Evolution of the Human Oral Airway and Apnea

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Educational aims

This article intends to present human evolutionary development in a different way to engender a better understanding of why humans are the way they are, to challenge the validity and rationales of some established treatment methods and perhaps shed light other more comfortable, effective and less invasive therapies.

Expected outcomes

Dental Sleep Practice subscribers can answer the CE questions on page 38 to earn 2 hours of CE from reading this article. Correctly answering the questions will demonstrate the reader will:

- Have a better understanding of the influence of evolution on the nervous system, structural and regulatory integrity of human function.
- Understand that evolution is random, opportunistic, unpredictable, strange and not logical.
- Appreciate that a unique relationship results from the small dimensions of the human birth canal mandated by the survival requirements of upright bipodal locomotion and the evolutionary advantages of developing progressively larger human brains.
- See that it is the unique evolutionary history of human facial development that results in swallowing and breathing operating by different anatomic details at the newborn stage and during adulthood.

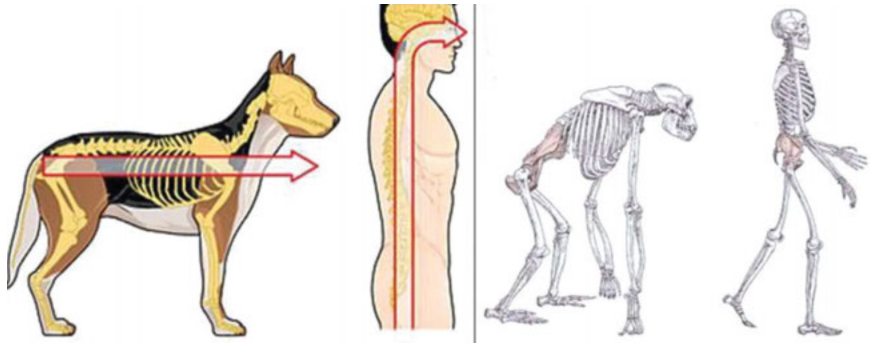
Introduction

Overwhelmingly, patients diagnosed with obstructive sleep apnea (OSA) receive treatment with continuous positive air pressure (CPAP), a pneumatic stent for maintaining airway patency during sleep. A significant problem is that patients do not comply at a rate substantial enough to indicate anywhere near universal acceptance of CPAP. The compliance rate reported in the literature is 40%. There are a multitude of reasons for CPAP noncompliance with the chief one being that OSA is an extremely complex malady.

Treatment of OSA requires a thorough understanding of the biomechanics, biochemistry, pathophysiology and morbid consequences of this complex phenomenon[1], but more than that, the human airway is part of our complex evolution. Evolution can be illogical and evolution is often quite strange. It is not always predictable. The thought is that understanding the history of what was may lead to clues to cope better with what is.

There has always been a common sense assumption that everything about homo sapiens must be a great improvement over any-

Figure 1: Examples of snout fetishes
Source: The Moses Collection



Figures 2A and 2B: Illustrate evolutionary changes from quadripodal to bipodal mobility; and cantilevered horizontal head posture to vertical, balanced head posture.

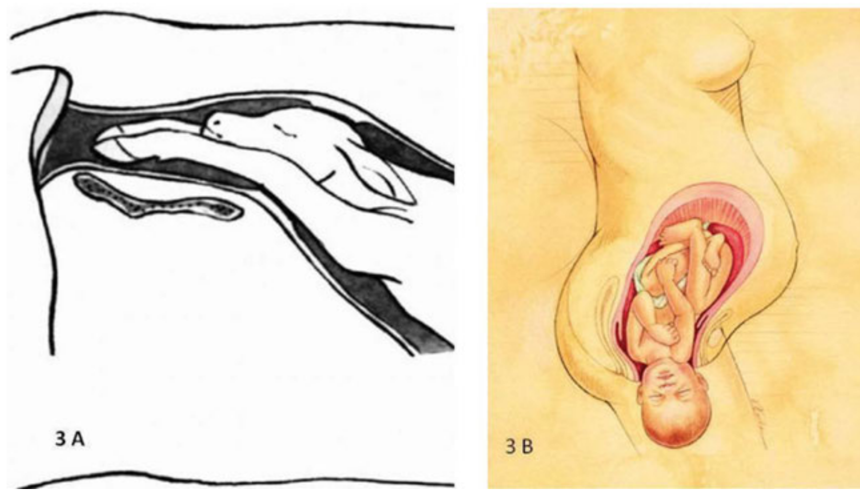
thing evolved by other animals. This may be totally irrational in terms of evolution of the head and will be a part of this discussion. The evolution of human beings is in fact a work in progress that is far from perfect, and understanding some of these imperfections may shed light on alternative treatments for OSA[2]. Some cultures seem to decry this evolution – snout fetishes are still found today and they may not be as ethologically baseless as it seems, and will be discussed.

Structural Changes

In lower animals the spinal column comes out the back of the head, is oriented horizontally and parallel to the ground. The head is cantilevered off the spinal column. Humans have evolved to an erect posture and the spinal column is vertical to the ground. The head is balanced on top of the spinal column. Humans are bipodal – walk on two legs. The reorientation from quadripodal to bipodal came with many structural changes, including a change in position of the foramen magnum which moved from being in the back of the head to the center at the bottom of the skull. Also the human head, in proportion to the rest of the body, is much larger than that of other animals. The most important function of the back and neck in humans is to balance the giant human head on the spinal column.

Humans have bigger heads for accommodating bigger brains than other primates; the switch to bipodalism required a great amount of neurological development. Numerous adaptations of the head had to occur to accomplish the increased cranial size. The evolutionary changes that occurred encompassed modularity, integration and multifunctionality of existing parts[3].

In all mammals the head emerges first from the birth canal. The snout being parallel



Figures 3A and 3B: It is normal for all mammalian newborns to emerge from the birth canal snout first or head first.

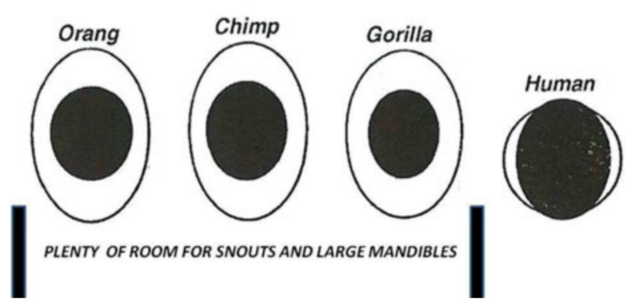


Figure 4: Head sizes at birth relative to size of birth canal.
Source: Rosenberg, K. & Trevathan, W. (2002). Birth, obstetrics and human evolution. *BIOG: an Internatlional Journal of Obstetrics and Gynecology,* 109, 1199-1206.

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to the spinal column, lower animals come out snout first.

Human heads emerge from the birth canal crown first as a logical evolutionary development so that human necks not break as infants emerge from the human birth canal[4].

The human birth canal must undergo a huge dilation during labor and[5] delivery to accommodate emergence of the jumbo human head crown first. In humans, a flat face is also a necessity for getting the head out of the birth canal but ultimately compromises nasal function, airway size, olfaction and condylar position[6]. It also reduces space for the tongue in the mouth.

The birth process would be virtually impossible if human newborns had a snout. Major structural changes occurred for human faces to eliminate the snout.

As it is, human birthing is difficult[7], but definitely facilitated by the soft fontanelles that allow a reshaping of the head during the birth process. The fontanelles also allow for brain growth to occur post-partum and remain soft to allow brain growth for a number of years.[8]

Figure 5: Illustrates large size of human head at birth.

Source: "Textbook of Obstetrics and Obstetric Nursing" Bookmiller, MM, Bowen, GL; section on the newborn by Bakwin, H. With original drawings by Frank Netter. Public Domain, https://commons.wikimedia.org/w/index.php?curid=30361510

Functional Adaptations

Significant evolutionary changes to the human head are flat face, smaller chin, shorter oral cavity, changes in jaw function, repositioning of ears behind jaws, ascent of the uvula and descent of the epiglottis, right angle bend in tongue, creation of compliant, combined, flexible airway-foodway, and speech.[9]

Humans, by virtue of their upright posture, bipodalism, big heads and larger brains to facilitate functional balance, speech and reasoning must try and orchestrate their survival as a species with repositioned, reconditioned, rebuilt, redesigned miniaturized and in many cases, parts of inferior design for olfaction, mastication swallowing, hearing, breathing and conditioning of inspired air.[10]

Lower animals have evolved structures of nearly perfect design for their particular function for olfaction, mastication, swallowing, hearing, breathing, and conditioning of inspired air. This optimal design observed by primitive cultures in lower animals might be a reason for the shamanic veneration of the snout.

The adult human pharynx is made up of a short oral cavity and an upright neck combined with a rounded tongue that has a 90 degree bend so 2/3 is horizontal and the posterior 1/3 is vertical. Lower animals have a horizontal tongue and a throat arrangement referred to as an intranarial or locked epiglottis.

The intranarial epiglottis diverts food around the trachea and into the esophagus during a swallow. This arrangement of parts deflects swallowed food over the tracheal airway and into the esophagus. It is beneficial because the animal can swallow and

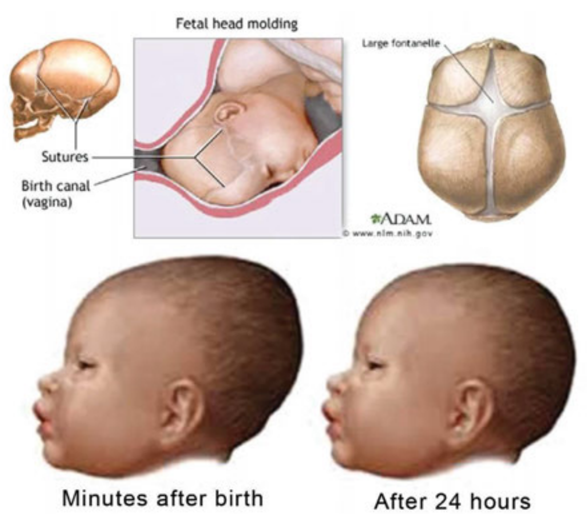
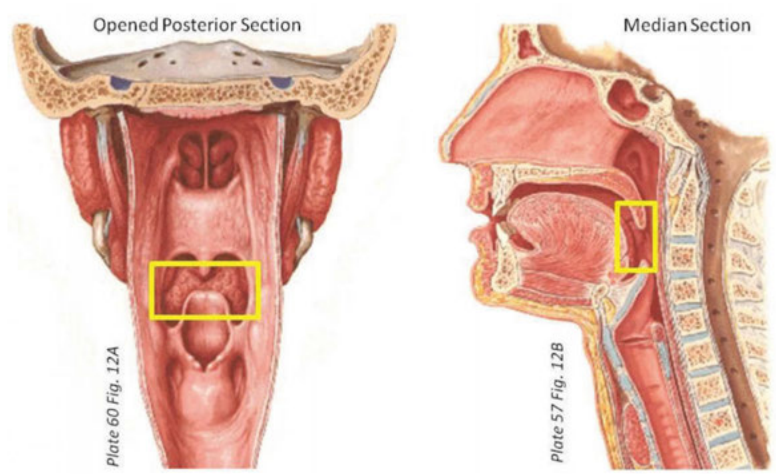


Figure 6: Fontanelles and soft sutures allow for a reshaping of the head during the birth process.

Source: Graham JM, Sanchez-Lara P. Vertex birth molding. In: Graham JM, Sanchez-Lara PA, eds. Smiths' Recognizable Patterns of Human Deformation. 4th ed. Philadelphia, PA: Elsevier; 2016: chap 35.



Figures 7A and 7B: The yellow outlined rectangles define the area of tongue collapse on the distal of the pharynx during sleep, called Obstructive Sleep Apnea (OSA). This open area of throat between soft palate and epiglottis defines non-intranarial airway is unique to humans makes it possible to choke to death on aspirated food and is essential to forming vowel sounds in speech. OSA does not happen the same in adults and children.

Source: "Atlas of Human Anatomy" 2nd ed. Netter FH; Novartis E. Hanover, NJ, 1997 breathe at the same time. Human newborns, until the age of 3 - 4 months, have this same intranarial arrangement.[11]

The tongue first appears in embryological development at approximately six weeks. It develops from swellings in the first four branchial arches, hence innervations from XII, X, VII, and V cranial nerves. The entire tongue is within the mouth at birth. It doubles in length and thickness between birth and adolescence, and always stays entirely within the mouth. The tongue position, swallow, as well as breathing modes influence development of the palate, the face and eruption of the teeth[12]. With no snout and a short, flat face the human tongue is not proportionately larger than other primates, but it must fit in a smaller space and allow a patent airway for breathing.

Newborn human babies suck only to attach to the breast.[13] They nasal breathe as they nurse and because of the locked epiglottis, they can swallow and breathe simultaneously. As the human infant grows the epiglottis descends and the uvula ascends with the soft palate to which it is attached. The descent of the epiglottis is not complete until about 15 years of age, or when the vocal cord is fully matured.

In adult humans separation of the epiglottis from the uvula allows mouth breathing, necessary when the nasal airway is obstructed. In mouth breathing the nasopharynx and the oropharynx are in open communication. The only bone intimately connected to the pharynx is the hyoid. It is literally a floating bone that lies at the base of the tongue, suspended by a series of muscles and ligaments.[14] It is the center of action for most movements of the pharynx.

The position of the hyoid changes during speech, swallowing and particularly in mouth breathers with their low tongue position. The lower the hyoid the more forward is the head position on the spinal column and the lower the tongue, the smaller the pharyngeal airway. The largest oropharyngeal airway is created with the person nose breathing, the lips sealed, dorsum of the tongue as far forward as possible and sealed against the hard and soft palate.[1]

In the newborn human the muscle fibers in the entire tongue are horizontally oriented. As the epiglottis descends and the uvula ascends, the pharynx grows vertically and the posterior one-third of the tongue simultaneously grows vertically as well. The elongated oropharynx has no bony or cartilaginous support to maintain patency. Longitudinal and circumferential muscles constitute the sides and posterior pharyngeal walls. The vertical portion of the tongue occupies the anterior wall of the pharynx. The oropharynx and tongue create a flexible, compliant, combined airway-foodway.

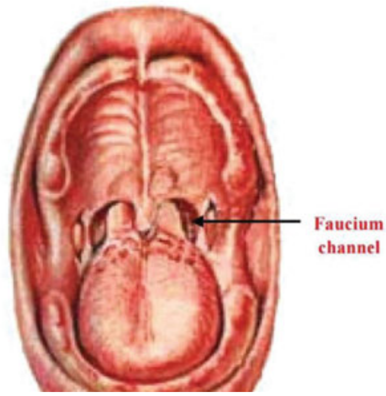


Figure 8: Frontal, open mouth view of a newborn. Interlocking of soft palate and epiglottis illustrates intranarial airway. Breast milk flows through faucium channels, infant's lips are sealed on breast and child can breathe and swallow at same time.
Source: Crelin ES. Development of the Upper Respiratory System, *Clinical Symposia,* Vol. 26, No. 3, 1976

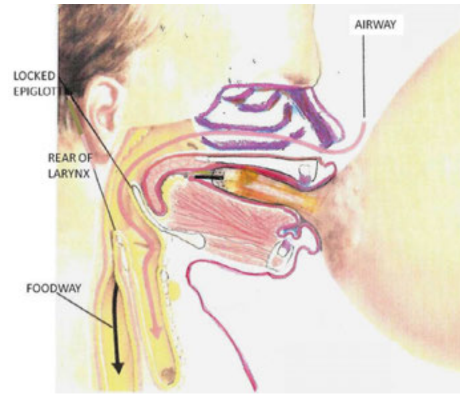


Figure 9: Sagittal section just lateral to midline showing infact suckling on mother's breast. Note: flat infant face from not having a snout, position of nipple just anterior to soft palate, lips sealed on nipple, nose breathe shape of mother's breast allows now breathing so infant can nose breathe and swallow simultaneously (intranarial arrangement). Tongue is all horizontal.
Source: Michael Woolridge, The 'Anatomy' of infant sucking. *Midwifery,* 1986 (2) 164-171

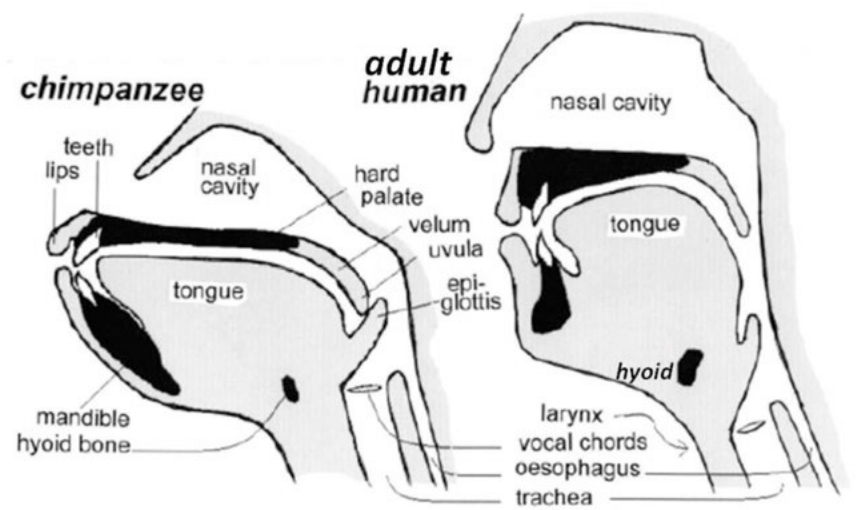


Figure 10: Chimpanzee demonstrates the intranarial airway arrangement. Chimp can swallow and breathe at the same time. Adult human on the right cannot breathe and swallow at the same time, demonstrating a non-intranarial airway.
Source: "An Introduction to Human Evolutionary Evolution"; Atella L, Dean, C; Academic Press, 1990. "The Ontogenetic and Phylogenetic Development of the Upper Respiratory System and Basicranium in Man". Laitman JT; PhD Dissertation, Yale Univ. 1977

Consequences of Rebuilt, Reconditioned, Repositioned, Redesigned Parts

To avoid choking, human swallowing requires more neurologic precision and coordination than in lower animals. As humans sleep, flaccidity of the tongue can bring about collapse of the tongue on the soft palate or flexible, compliant walls of the oropharynx, causing obstructive sleep apnea (OSA) and/or snoring. A very positive evolutionary development resulting from the flexible, compliant adult human airway is the capability to create formant sounds, instrumental in the articulation of speech.[15]

In adult humans the pharynx remains open for passage of air at all times except during swallowing, and regurgitation. Breathing cannot occur simultaneously with swallowing. The good news is speech. The negative consequences are choking, snoring and obstructive sleep apnea (OSA). OSA occurs when the luminal cross-sectional area of the upper airway collapses during inspiration, at or below the level of the soft palate and above the epiglottis.

Young children do not experience Obstructive Sleep Apnea at the same site or sites as adults.

An apneic event is created in adults by either the tongue or soft palate or both together collapsing on the back of the airway during sleep. The collapse can be caused by muscle flaccidity, negative airway pressure brought about by increased nasal airway resistance, or a combination of both. It can be predisposed by muscle fatigue, CNS misfiring or incoordination, pulmonary diseases or neuromuscular diseases.

Combinations of the following can also contribute to the airway blockage: swollen, hyperplastic or redundant tissue, large tonsils, obesity, nasal obstructions, deviated septum, dysphagia, broken nose, long soft palate, large uvula, macroglossia, edentulous collapse, iatrogenic micrognathia (otherwise known as four bicuspid extraction orthodontics).

Young children, with the intranarial or locked epiglottis do not experience OSA in exactly the same way as adults. Young children most commonly experience what is called Upper Airway Resistance Syndrome (UARS). UARS is not so much a collapse of the tongue, as a distinct airway obstruction by inflamed, edematous tissue. UARS in juveniles occurs at the level of the tonsils and adenoids.

The immune systems of young children have not yet developed to the advanced status of adults. These lymphoid tissues can proliferate to obstruct airflow due to environmental irritants, allergic rhinitis, asthma, viral infections or genetic factors. This tissue enlargement can obstruct air flow to various extents that rarely result in overt OSA but most commonly in UARS, snoring or just mouth breathing. If undiagnosed or just left untreated, under-development of facial structures, adult OSA and serious other adult morbid consequences can result.

Most mammals ventilate almost exclusively through their noses. Mouth breathing usually only occurs in mammals when suffering from hyperthermia. Human children with enlarged tonsils and adenoids however, usually become mouth breathers. Kids who chronically mouth breathe experience reduced nasal cavity growth, developing smaller midfaces, narrower maxillae, smaller noses and narrower nasal cavities. After surgical removal of the tonsils and adenoids, young children rapidly undergo a catch-up period of growth, developing wider, longer, deeper nasal cavities and maxillae as well.[17]

Obese children are also at risk for sleep disordered breathing (SDB) and OSA. Fatty infiltration of subcutaneous anterior neck tissue and cervical structures can exert collapsing forces on the pharynx. Obesity and fat buildup can also cause mass loading of the respiratory system in the chest wall and abdomen forcing reduced diaphragm movement in breathing. Gozal proposes that these are two distinct types of OSA in children.[15]

Concluding about evolution and airway development

Evolution is not the same as biologic engineering, where a designer has a goal in mind and tools or components are created to fulfill the new function. Evolution is random

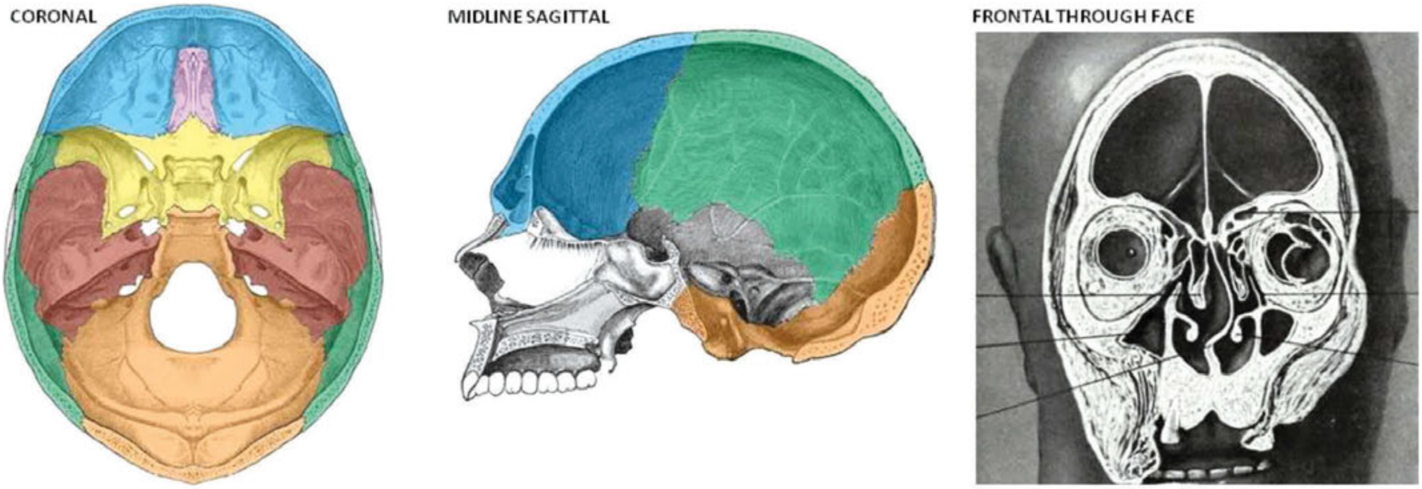


Figure 12: Sectioned skulls demonstrate that the roof of the mouth is contiguous to the floor of the nose, the lateral wall of the nose is contiguous with the maxillary sinus and the medial wall of the eye. The tops of the nose and eye border the brain. The roof of the mouth is contiguous to the floor of the nose. Evolutionary changes involve integration, modularity and multifunctionality of parts. Bone growth in one area may stimulate or retard other areas from developing.
Source: "Essentials of Human Growth" 2nd ed. 1996, Enlow D, Hans M, Saunders Pub, Philadelphia

and opportunistic. Bones in the skull share walls, so that bone growth in one region accomodates growth in an adjacent area.[18] Evolutionary changes in the head encompass modularity, integration and multifunctionality of existing parts.

The roof of the mouth is the floor of the nose. The lateral wall of the nose is contiguous to the medial wall of the eye. The top of the nose and eye border the floor of the brain. The chewing muscles and TMJ attach to the skull. Tongue movement, nose breathing, mouth breathing, swallowing, speaking and OSA are complexly integrated in terms of development, structure and function so that new and different function in one part may stimulate or retard others from developing as growth continues.

The only bone intimately connected to the flexible, compliant oropharynx is the hyoid, which lies beneath the base of the tongue. Positioning and coordination of the hyoid, the tongue, jaws, cervical vertebrae and larynx requires frequent intermittent changes during breathing, speech, swallowing, mandibular function and apnea episodes. Maintaining head balance during this nearly constant repositioning and coordination of changing function requires the involvement of tremendous neurologic circuitry. **Humans need all the brains they can get to survive and function with all their redesigned parts and no snout.**

This concludes Part 1 of a four part series.

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