Name:_____Period:_____Date:___
Ms. Randall A & P (Compliments of Biology corner)

# How Do Tibetans Survive at High Altitudes?

Adapted *From Understanding Evolution; Berkeley*

If you live in the lowlands, you may have experienced the huffing and puffing that typically accompany a trip to higher altitudes. That's because oxygen levels go down as one goes up. Travelling to Denver from sea level means a 17% decrease in available oxygen. Our bodies **compensate** for even this small change with faster breathing and a higher heart rate — at least until we **acclimate** to the thinner atmosphere.

**What happens when you travel to the mountains?**

As you increase elevation the $PO_2$ in the air drops which affects the pressure in arterial blood ($PAO_2$). The brain detects these changes and sends a message to increase respiration rate, a condition called **hyperventilation**. You are likely to take deeper breaths in addition to breathing faster and your heart rate will increase. You may experience dizziness, nausea, fatigue, and headaches.

Low arterial $PO_2$ will cause the release of **erythropoietin** from the kidneys. EPO will stimulate the bone marrow to produce more red blood cells to increase the concentration of hemoglobin in the blood. This hemoglobin will have the effect of providing tissues with more oxygen.

Extra hemoglobin may compensate for decreased oxygen levels, allowing breathing and heart rate to return to normal. This is an example of **phenotypic plasticity**, shifts in an organism's body, physiology, or behavior that are dependent upon the environment it occupies, it is not a genetic change. People can usually acclimate to higher altitudes within a couple of weeks.

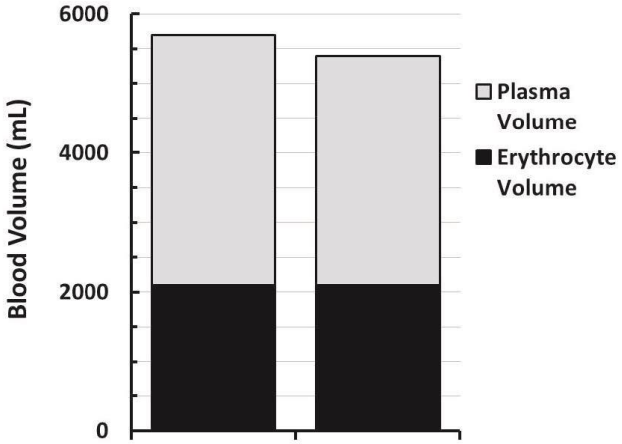
1. What does the word “compensate” mean? How does your circulatory system compensate for low levels of oxygen?

2. What is hyperventilation? What are side effects of hyperventilation?

3. What is the role of your kidneys in compensating for low levels of oxygen?

4. Read the example of phenotype plasticity and provide another example of this phenomenon. Think about this!

5. The following chart compares the **hematocrit** of blood samples taken from a person at sea level and one at a high altitude. Identify the one at high altitude and explain your choice.




**Some People Didn't Just Acclimate, They Evolved**

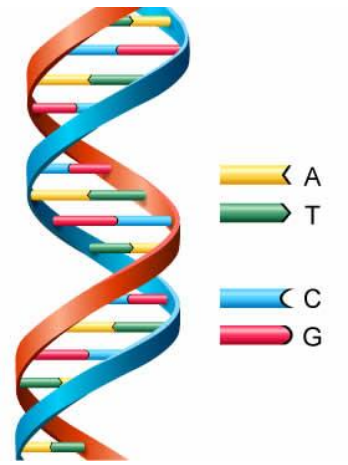
Tibetan highlanders have no trouble living at 13,000, and many of them can climb parts of Mount Everest without supplemental oxygen. How do they do it? New research makes it clear that Tibetan highlanders haven't just acclimated to their mountain home; they've **evolved** unique physiological mechanisms for dealing with low oxygen levels.

The evolutionary **adaptations** that allow Tibetans to function at high altitudes are very different from the acclimatization process that most of us go through when we spend time in those places.

One of these adaptations is almost exactly the opposite of a lowlander's response to high altitude: Tibetans have **gene** versions that cause them to produce *fewer* red blood cells. How is that helpful? It turns out that extra red blood cells make blood thicker — more like honey than water — and after a certain point, this cell-laden blood can actually get *so* thick that it doesn't pass through capillaries efficiently to oxygenate cells. Having blood with too many red blood cells can be particularly problematic during pregnancy since it is linked to slow fetal growth and high rates of **fetal mortality**.

The basis for the Tibetans' adaptation is not a change in a gene that produces hemoglobin or any one of the other proteins that make up red blood cells. Instead, the key change seems to be in a stretch of DNA, called ***EPAS1***, which helps control the process of producing red blood cells. The change in *EPAS1* seems to make Tibetans less likely to overproduce red blood cells at extreme altitudes.

Biologists compared the genomes of ethnic Tibetans to the genomes of Han Chinese individuals. The basic reasoning was that if a particular gene version was found in Tibetans, but not in their close relatives who lived in lowlands (Han), then that gene likely arose from **natural selection**. It was found that the Tibetans were much more likely to have this gene than Han Chinese.




Genetic studies estimate that the Tibetans split from the Han Chinese population and began migrating to the highlands less than 3000 years ago, which means adaptation for living at high altitudes occurred in the population in about a hundred generations. That would represent the fastest example of human evolution ever documented!

6. How is **adaptation** as observed in the Tibetan population different from acclimatization? (as described on page 1)

7. What are the consequences of having too many red blood cells?

8. What is EPAS1 and what is its role in circulatory system?

9. Why did scientists want to compare the genes of Tibetans to the genes of Han Chinese?

10. Scientists examined Tibetans and Han Chinese to compare average hemoglobin (Hb) amounts the blood.

| Group | Average [Hb] (g/dL) at high elevation | Average [Hb] (g/dL) at sea level |
|---|---|---|
| Lowlanders (Han Chinese) | 18.5 | 15.3 |
| Tibetans | 15.8 | 15.6 |

Why would scientists want to compare the Hb levels of Tibetans to the TWO groups of Han Chinese?
**Summarize** the chart above.

11. Does the data support the CLAIM that Tibetans have <u>evolved</u>? Or does it provide evidence that the Tibetans have <u>adjusted</u>? Explain your Reasoning.

12. This table from an original journal article on altitude adaptation in Tibetans. It shows data from individuals with different versions of the *EPAS1* gene. The different gene versions are called "C" and "G." Remember that humans have two copies of each gene, so this table shows data for people who carry two copies of these gene versions (CC and GG) and for individuals who carry one of each (CG).

| Genotype | Tibetan individuals with this genotype in sample | Mean hemoglobin concentration | Mean oxygen level in blood |
|---|---|---|---|
| CC | 10 | 178.0 | 87.5 |
| CG | 84 | 177.9 | 86.9 |
| GG | 272 | 167.5 | 86.4 |

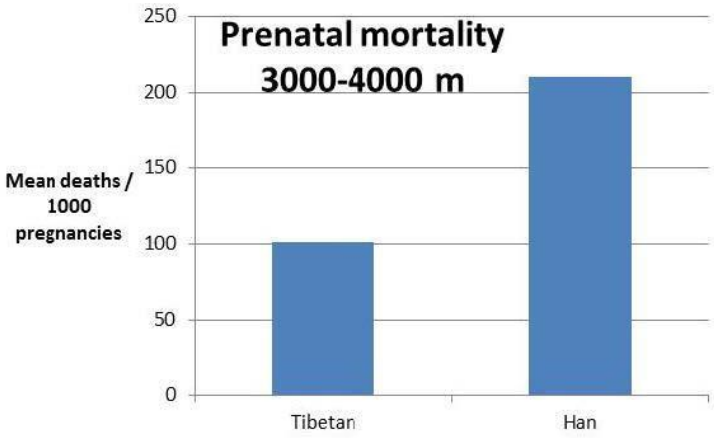
13. Which gene version is most likely to be adaptive for Tibetans living at high altitudes? How do you know (reference data in the table)?

14. What is the **phenotypic** difference between a person with CC genotype and one with CG? How do you think a person with the CG variant would fair at high altitudes?

15. Doctors studied infant mortality rates among Han Chinese population who had moved to Tibet (high altitude).

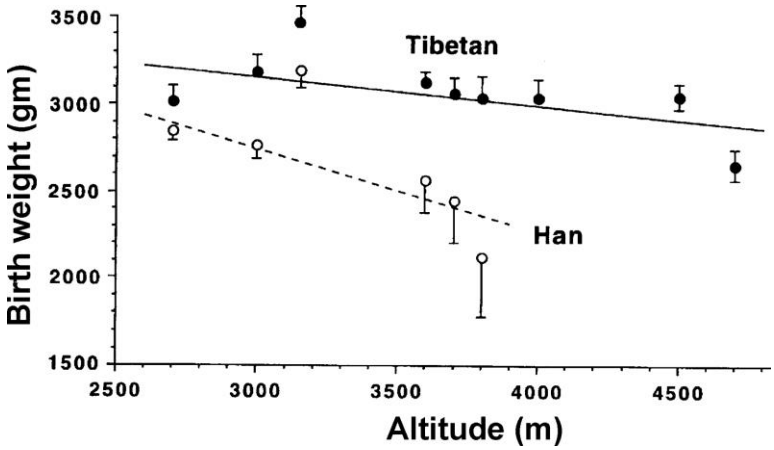
How many prenatal deaths were recorded for Tibetans? ____ How many for Han? ____

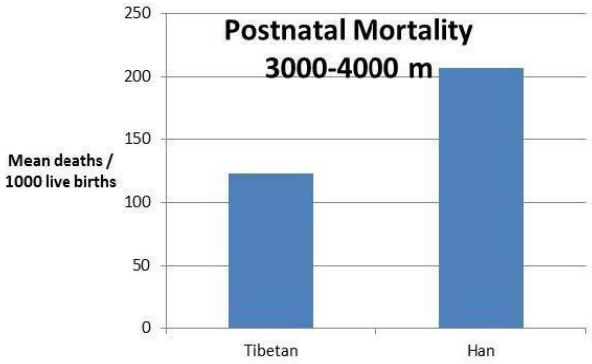
What does "prenatal mortality" mean?




Add another bar to the chart that would represent Han Chinese at low altitudes. Pay attention to the height of the bar and provide a short explanation for your choice.

16. The following graph compares birth weights and postnatal mortality among the two populations. Annotate (Summarize) the graph to explain what it is telling you about the two populations. (Source: http://jap.physiology.org/content/116/7/875)




**Final Synthesis**

*Evolution refers to the change in populations over time. This change can be caused by natural selection, where some traits provide an advantage to the individuals, who then pass those traits to their offspring.*

How does the evidence about the Tibetans support the claim that humans are evolving? Provide supporting EVIDENCE using specific details from this case. *(2-3 sentences)*