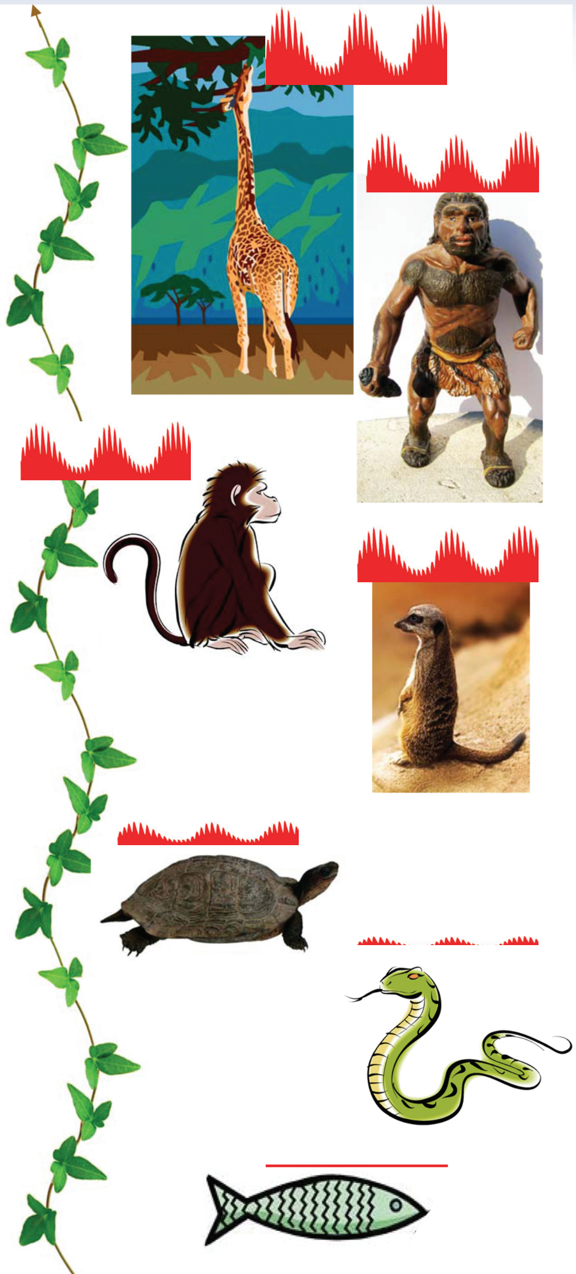
Hello all,

Welcome to the September 2010 ***COHERENCE Newsletter***. I hope you enjoyed last month's article, ***Matrika - The Source of Internal Dialogue***, Part 3 of our exploration of *The Six Bridges*. This month we go back - *way back* - with the feature, ***Thoughts On The Evolutionary Origin Of The Valsalva Wave.***



Evolutionary Continuum Toward "Erectness"

Vertebrates, including fish, amphibians, reptiles, birds, and mammals, share the same basic biology. This includes circulatory, digestive, and nervous structures, as well as subtle chemistry. Structurally, we are far more alike than not, primary distinctions between vertebrate groups being brain, respiratory, and reproductive anatomies, and "shape".

The fundamental difference in respiratory anatomy is "gilled" vs. "lunged", where only fish and amphibians possess gills, all other vertebrates possessing lungs. Interestingly amphibians and even some fish possess both gills and lungs.

As animals evolved, "air breathing" was one of the key adaptations, and with air breathing, the development of lungs. The key difference in lunged animals is the means by which the lungs are caused to inflate and deflate. In mammals this function is provided by the diaphragm. Reptiles employ various mechanisms including action of rib cage and action of the axial musculature. Some also have proto-diaphragms, complex muscle groups that perform roughly the same function as the diaphragm.

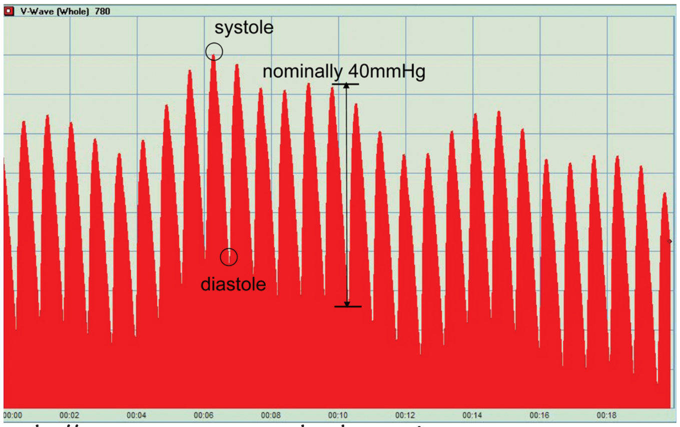
With the emerging understanding of the Valsalva Wave phenomenon, I suspect that there was a second critical evolutionary imperative - the facilitation of upright posture, in particular, carriage of the head above the body, and within it the brain. I hypothesize that if we trace the anatomy of various vertebrate species, we'll find that the presence or absence of the diaphragm and its relative size varies with uprightness.

Lifting the head to sense the environment

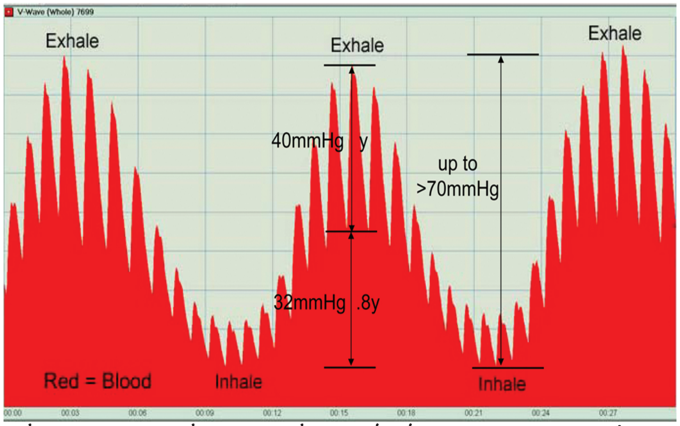
An evolutionary trend toward erectness makes sense because a very first action of an aquatic animal as it senses the environment above it, is to stick its head above water to look or smell. Once adapted to land, there is the ever present need to raise the head to observe the surroundings for food and predators, again using sight and smell. Hence, I propose that "lifting the head" has very ancient evolutionary roots.

But having the head and the brain elevated above the body presents physiological challenges, specifically, the movement of blood upward against gravity. Is the heart able to supply this demand? The answer is certainly, “Yes”. The questions are for how long, and are there circumstances where the heart alone is unable to perform this function adequately, for example during “flight” from a predator. And, what are the long term consequences of the burden of erectness on the heart relative to longevity? I believe the Valsalva Wave offers us some insight into these questions.

Below, we see two views of the heart beat and related blood volume (which correlates with pressure), as observed in the earlobe. The one on the left is that of shallow breathing. There the pressure of the heart beat is nominally 40mmHg and varies little.



Shallow respiration: the heart beat demonstrates ~40mmHg between systole and diastole



Coherent Breathing - The Valsalva Wave contributing an additional ~32 mmHg.

The view on the right is the heart beat and blood volume during Coherent Breathing. Here the pressure at peak heart beat amplitude is again nominally 40mmHg, but in this case the Valsalva Wave is contributing another ~32mmHg of pressure, the total pressure differential of the wave being about 70mmHg. Interestingly, instead of adding to the quiescent pressure of non-breathing, the Valsalva Wave reduces it, so where non-breathing quiescent blood pressure might be 120 over 80, when the wave is fully present it may drop to 110 over 60 or even 50. I believe this large drop is primarily due to the augmentation of venous return that comes with relatively complete rhythmic inhalation, i.e. relieving the heart of this burden.

If the Valsalva Wave contributes substantially to blood flow against gravity, then we might expect a correlation across various lunged vertebrates between Valsalva Wave amplitude and uprightness. As the Valsalva Wave is a function of the “thoracic pump” powered by the diaphragm, we might also expect a correlation between the relative size of the thoracic organs and uprightness.

Of course, the fish is more or less horizontal and due to the density of water, largely unaffected by gravity, so for it, moving blood upward against gravity is irrelevant. And because the fish generally has no lungs is should not exhibit either Valsalva Wave or breathing induced heart rate variability. At the other end of the spectrum is the giraffe, which has an unusually large diaphragm as compared to other animals of equivalent mass, the imperative being adequate cerebral blood flow via it’s extremely long neck. (One of my goals is to measure the Valsalva Wave at a giraffe’s ear :)

You may recall that breathing induced heart rate variability (an outcome of baroreceptor response to changes in blood flow and pressure due to respiration) changes dramatically with body inclination, i.e. it diminishes as we move from upright to horizontal body position. Next month we’ll consider why....

Thank you for your consideration, Stephen Elliott - COHERENCE

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