Case File 2: ABO Blood Group System

Introduction
Human blood can be assigned to one of four types of blood groups (A, B, AB, O) depending on the presence of A or B antigens ('flags') on the surface of red blood cells (RBCs). Basically, type O blood has no flags (antigens), type A blood has only A flags, type B blood has only B flags, and type AB blood has both A and B flags. This is represented in the figure below:

![Blood Types Diagram]

Figure: This picture represents three blood samples being tested to determine ABO blood group. The presence of A flags (A antigens) is represented by the green 'A'. The presence of B flags is represented by the blue 'B'.

Further, the production of A or B flags (antigens) is determined by 3 alleles: \(I^A\), \(I^B\), and \(I^O\) as shown in the table below. \(I^A\) leads to A flags, \(I^B\) gives B flags and \(I^O\) provides no flags.

<table>
<thead>
<tr>
<th>Alleles</th>
<th>Antigen ('flag') type</th>
<th>Blood Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I^A I^A) or (I^A I^O)</td>
<td>A antigen</td>
<td>A</td>
</tr>
<tr>
<td>(I^B I^B) or (I^B I^O)</td>
<td>B antigen</td>
<td>B</td>
</tr>
<tr>
<td>(I^A I^B)</td>
<td>A and B antigen</td>
<td>AB</td>
</tr>
<tr>
<td>(I^O I^O)</td>
<td>No antigens</td>
<td>O</td>
</tr>
</tbody>
</table>

Remember, alleles are different versions of genes. We have two copies of all of our genes and therefore two alleles. In the figure above, blood type B is probably \(I^B I^O\) because only \(\frac{1}{2}\) the rbc have flags.
The Scenario
Bob and Teresa Singh have three children. One of their sons has blood type AB. Another son is type O and their daughter is blood type B.

1) What are the genotypes of the children?
2) What are Bob and Teresa’s genotypes?

The Singh’s daughter has children with a homozygous type A man.
3) What are the possible genotypes and phenotypes in the children?

Tests show that Teresa’s genotype is IA IO and Bob’s genotype was actually IB IB .
4) What is a possible explanation for having a child with type O blood?

Hint: to answer the following questions, it may be helpful to reflect on the picture of blood types above.

5) Describe the A, B and O alleles as either dominant or recessive and explain your answer.

6) Which blood type demonstrates co-dominant alleles?

Bonus Question: What is the medical importance of the ABO blood system?
Case File 2: Answers

Question 1

**ANSWER:**
Genotypes: sons: $i^A i^B$ and $i^O i^O$. daughter: $i^B i^O$

**EXPLANATION:**
- One son has type AB blood. Therefore his genotype must be $i^A i^B$.
- Another son has type O blood. His genotype must be $i^O i^O$.
- The daughter has type B blood. Her genotype could be either $i^B i^O$ or $i^B i^B$. We can pinpoint this further if we consider her brothers blood types. We know that the brother with type O blood must have received one O allele from his mother and one O allele from his father. We also know that the brother with type AB blood must have received one A allele from one parent and one B allele from the other parent. Therefore only one parent has a B allele. This means the daughter can’t be $i^B i^B$ (as this would require both parents to have a B allele). Consequently the sister’s genotype must be $i^B i^O$.

Question 2

**ANSWER**
Genotypes: $i^A i^O$ and $i^B i^O$
Phenotypes: One parent has type A blood; the other has type B blood.

**EXPLANATION:**
We know that the one son with type O blood must have received one O allele ($i^O$) from his mother and one O allele from his father. Therefore we know each parent has one O allele each. We also know that the son with type AB blood must have received one A allele ($i^A$) from one parent and one B allele ($i^B$) from the other parent.

Question 3

**ANSWER**
Genotypes: $i^A i^B$ and $i^A i^O$
Phenotypes: $\frac{1}{2}$ of children will have type AB blood, $\frac{1}{2}$ children will have type A blood

**EXPLANATION:**
From question 1, we know that the daughter’s genotype is $i^B i^O$. Her partner’s genotype is $i^A i^A$

| Heterozygous type B blood type x Homozygous type A blood type: $i^B i^O$ x $i^A i^A$ |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| $i^B$                           | $i^A$                           | $i^A i^B$                       | $\frac{1}{2}$ type AB blood   |
| $i^O$                           | $i^A i^O$                       | $i^A i^O$                       | $\frac{1}{2}$ type A blood    |

Question 4

**ANSWER:** Non-paternity. Bob Singh may not be the biological father of the son with type O blood.

Question 5

**ANSWER:**
- $i^A$ is a dominant allele (to O)
- $i^B$ is a dominant allele (to O)
- $i^O$ is a recessive allele (to A and B)

**EXPLANATION:**
- A dominant allele is one that ‘trumps’ another form of the allele. For example, if you look at the picture of blood types in the introduction, in the second circle the individual’s genotype is $i^B i^O$ as they produce both red blood cells with B antigen and with no antigen. The B allele ‘trumps’ the O allele and the blood type is B.
A recessive allele ‘hides’ behind the more dominant allele, unless it is paired up with another recessive allele in which case there’s no where to hide and the phenotype of the recessive allele is seen (as seen in the third circle pictured in the introduction).

**Question 6**
**ANSWER:** Blood type AB. The A and B alleles are co-dominant when both are present.

**EXPLANATION:**
- Co-dominance is when each allele is expressed (and detectable) at the same time in a heterozygote individual.
- Individuals with type AB blood show characteristics of both type A and type B blood in that they have both A and B flags (antigens) on their red blood cells.

**Bonus answer:**
**ANSWER:** The primary medical importance of the ABO blood group is in blood transfusion and tissue or organ transplantation. Being given an incompatible blood type could lead to rejection of the blood/organ/tissue and harmful medical consequences for the individual.

**EXPLANATION:**
- Our body’s immune system reacts to the flags (antigens) present on the surface of donor red blood cells (RBCs) that are different to the flags present on our body’s own RBCs.
- For example, an individual with type O blood can only accept blood from other type O individuals. If a type O individual was given type A blood, their body would mount an immune response against the A flags present in the type A blood.
- Similarly, an individual with type A blood can only receive blood from another type A individual or a type O individual (because type O blood does not have any flags to set off the immune system). If a type A person was given type B or AB blood, the B flags would cause an immune response in the type A individual.

**Reference:**