Linkage and Recombination

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Is it possible, through mutation, for two blood type O (OO) parents to have a non type O child? Along the same lines, it is possible for mutation to account for any blood type in a child or are there limitations on which mutations are possible?

-A curious adult from Oregon
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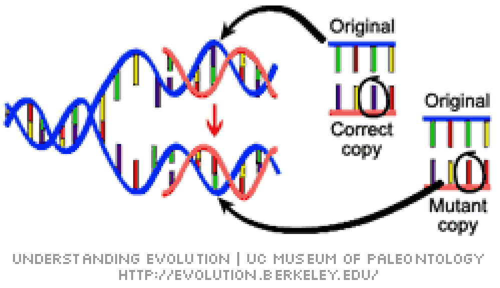


Changes in our DNA can and do happen. Sometimes a new trait can arise.

Yes, changes in the DNA -- also known as mutations -- can cause these kinds of uncommon scenarios. In fact, there are documented cases where things like this have happened!

Keep in mind, though, that mutations are very rare. Two O parents will get an O child nearly all of the time.

But it is technically possible for two O-type parents to have a child with A or B blood, and maybe even AB (although this is really unlikely). In fact, a child can get almost any kind of blood type if you consider the effect of mutations.

How does this happen? Well, the genetic differences between you and me are very small. We inherit these differences from our parents, but our own DNA changes during our lifetimes too.

These changes come about because we are alive. Turning our food into energy can mutate our DNA. As can the sunlight that hits us or chemicals in the air we breathe.

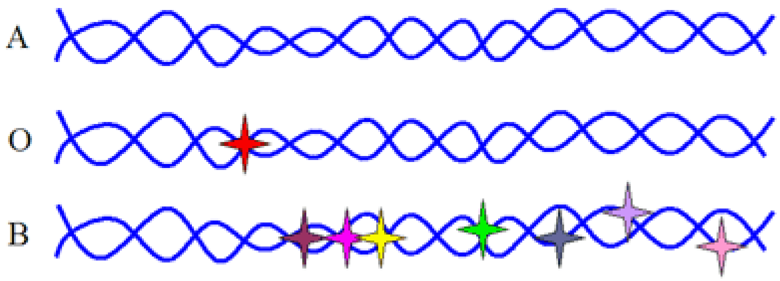
DNA can also change when our cells copy their DNA. This copying process is incredibly accurate but doesn't work perfectly. By the time we are born, we have on average 100 or so new mutations.

This is important to know because the differences between A, B, and O blood types are actually very small. This makes it more likely that a small change can cause an O mom to make an A egg (or an O dad to make an A sperm).

What changes are we talking about? To understand this, we need to go into a little bit of detail about DNA.

Remember, DNA is made up of four different kinds of chemicals called "nucleotides" or "bases." Each gene is a code, or recipe, for how to make a protein.

The ABO blood type is determined by a single gene that comes in three versions, A, B, and O. The difference between A and O is a single base -- the O type is missing a base. The difference between A and B is seven bases.



There is only one difference between blood type A and O.
There are 7 between B and A.

You're probably thinking that one less base or seven different bases shouldn't matter that much. But it can actually make a big difference.

See, the gene is actually a code that is read by the cell three bases at a time. Changing only one base can change the code entirely.

As an example, here's a sentence that uses only three-letter words: "*The old man had one new hat*."
If you change the last "T" to an "M", the sentence would read: "*The old man had one new ha***m**."
Now let's take out the first "E", and move all the other letters up so that each word is still three letters long: "*Tho ldm anh ado nen ewh am*."
Now the sentence is complete nonsense. Mutations can have the same effect on genes*.

The O version is most commonly a nonsense version of the A form. At some point in our distant past, someone got a mutation that caused a base to go missing in their A gene. Now that person has the O form. And that person was successful and so the O mutation spread.

Now what would happen if the cell added back that letter to the O version? If it were in the right place, it'd change it back to A.

In fact, you might be able to add back a letter nearby without too much trouble. Sometimes changing one word in a long sentence isn't that big a deal. You can still sort of figure out what is going on.

So this is how an O parent could produce an A child, with a single base change. Again, I want to emphasize that this situation is very rare. But it is theoretically possible. The rate of this happening is about one in a million.


Recombination can cause supposedly impossible genetic things to happen.

Could you get a B child from an O?
Yes, with a similar mutation to the one we already talked about. This time though, the parent would have to have O-type blood which looked more like B-type than A-type.

This scenario is more rare because most people with O type blood look more like the A gene than the B gene. And it would be very unlikely to get 7 of the right base changes all at once to go from the common O to B.

Can you get A type from B type?
Well, yes. But it requires a different kind of mutation.

As we talked about, the odds against changing 7 bases all at once are so high that it is pretty much impossible to change an A to a B that way. However, there is yet another kind of mutation, called recombination, which can make it possible to get A from B.

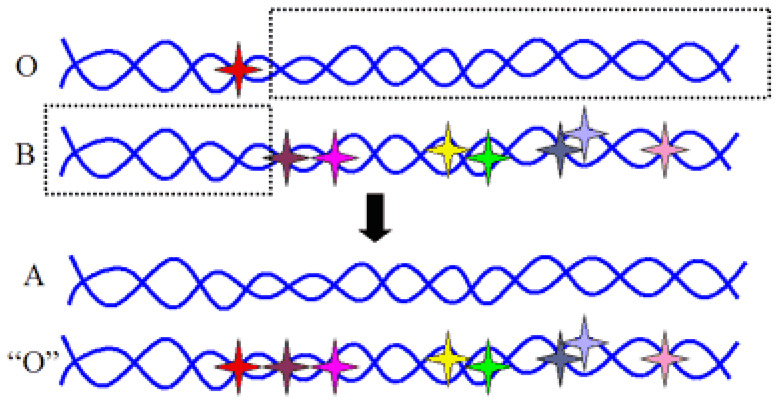
You can think of recombination as a "cut and paste" of the two different forms of a gene within a single person.

So far we've been thinking about each person as having either A, B or O type genes. But remember that every person actually has two different forms of a gene -- one from each parent. By the way, these different "forms" of a gene are called alleles.

Let's say there's a man named Bob with one B type and one O type allele. With this combination, Bob must have B type blood.

When Bob produces sperm, only one allele is selected to be carried by each sperm cell. Sometimes it's the B allele, and sometimes it's the O allele.

Remember that the most common O alleles look like the A allele except they're missing one base in the middle. If you took the beginning of Bob's B allele and placed it onto the end of his O allele, you would get a new allele that works just like the A type.



Swapping part of O with part of B can make an A blood type.
This is called recombination.

Therefore, if Bob has a child with an O type mother, the child would have A type blood, even though neither parent had an A type allele. If he has a child with a B type mother, the child would be AB.

This sounds strange, and indeed it is a rare event, but it can and does happen. In fact, we know that this specific scenario occurred in one Japanese family back in 1997.

In this case, the mother had B type blood and her child A type. The father, with type O blood, was originally told that he couldn't possibly be the father.

After further protest by the father, scientists looked closer at the DNA of both the father and the child. Looking outside of the abo gene at markers in other segments of the DNA, they found that indeed the O type man was the father.

They concluded that the child must have inherited an allele that was the result of a recombination in the mother between the B and O alleles.

So, as you can see, mutations can explain some of the rare outcomes that seem to defy the common genetic rules. Though they are very rare, they are a key part to understanding genetic inheritance.

** Each group of three DNA bases tells the cell which kind of protein building block to use. There are 20 different kinds of amino acids, the protein building blocks.*
Here's a sequence of DNA bases from the ABO gene.
GTC CTC GTG GTG ACC CCT TGG
If you were a cell, you would know that this DNA sequence makes a protein with the following set of amino acids:
Val Leu Val Val Thr Pro Trp
Now imagine that one of the "G"s in the middle (the red one) is taken out of the DNA sequence. All the bases after it get shifted to the left:
GTC CTC GTG GTA CCC CTT GGC
That changes the protein sequence after the mutation to:
Val Leu Val Val Pro Leu Gly

Second letter

First letter	U	C	A	G	Third letter
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG Met	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

That's a completely different set of amino acids, and therefore a completely different protein. Now, what I didn't tell you is that there is a three-letter code that tells the cell when to stop making the protein -- when you've reached the end of the gene.
It turns out that by removing this particular G, the cell finds a stop signal earlier than usual. This is the exact difference between A type and O type blood. Most people with O type have a single nucleotide deletion that causes the cell to stop making the protein too early. Therefore they never make a working enzyme.

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