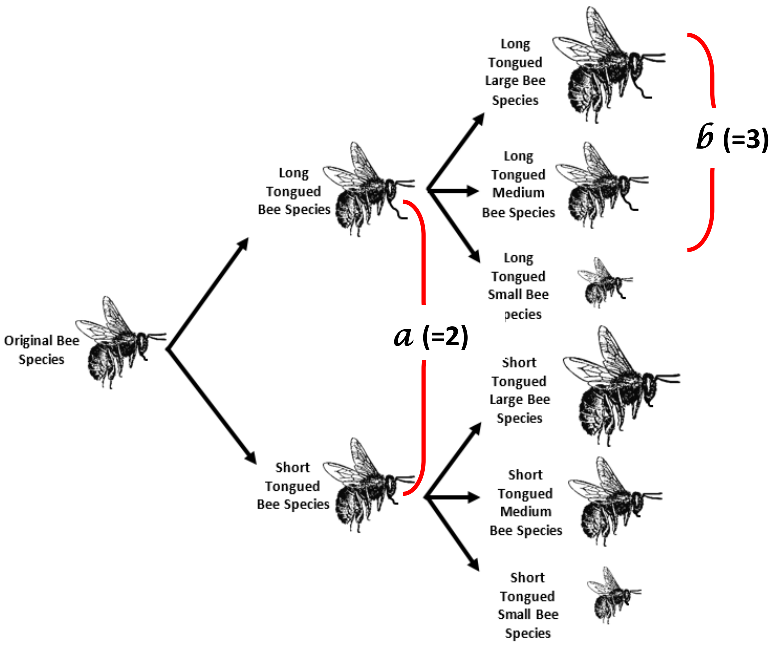
The number of honey bee species = ____________

B. Working Algebraically

We can actually work out the total number of species after a given number of adaptive variations without the use of a diagram, using some simple algebra.

If we give a letter to each event in which a population of bees varies from the original, then the value of this letter can be the number of variations that occur in that event. So, in the example discussed above, the first variation we will call 'a' and the second variation we will call 'b'. In our example, $a = 2$ because there are two variations

(Long tongues / Short tongues), and b = 3 because there are three variations (Large body, Medium body, Small body):



Let's also call the final number of species 'S'. We now can calculate S using a simple algebraic formula:

$$S = a \times b \times \ldots \times n$$

…where n is the last adaptive variation in the string of variations being observed.

In the above example, $S = a \times b$ where $a = 2$ and $b = 3$. So,

$$S = 2 \times 3 = \mathbf{6}$$

Okay… so what about when we have our further variation of bees into straight or plumose-haired pollen collectors?

This third variation we will simply call 'c'.

What value does c have in the above example? c = _____

After this more recent adaptive variation, the number of species (S) is given by:

$$S = a \times b \times c.$$

Therefore, S = ___ **x** ___ **x** ____

Therefore, S = _____ **.**

Now we're ready to add one more variation, which we'll call 'd'. Can you remember the adaptive variation for honey bees we mentioned earlier, where the bees changed the type of pollen they collected? This resulted in bees that were either 'monolectic' (only collect one type of pollen); 'oligolectic' (only collect pollen from limited type of plants, such as eucalypts); and 'polylectic' (collect pollen from a wide variety of plants).

From this information, we know that the value of d = ____.

Our new number of honey bee species S can be recalculated using our algebraic formula:

$$S = a \times b \times c \times d$$

= _____ x _____ x _____ x _____

= ______.

Wow! After only 4 adaptive variations in our original species of honey bee, we now have _______ species!

Don't forget that changes in the genes (mutations) of living things in nature happen all the time. Most of these are not passed on to the next generation, most often because the variation does not result in an environmental advantage for the living thing (this often means the mutated individual does not survive or cannot compete in its environment and so it doesn't get to successfully breed with other individuals).

However, every now and then variations result in a successful environmental adaptation and so that characteristic is passed on successfully to future generations.

Eventually, the changed population becomes so different from the original population that the two groups can no longer breed – and so a new species is 'born'!

Activity 1 - Understanding

Create your own bee-like insect in the space below. Make sure your insect has six legs, antennae, a thorax, head and abdomen. Briefly write about your insect – how big it is, what it eats and where it lives:

Name of my Insect: ______________________________

Now, come up with 3 adaptive variations your insect might develop over time.

Your variations could be:

- **binary** in nature (that is, **2** varieties of difference, such as long antennae / short antennae);
- **ternary** in nature (with **3** varieties of difference, eg. hairy legs / smooth legs / spiky legs); or
- **quaternary** in nature (with **4** varieties of difference).

Use the space below to write down or describe each of your three variations:

Adaptive Variation a	**Adaptive Variation b**	**Adaptive Variation c**

Next, assign a value (2, 3 or 4) to each of a, b and c (depending upon whether the variations are binary, ternary or quaternary).

a = _____ b = _____ c = _____

Now, use the formula $S = a \times b \times c$ to calculate how many new species (S) of your very own bee-insect you have generated:

$S = a \times b \times c$

S = ________

Activity 2 – Problem Solving

20 million years ago, a prehistoric ancestor of Apis mellifera Linnaeus (the European Honey Bee) lived in a colony in a forest in what is now North Eastern Africa.

Over time, this bee species spread and changed and adapted to new environments, changes in climate (such as ice ages), changes in flowering plants and new predators.

If the original African bee species generated one new species as the result of adaptive variation every 2 million years, how many adaptive changes (n) would this be after 20 million years?

n = _____________

Assuming that **each adaptive variation** was **binary** in nature (ie, only 2 variations each time the bee adapted), can you use the formula $S = a \times b \times \ldots \times n$ to work out how many modern varieties of bee would have descended from this original species of pre-Apis mellifera?

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Other working:

<u>Hint</u>: This problem can be calculated through the use of **indices**. To multiply the same number (let's call the number 'x') a certain number of times ('n' times), we can express this simply as 'x^n' (said "x to the power of n ").

Thus, $x \times x \times x \times x$ *(Note that x is multiplied by itself* 4 *times, so* n = 4)
$= x^4$

If n is a fairly big number – for example, anything larger than 5 – there is a handy button on your scientific calculator (or on the calculator on your PC or iPad) that your teacher might show you - the x^y button – that can give you a shortcut to calculating indices.