Curious Genetics

What makes for evolutionary success—for evolutionary fitness? Is it the more children you have, the more fit you are? Is it the more grandchildren? Or is it perhaps the number of direct descendants you will have in a thousand years or more?

The question is more complicated than it seems. It's got to do with genetic recombination, which is the process of how you inherit traits from your parents. Traits are the phenotypical manifestation of genes, and genes are what are being shuffled during genetic recombination.

A normal human being's genome is made up of 46 chromosomes, or 23 pairs. During the process of meiosis, germ cells get half the genetic information of the individual; forming 23 chromosome sperm cells in males, and 23 chromosome egg cells in females. During sexual reproduction, the 23 chromosomes from the sperm are scrambled with the 23 chromosomes from the egg, during what is called chromosomal crossover; forming a 46 chromosome zygote with a unique set of genetic information. This is the birth of the first cell of a new human being.

So, any person gets exactly half their genes (traits) from their dad, and half from their mom. Because of meiosis, the mixing of genes from either parent to form the germ cell, this is not true for the next generation. It cannot be said that exactly 25% of your genes get inherited by any grandchild; though it can be said that an average of 25% of your genes do.

Many deductions can be made from these facts—some of which are:

Why your siblings may be more essential than you…

Evolutionary fitness comes from the successful passing on of your genes to the next generation. Due to genetic recombination, you, on average, share 50% of your genes with any of your siblings (100% in the case of identical twins). You share exactly 50% of your genes with direct children, and an average of 25% with your grandchildren and the children of direct siblings.

Now, it may be that your time would be better spent helping your siblings reproduce instead of reproducing yourself. If helping them procreate results in more than twice as many progeny than you would otherwise have produced on your own, it makes you more evolutionary fit.

So, if you could, you should sacrifice yourself if that would mean that more than two of your siblings, who would otherwise die, would live and have children. Do the math and the same holds true for cousins—although you would have to save more than eight of them (on average) to be sure to pass on more of your common genes.

Today, an intelligent species as we are, we normally know who our siblings are, as well as our children, grandchildren and cousins. This wasn't always true. So, how would you know who was important to save? You didn't. This is how altruism evolved—kindness to strangers. It's also the reason, not really why people distance themselves from others, but rather why they prefer like people. The more a person looks like you, share traits, the more likely it is that that person is a close relative.

Why you will likely be a progenitor of all future humans…

How many ancestors do you have? And how many do other people have? You have two parents, whom both have two parents each—and so it is with everybody. So the number of ancestors increases by the power of two for each generation. You have $2^1=2$ parents, $2^2=4$ grandparents, $2^3=8$ great grandparents, and so on. If we say there's an average of four generations each one hundred years, going back a thousand years we then have 40 generations. How many of your direct ancestors walked around then? Following our calculation, it would be 240 ancestors, which turn out to be more than 1 trillion. Not only that, everybody would seem to have had that many direct ancestors only one thousand years ago. Something is very wrong!

Well, what's wrong is the obvious fact that we all share ancestors. Even within individual family trees the same ancestor is present in separate branches. Your mother's mother's mother's mother may very well be the same person as your father's mother's father's mother.

The further back you go, the more likely it is that you share an ancestor with a stranger. If you think about it you will understand that if you go back far enough any single individual must either be the direct ancestor of all human beings alive today, or none. If he wasn't, it would mean that one human being could trace his lineage back to a common ancestor (an early mammal perhaps) of, say, humans and cats, while another human could do the same to a different early mammal. With no intermingling, these two lineages would then evolve to produce two individuals so similar (human like) that they can reproduce today. This is not realistic!

In fact, it's been estimated that the time you would need to go back to reach this point may be only a few thousand years. Now, the calculations are too complex to go into here, but it's been assessed that the chance of any singular individual human being prior to this convergence time being an ancestor too all humans alive today is around 80%.

As people die off, the point in time for this convergence moves forward. This means that our time today will, in a few thousand years, lie prior to this convergence time. Thus, you and I have an 80% chance of being a direct ancestor of all people on earth at that time. Either that or we will be the ancestors of none!

Why you may be less related to your own grandfather than to his brother…

Going back to the question of evolutionary fitness, this reasoning seems to say that 80% of us are 100% "fit", while 20% are not "fit" in the least. This cannot be correct, and it isn't. It's got to do with the fact that "normal" ancestry differs from genetic ancestry. As people, we all have exactly two parents, while genes have only one. Each of your genes comes from one or the other of your parents, not from both.

If you think about it, this means that you may have ancestors from whom you haven't inherited any genes at all. In fact, think about it some more, and you realize that not only may you have them—it's guaranteed that you do if you go far enough back.

Recent estimates give 20,000 as the number of protein-coding genes in human beings. Given the formula discussed above, we can calculate how many generations ago you had 20,000 ancestors as $2X=20000$. We find that to be just around 15 generations (400 years) ago. (This of course disregards the fact that many of your ancestors converge to the same people, as discussed above. However, the argument is still valid; only the number of generations will be higher.) This means that even if you inherit one gene from each of your ancestors, if you go far enough back, you will reach ancestors from whom you obviously don't inherit any gene at all.

As discussed, you inherit exactly 50% of your genes from each of your parents, while only an average of 25% from each grandparent. It could be, however extremely unlikely, that you don't inherit any gene at all from your paternal grandfather; instead you get 50% of your genome from your paternal grandmother.

You can see that, even if you could prove direct decent from, say, Julius Caesar, the likelihood of you having inherited even a single gene from him is extremely low. In a strict sense you would not be related to him.

In this view, individual organisms are only vessels carrying genes from one generation to the next. Genes are what matters when it comes to you being you, but as genes have only one "parent" while you have two, the ancestry for you and for your genes differ.

So what was that about your grandfather's brother?

Well, say your maternal grandfather's maternal grandmother was the same person as your paternal grandfather's paternal grandmother. You would then (on average) inherit 6.25% of your genes from her through each of your parental lineages, while your paternal grandfather's brother would (on average) inherit 25% of his genes from the same woman. You are thus very likely to share genes with your grandfather's brother. And, as we hypothesized previously, it may be that you don't inherit any of your genes from your paternal grandfather. You would thus be more "related" to his brother than to him himself.

This is of course a highly unlikely scenario, being only a few generations. The more generations there are between, the more likely it is, so it does serve as an illustration.

Why a guppy is more closely related to you than it is to a shark

Guppies are sweet. Sharks are harsh and unpleasant. But sharks are also weird! That weirdness may help explain the initially baffling truth that a guppy is more closely related to you than it is to a shark.

Take the fact that sharks have been around for around 450 million years. Compare that to guppies which have evolved from other fish in the last million years or so, and humans in the last few hundred thousand.

Sharks don't have bones like guppies and humans do, instead their skeleton is made out of cartilage – and their scales are made from modified teeth. They can only swim forward and some of them never stop – they can't since they need to keep water moving over their gills in order to breathe.

Bony fish have swim bladders which let them adjust their depth in the water. Sharks never evolved such organs. This means that they sink if they're not swimming; they navigate their depth more like an airplane than like other fish.

Sharks are stealthy. In addition to their sleekness they are silent. In fact they cannot make any sounds since they lack any organ for producing them – no vocal cords, no swim bladders, no sounds!

Even knowing all this, it may still seem a stretch that guppies are closer to us than to sharks.

This "closerness" implies that guppies and humans share a common ancestor; an ancestor sharks don't share. Going back further in time the guppy/human group "meets" the sharks in a common ancestor of all three.

Humans' closest extant relatives today are chimpanzees; *our* common ancestor lived maybe 7 million years ago. Our common ancestor with gorillas lived a few million years before that and the one with orangutans some million years even further back. And we can keep going back, finding common ancestors with all forms of life. To find our and guppies' common ancestor we have to go back closer to 400 million years!

An additional fact is that both guppies and humans are *equally* close to sharks. Imagine that we could set a number on it – let's say guppies share 65% of their DNA with sharks, well then, so do humans!

So how come guppies and sharks look so much more alike than guppies and people?

Well, guppies and their ancestors never left the ocean – they stayed in the same habitat as sharks. The fish shape is one of the most efficient shapes to possess in water, which is why both sharks and bony fish have preserved that shape for millions of years. It's not a good body shape for living on land, which made it necessary for later human ancestors to adapt and change their form.

You probably know that whales and dolphins are descended from land dwelling mammals. Their closes extant relatives are hippos, yet they look more like fish. They had to adapt in the opposite way, in what is called convergent evolution. That they also developed roughly the same shape as fish is evidence of the fact that that shape is favorable under water.

Now I'm thinking my next chapter should be called 'Why humans are more related to fungi than we are to flowers'.

Afterthought…

Be proud of your genes. They are the result of billions of years of evolution, and they are the reason why I am I and you are you—so that you're not me, I'm not you, and each person is uniquely new.