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species in transition

a lesson plan for biology teachers

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Title: *Species in transition: A lesson plan for biology teachers*

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Foreword

> *“Lurking in our anatomy are some odd arrangements, inefficient designs, and even outright defects. Mostly these are fairly neutral; they don’t hinder our ability to live and thrive. If they did, evolution would have handled them by now*.”
>
> [quoted from: *Human Errors: A Panorama of Our Glitches, from Pointless Bones to Broken Genes*]

Science is not a collection of facts to learn or formulas to memorize. It is a process of inquiry and discovery. Science is what happens when we merge curiosity about the natural world with careful measurement and reasoned analysis. Above all, science is about asking questions, and this laboratory exercise exemplifies that spirit perfectly. The best way to *learn* science is to *do* science. When scientists enter our laboratories and begin our work, we are not hoping to recreate some pre-defined outcome. We don’t always know how to get the answer, let alone what the answer will be. We spend more time being confused than being certain. And that’s why this laboratory exercise is so spectacular. It captures the experience of doing scientific research, where the questions are fascinating and the answers are elusive.

Another strength of this laboratory is that it recognizes the full messy glory of the evolutionary process. Evolution has no target or set trajectory. It’s aimless, sloppy, and inefficient, and it does not produce anything close to perfection. In fact, natural selection is better understood as “survival of the fit enough!” What constitutes “fitness” is constantly changing anyway and the result is that living things are a strange hodgepodge of adaptations, many of which were shaped in different times and in different environment than the current ones. Humans are probably the most pointed example of this mismatch of environment and biology, having created a world for ourselves that is very different than the habitats we adapted to for millions of years before. Furthermore, we have been subverting traditional natural selection for millions of years as well. We tend to solve our survival challenges with our brains and sociality, rather than our bodies, which has reduced the evolutionary scrutiny on our anatomy and physiology. Despite what our species-chauvinist instincts tell us, we might be the most flawed species of all.

As you complete the many well-crafted exercises in this project, keep in mind how our ancestors might have found “work arounds” for the various curiosities you will encounter. The story of our quirks and glitches is a happy one because it reminds us that our potential is not limited by our imperfection. We possess so many flaws because they were never able to hold us back!

Nathan H. Lents, Ph.D.

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1 Introduction

Our species is not a perfectly designed monolith, static through time. Rather, it is full of traits and quirks that, over generations, are in flux due to the interplay between mutations, trait diversity and selection pressures. Some organs have a function for which our current survival strategies and lifestyles no longer have a good use, thus becoming *vestigial*. In other cases, traits jostle *in competition* with another.

The objective of this lab, premised on inquiry-based learning, is to illustrate, using particular physical traits of the human body as examples, (1) how the very physiology of specific traits varies across populations, and (2) how they are changing – over generations – due to certain evolutionary pressures. In some cases – e.g. jaw vs. wisdom teeth, female pelvis vs. prenatal brain, or hair follicles vs. sweat glands – traits “compete” over generations. Other cases – e.g. the palmaris longus muscle in the forearm or the auricular muscles surrounding the ear – are vestigial organ candidates, as their primary function is no longer needed.

These physical characteristics also reveal some aspect of *Homo sapiens*’ evolutionary past. Through an investigation of these physical idiosyncrasies and their history, it is revealed that the evolutionary fine-tuning in our species is far from over: our species is caught up in evolutionary currents in which specific, physical traits are still being field tested on the battlefield of life, and will ultimately be granted or refused survival. Albeit moderated by technologic and medical advances, evolutionary pressures continue to target traits. As such, the combination of traits that make up an individual, to a degree, compete for the “design award.”

Using our own bodies as a point of reference, students may better relate the material to their own experience and deepen their understanding of evolutionary dynamics fundamental to the theory of evolution.

These characteristics all indicate that we, as well, are a malleable species and that we are indeed adapting through the generations in response to selection pressures. In a sense, connected to our past and beholden to our genes, we are iterative time travelers.

In this lab, students:

- carry out measurements or explore the characteristics of each featured trait;
- investigate the physiological / morphological function of each trait;
- use their own bodies as examples, relate the investigated trait back to evolutionary pressures;
- project what would likely happen to the trait in future generations.

In sum, the lab features five examples of competing or vestigial traits, which students can study using their own bodies and hominin skulls. In doing so, students engage in discovery (inquiry-based) learning, which has been shown to yield stellar outcomes.

2 Featured Traits

The physical traits scrutinized in this lab can be identified through sight or touch, and are thus readily identified by the student. Also, these traits all reveal some aspect of the evolutionary past of *Homo sapiens*. In some cases, they served a function for which our own bodies no longer have a good use. In other cases, the physical traits exist in competition with one another and must navigate a balance.

Table 1:

trait under scrutiny		*adaptation (over eons, also between species within a lineage)*	*competing traits*	*negative selection pressures (in concert with natural selection)*	*(potentially) vestigial organ?*
1	**wisdom teeth**	1. less mastication of robust foods 2. reduced jaw size (orthognathism) potentiated by less mastication strength requirements due to technology (fire, cooking, and food processing)	wisdom teeth (3rd molars for better grinding) vs. orthognathism (linked to diet)	risk of impacted molar complications	partially; 3rd molar impacted in 24% of the general population, missing in 22% of the population
2	**palmaris longus muscle**	less tree swinging with arms	none	none	partially; missing in 14% of the world population on average
3	**cranial capacity**	generally increasing cranial capacity	female locomotion and pelvic strength vs. size of the fetus' head (cranial capacity)	higher risk of complications at birth with large fetus' cranium	no; as both a certain pelvis and brain size are vital for survival
4	**auricular (ear) muscles**	from pivoting to more stationary ears	none	none	potentially; little-to-no current physiological function
5	**hair**	loss of fur/hair and more sweating	sweat glands (cooling) vs. fur (warmth)	1. need for sweat glands in African savanna 2. sexual selection	yes and no: significant reduction of hair over the eons as sweating became more important than having fur, but current sexual selection preferences speak against going *completely* hair-free

For each trait, the physiological function – past, present and future – will be treated and discussed:

past: Why do you think "we" used to have it?

present: Why do you think "we" have it?

future: Do you think the organ will become vestigial?

3 Operational definitions

Evolution: Evolution is the differential replication of life cycles (Griffiths & Gray, 1994). Evolutionary change occurs through changes in the genetic structure and the informational ecology of a species. *Mutation* within an individual produces new traits which are acted on by external sources of selection, including *natural selection* and *sexual selection*, resulting in trait variation at a population level. *Genetic drift* and *gene flow* produce either the fixation or the dilution of certain genes, respectively, at the population level. When new gene-derived physical traits are successfully applied by an organism, or when an organism develops new behavioral traits, advantages are secured individually (*fitness*). Behavioral traits also have a chance of being learned by others in the population (*cultural evolution*). Although behavior does not directly re-write one's genes, certain environmental influences can alter the *epigenetics* of the organism.

Evolutionary/selective pressure: Environmental (external) conditions that influence the expression or function of traits – i.e. whether a trait will help or hinder the survival and reproduction of the organism, resulting in certain characteristics becoming more common or rare within a population.

Fitness: A group of individuals is fit when they are collectively adapted for survival, which includes the potential for having offspring (reproduction). Fitness is therefore *not* to be understood as survival of the *strongest*, in a King Kong sort of way. For today's *Homo sapiens*, fitness receives very little input from natural selection compared to how it operates in every other species, or how it operated in our distant past. For every other species on earth, the most successful individuals seek and obtain as much prolific reproductive output as possible.

Gene flow: The transfer of genetic material from one population to another (e.g. that had previously been separated).

Genetic drift: The change in the frequency of an existing gene variant in a population due to random sampling of organisms (e.g. a cataclysmic event wiping out most of the population). Genetic drift may consequently cause gene variants to disappear completely, or it can cause initially rare alleles to become much more frequent and even fixed.

Hominid: The group consisting of all modern and extinct Great Apes (that is, modern humans, chimpanzees, gorillas and orangutans, plus all their immediate ancestors).

Hominin: The group consisting of modern humans, extinct human species and all our immediate ancestors (including members of the genera *Homo*, *Australopithecus*, *Ardipithecus, Sahelanthropus,* and *Orrorin*).

Morphology: The study of the physical form and structure of organisms.

Mutation: A mutation is a change in a DNA sequence, resulting from DNA copying mistakes due to cell division, exposure to ionizing radiation or chemicals, or virus infections. Nathan

Lents explains: “All of our genomes are affected by mutations like a scattershot. Humans each harbor 100-200 novel mutations, which are added to the gene pool. Natural selection weeds out the harmful mutations and increases the frequency of the rare beneficial ones, even to the point of complete fixation of the new allele. But the vast majority of these mutations are selectively neutral, even if they do have some consequences.”

Natural selection: Natural selection is the process by which external selection pressures favor the survival and reproduction of organisms with certain traits over others. This process acts on living organisms, “rewarding” traits by allowing their carriers to survive and reproduce. Individuals with fewer “desirable” traits – or lacking a critical trait – will, in turn, will reproduce less or even perish. Non-selected-for traits will be excluded over generations, while favorable traits will remain as their carriers pass them to the next generation.

Sexual selection: An instance of natural selection in which, for the purposes of reproduction a member of has a preference for certain characteristics in their selection of a member of the opposite sex. As such, sexual selection acts as selection pressure. If selected, and the organism manages to successfully copulate with a mate, their genes are passed on to a new generation. Over time and between cultures, sexual selection is observed to be a highly variable force.

Trait: A feature of an organism, whether a genotype (genetic-level) or phenotype (physical, developmental, and physiologic properties), which is affected by its environment and thus subject to the action of natural and sexual selection.

Vestigial organ: If a trait is no longer needed for the organism’s function or reproductive success, yet still present, it is called “vestigial.” While certain traits are neither clearly favorable nor unfavorable, as are they are genetically intertwined (encoded along) with other traits, they may continue to appear in successive generations.

4 Lab prerequisites

The *Be a Paleoanthropologist For a Day!* Lab treats concepts such facial prognathism through the measurement of the maxillary angle in hominins, which has bearing on this lab in the subject of wisdom teeth. Another concept treated is cranial capacity, which is featured in this lab’s discussion on skull size vs. the female pelvis at birth. Furthermore, students gain an appreciation for the various time periods the species lived. We therefore recommend that students have performed the *Be a Paleoanthropologist For a Day!* lab as an “anchoring event” before tackling this lab. For the latest lab version, visit: www.ancientancestors.org.

5 Materials

Table 2: Materials needed

	Trait	*materials needed*
1	wisdom teeth	a. set of 6 hominin skulls (*Homo habilis, Homo erectus, Homo sapiens, Homo neanderthalensis, Australopithecus afarensis, and optional: Ardipithecus ramidus*) b. tape measure (soft tape measure) c. panoramic dental x-rays of impacted teeth (either example x-rays, those of the students, or print-outs of Figures 1-3)
2	palmaris longus muscle	none: students use their own forearms for this lab.
3	cranial capacity	set of 6 hominin skulls (*Homo habilis, Homo erectus, Homo sapiens, Homo neanderthalensis, Australopithecus afarensis, and optional: Ardipithecus ramidus*)
4	auricular (ear) muscles	none: students (attempt to) manipulate their own ear muscles
5	Hair	none: students inspect (any) hair on their fingers

6 Five traits

6.1 Wisdom teeth

6.1.1 Subject introduction

ask class: *Who among you has had one or more wisdom teeth removed? Do you know someone who has had a wisdom tooth removed? Who among you has not yet had your wisdom teeth come in?*

Show and tell: Have the students who brought along panoramic dental X-rays identify any anomalies from the 3-molar formula: any impacted teeth, missing 3rd molars, etc. If they volunteer, have a few students tell to the class their own wisdom tooth story, or that of a family member.

Present: Teeth support the severing (tearing off) and mastication (chewing) of food – their so-called *morphological function*. But how many teeth do you need to do the job?

Humans possess 32 permanent teeth with a dental formula of 2-1-2-3: 2 incisors, 1 canine tooth, 2 premolars, and 3 molars, mirrored on both the right and left sides of our upper and lower jaws (Scott & Turner, 2015). *Homo sapiens* share this very dental formula with its fellow catarrhines, which is a clade that encompasses Old World monkeys and apes, including the chimpanzee.

Starting with the first molar and incisors between ages 6 to 9 years our permanent teeth progressively emerge from the gums (Hillson, 1996). By the early teens most teeth are in place, except for the third molars (M3s), which usually appear between ages 17 and 24 (Boughner, 2018). Yet wisdom teeth may also emerge later in life. Aristotle (1862), writing in the 4th century BCE, astutely observed:

> *The last teeth to come in man are molars called 'wisdom-teeth', which come at the age of twenty years, in the case of both sexes. Cases have been known in women upwards of eighty years old where at the very close of life the wisdom-teeth have come up, causing great pain in their coming; and cases have been known of the like phenomenon in men too. This happens, when it does happen, in the case of people where the wisdom-teeth have not come up in early years.*

Third molars develop entirely after birth, the only teeth to do so. The hypothesized reason for presentation of the M3s later in life is so that mastication (chewing) is supported after the other molars have possibly decayed.

Complications arise when M3s are ready to present, but – akin to fitting too many books on a shelf – there is insufficient space. The result is impacted wisdom teeth that are unable to properly penetrate the gums, illustrated in Figures 1-3 (Björk et al., 1956).

In *Homo sapiens*, almost half of the third molars worldwide present some form of anomaly: in 24% of people they are impacted (Carter & Worthington, 2015a), and in 22% of people they are simply absent (Carter & Worthington, 2015b; Sujon et al., 2016).

For wisdom teeth to form, the tissue that starts the process of tooth building has to migrate back in the mouth and interact with the hind jaw tissue. If this migration does not occur, then no tooth will grow there. The condition where one or more wisdom teeth are absent is called *tooth agenesis*. The prevalence of third molar agenesis varies across geographies (Table 3).

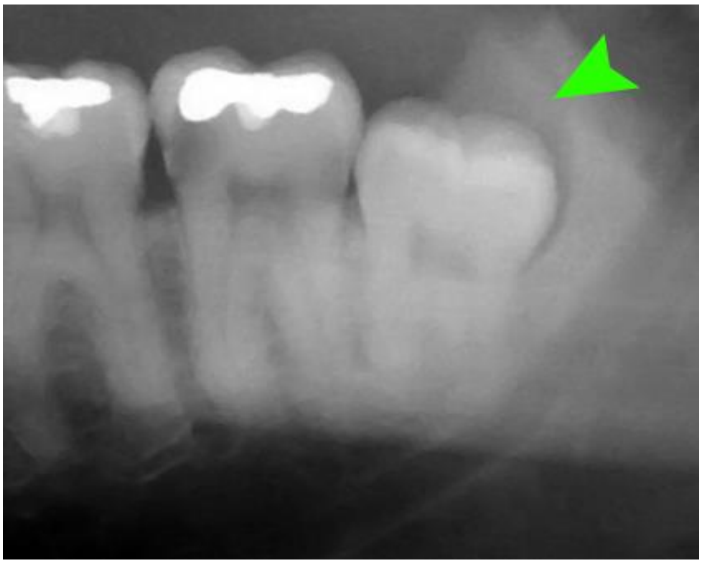

Figure 1: Impacted wisdom tooth with a backward tilt (distoangular impaction)

Source: (CDSG, 2020)

Figure 2: Impacted wisdom tooth with a horizontal orientation (horizontal impaction)

Source: (CDSG, 2020)

Figure 3: Impacted wisdom tooth that is tilted forward (mesioangular impaction)

Source: (CDSG, 2020)

Table 3: Prevalence variation of third molar agenesis

	country / ethnicity					
	Great Britain	***Chile***	***South Korea***	***Malaysian Malay***	***Malaysian Chinese***	***Bangladesh***
3rd molar agenesis	12.7%	24.8%	41.0%	30.0%	33.0%	38.4%
source	Shinn, 1976	García-Hernández et al., 2008	Lee et al., 2009	Alam et al., 2014	Alam et al., 2014	Sujon et al., 2016

6.1.2 Discovery lab

Measure: With a tape measure, have students measure mandible's (lower jaw) arch circumference (see Figure 4 below), i.e. the outside of the teeth. Students record their answers in the worksheet (*maxillary angle* is provided).

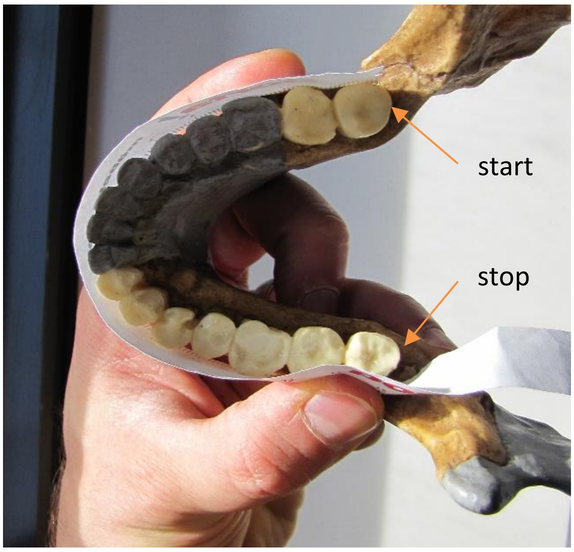

Figure 4: Arch circumference measurement

Table 4: Arch circumference and maxillary angle

Species	*lived (approximately)*	*arch circumference (in cm)*	*maxillary angle*
Homo sapiens	300 k to present	*13.2*	54
Homo neanderthalensis	800 k to 40 k	*13.5*	54
Homo erectus	2 mya - 108 k	*15.5*	51
Homo habilis	2.3 – 1.65 mya	*15.3*	44
Australopithecus afarensis	3.9 – 2.9 mya	*14.5*	35
Ardipithecus ramidus	4.4 mya	*14*	35

6.1.3 Discussion & short lecture

ask class: *What did you observe?* Have students interpret the data, observing the evolution of arch circumference and maxillary angle.

Present: Having 12 molar teeth allowed our ancestors grind and masticate a whole host of foods. Being able to handle hard, abrasive foods was especially imperative for the Australopithecus genus (Teaford & Ungar, 2000). Since the era of australopiths, dental size has been on the decline in the human lineage, evolving at a relatively consistent neutral rate (Gómez-Robles et al., 2017). The series from *H. habilis* to *H. erectus* to *H. sapiens* shows strong negative allometry, which implies a sharp reduction in the relative size of the posterior teeth, along with jaw size decrease (measured here through the maxillary angle). Compared to *Homo erectus* ~2 million years ago, molar surface area was about 1.5 times what it is today.

Tellingly, *Homo sapiens* was not the first hominin to have teeth issues: Gibson and Calcagno (1993) provide evidence of impacted molars and crowding of the anterior dentition among other hominin species, such as is the case with *Australopithecus africanus* (STS52b) and *Australopithecus boisei* (KNM-WT 17400). A recent study of a 10-year-old *Homo antecessor's* wisdom tooth found that one 3rd molar was sitting on top of the second molar – a place where it should not have belonged, and is due to lack of space in the maxilla (Martín-Francés et al., 2020). The author concluded: “We can be sure that around one million years ago, this person would have suffered from severe toothache" (CENIEH, 2020).

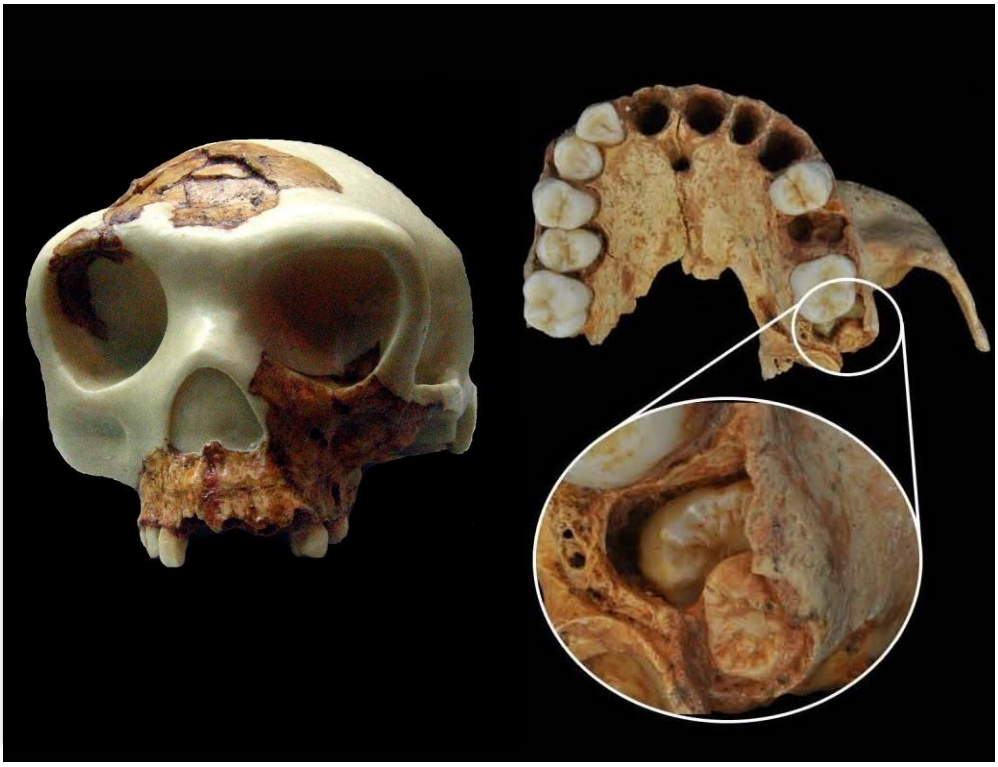

Figure 5: Secondary impacting of the second molar in 10-year-old *Homo antecessor*

Source: CENIEH, 2020

ask class: *What might be the hypothesized behaviors that could potentiate a reduction in arch circumference and a smaller maxillary angle?*

Various contextual factors have been posited as setting the stage for a reducing maxilla and jaw size. The fact that since *H. habilis* all human ancestors had a larger arch circumference and maxillary angle than *H. sapiens*, suggests that with more reliance on tools to process foods, the use of fire and cooking, as well as a shift to calorie-dense foods, the hominin masticatory system would have the "luxury" of decreasing.

1. *Reduction of teeth utilization through tools*
   It is known that australopithecines used stone flake tools. There are numerous examples of cut marks on the bones from the Pliocene-Pleistocene period (ca. 5 mya to about 12 kya) that were not made by carnivore teeth but by tools (Bunn et al., 1986; Sahnouni et al., 2013). *Homo habilis* – the "handy man," however, took tool use to another level: he fashioned a "core chopper" stone to chop up carcasses and break animal bones to reach the marrow inside.
2. *Reliance on fire and cooking to tenderize food*
   Cooking is another factor on lessening the need for mastication-intense adaptations. While remnants of a campfire in Israel dates back to 1 million years ago (Shimelmitz et al., 2014; Zink & Lieberman, 2016), since *Homo erectus* molar sizes rapidly declined 1.9 million years ago – which cannot be explained by general changes in head and jaw sizes – it is likely that early *Homo erectus* had harnessed the barbecue at such time (Wrangham, 2010).
3. *Shift to calorie-dense foods*
   The advent of agriculture is documented to have occurred approximately 11,500 years ago, when the eight Neolithic founder crops (emmer and einkorn wheat, hulled barley, peas, lentils, bitter vetch, chick peas and flax) were cultivated in the Levant (Zohary et al., 2012). This form of sustenance was marked by the consumption of softer, more calorie-dense foods compared to hunter gatherer diets. Humans relying on agricultural products would have, in turn, required less mastication capacity.

In *Homo sapiens*, a significant number of people's wisdom teeth are either impacted or absent (3rd molar agenesis). Since dental traits are highly conserved,[1] the fact that they vary in modern humans (through the presence or absence of the 3rd molar) can only be explained by significant selection pressures.

Conventional thinking was that before the time of modern medicine, the unlucky people with impacted M3s simply perished due to tooth infections associated with sepsis. As a work-around, and likely precipitated through a random mutation that spread through generations, some people entirely circumvent wisdom teeth complications survived, with a slightly better chance of passing on their genes to future generations – the survival-of-the-toothless explanation.

Yet modern medicine has also found a work-around that sidesteps any even potential complications due to impacted molars: oral surgeons allow individuals with impacted teeth to survive and continue to contribute to the gene pool (Gibson & Calcagno, 1993).

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[1] In fact, in order to identify a species, anthropologists usually rely on the teeth, provided they are available.

While the survival-of-the-toothless hypothesis (to play it safe) provides a genetic explanation why some individuals lack a 3rd molar, the story does not end there: The chance of impacted wisdom teeth is also linked to one's diet. In fact, people may actually be able to influence their chances of developing wisdom teeth complications.

The physiological reason for impacted teeth is related to jawbone development. Multiple studies showed that diet influences jaw size: The harder the foods that are consumed, the longer the jaw: One study, comparing farming and hunter-gatherer groups, found that the farmers, raised on softer foods, consistently had shorter jaws, which would have provided less space for tooth formation (Katz et al., 2017; Von Cramon-Taubadel, 2011). In fact, our jaws need biomechanical stimulation from a diet of robust foods in order to properly develop (Ungar et al., 2012). Indeed, access to processed foods is a predictor of wisdom teeth problems. For example, one study looked at third molar impactions among 900 rural and urban people in South India (Venu Gopal Reddy, 2012). Impactions occurred in about 15 percent of rural participants, compared to nearly 30 percent of the urban dwellers. With 2,400 participants, a study in Nigeria found that impacted third molars were seven times more common in urban versus rural communities (H.O. OLASOJI, 2000).

Even back in 1871, Charles Darwin commented in *The Descent of Man* on the vestigial nature of the 3rd molar, differences between 3rd molar morphology across geographies, and related wisdom teeth complications to jaw size and to diet type. In certain populations, he noted, it appeared *"as if the posterior molar or wisdom-teeth were tending to become rudimentary."* In populations that were *"civilized," "the posterior dental portion of the jaw"* was *"shortened."* Further, *"this shortening may, I presume, be safely attributed to civilised men habitually feeding on soft, cooked food, and thus using their jaws less. I am informed by Mr. Brace that it is becoming quite a common practice in the United States to remove some of the molar teeth of children, as the jaw does not grow large enough for the perfect development of the normal number"* (Darwin, 1871).

Figure 6: Charles Darwin

Source: One of Darwin's kids

In conclusion, the genes controlling jaw and teeth size are not always aligned, and these variables jostle over generations. Furthermore, empirical evidence suggests that people who eat harder foods have higher chances of proper jaw development. Since humans nowadays rely on cooked and sometimes processed foods, the growth potential of jawbones is often not maximized. In other words, keep eating your nuts and uncooked veggies!

Fun fact: While we are on the subject of jaws, did you know that among our hominin ancestors, only humans have chins? Our chins also come in various shapes and sizes: some people have a cleft chin (think Ben Affleck), which occurs in people where the left and right halves of the mandible (lower jaw bone) were incompletely fused during the embryonic and fetal development.

6.2 Palmaris longus muscle

6.2.1 Subject introduction

Present: The palmaris longus is a muscle with tendons on either end that runs from your elbow region to your palm (see Figure 7). It, however, may or may not be present in a person's forearm. How can you tell?

If you have the muscle, its tendon is readily observed right below your wrist, as it does not run through the carpal tunnel to connect with the palm like the other tendons.

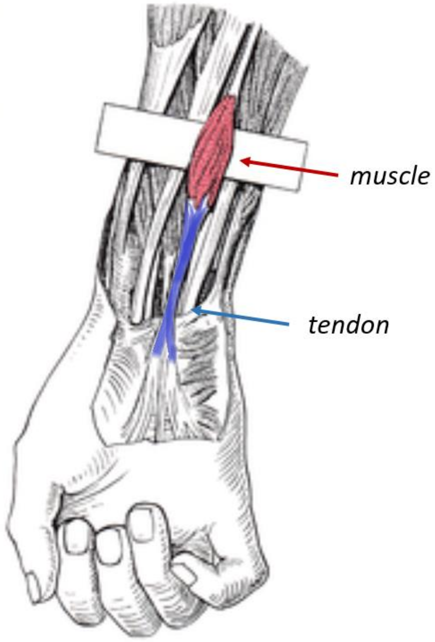

Figure 7: Palmaris longus muscle and tendon

6.2.2 Discovery lab

Present: How can you detect the existence or absence of this tendon? The standard test for the assessment of the palmaris longus tendon is *Schaffer's Test*. A subject opposes the thumb and the little (pinky) finger, and then flexes the wrist slightly towards one's forearm. The tendon, if present, will be visible in the midline of the anterior wrist (see Figure 8).

But be careful: the tendon belonging to the palmaris longus muscle runs in the middle of one's wrist. If you do see a tendon, but it does not run in the middle of wrist, it may be the flexor carpi radialis (which runs on your left hand to the left, and on the right hands to the right – see Figure 9).

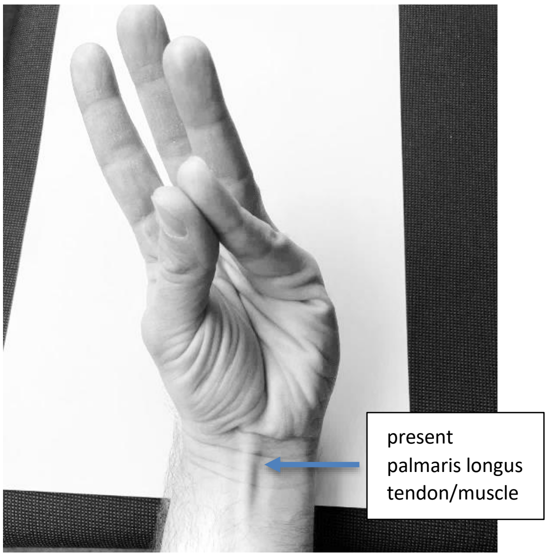

Figure 8: Presence of the palmaris longus tendon/muscle

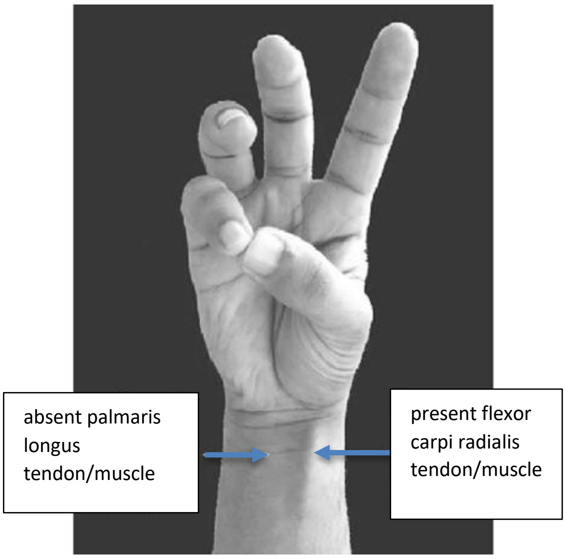

Figure 9: Absence of the palmaris longus tendon/muscle; presence of flexor carpi radialis tendon/muscle

ask class: <u>Pose question</u>: *Who has a palmaris longus muscle?*

<u>Show and tell</u>: Have the students that have it show those who do not and vice versa.

Take a show of hands and record the number of each cohort. Since the average prevalence of palmaris longus in the USA is 86% (Sebastin et al., 2005), one can compare whether the classroom average lies above or below the population average.

6.2.3 Discussion & short lecture

ask class: In plenary, have the students answer the following questions:

- *What function do you think the palmaris longus muscle serves?*
- *Why do some people have this muscle, and others not?*

<u>Present</u>: One meta-analysis of relevant studies involving *in vivo* (living) and *cadaveric* (dead) subjects conducted by Sebastin et al. (2005) observed a low absence in Asian, Black and Native American populations, and a higher absence in Caucasian and Turkish populations (see Table 5).

The absence of the palmaris longus does not have a significant effect on grip strength (Sebastin et al., 2005). In vertebrates, the palmaris longus muscle is most developed in mammals that use their forelimbs for ambulation (walking). Similarly, in the foot, the plantaris muscle is used by animals in gripping and manipulating objects with their feet.

Table 5: Absence of palmaris longus muscle

Ethnic group	*No. of papers from which data were collated*	*Total no. of subjects examined*	*Palmaris longus absence (unilateral or bilateral)*	*Palmaris longus absence (%)*
In vivo studies				
Caucasian	8	7993	1789	22.4
Asian	9	5332	259	4.8
Black	5	2461	74	3
Native American	3	854	61	7.1
Turkish	1	7000	4477	63.9
Cadaveric studies				
Caucasian	14	2857	614	21.5
Asian	4	551	24	4.3

Source: Sebastin et al. (2005)

Orangutans, which spend almost their entire lives in trees, always have a palmaris longus muscle, while it is variably absent in "higher" apes such as gorillas and chimpanzees (Thompson et al., 2001), which spend almost half the time on the ground and only move in trees 3.1% of the time (Takemoto, 2004).

In order to tease out the role of the palmaris longus, scientists have not only looked at its presence or absence. In addition, they analyzed the ratio between muscle length and tendon length ($\frac{\text{muscle length (cm)}}{\text{tendon length (cm)}}$). The more "tree-swinging" activities, the more pronounced the muscle (high muscle length/tendon length ratio) → see Figure 10.

In sum, the muscle is shorter and more likely to be missing in animals who do not use their arms regularly for "tree-swinging."

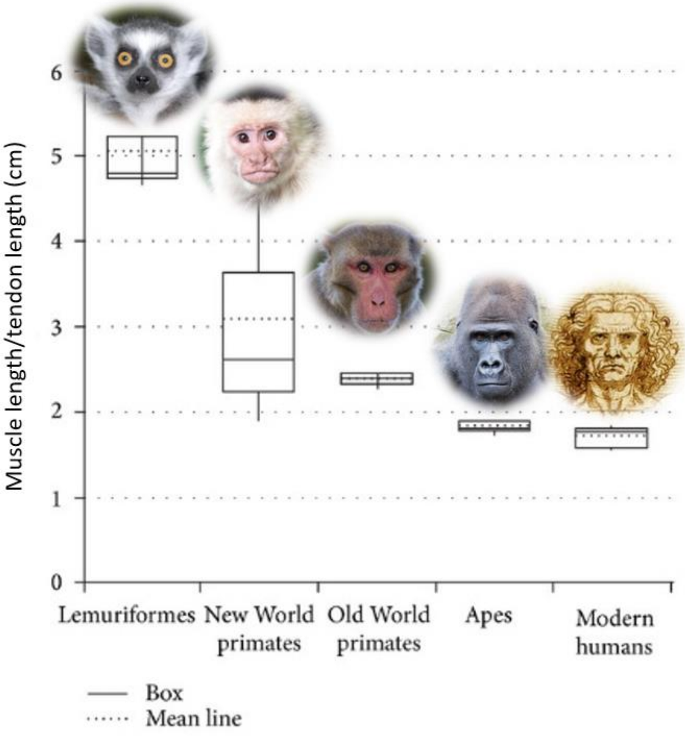

Figure 10: Palmaris longus muscle/tendon length in monkeys and apes

Source: Aversi-Ferreira et al., 2014

ask class: *Why do you think the majority of populations held on to the palmaris longus muscle?*

We must recognize the staying power of the palmaris longus muscle and tendon in our species: in spite of the clear absence of a physiological advantage for non-tree-swingers, the trait is retained by the majority of humans in most populations. Since the ponginae-hominoinea split-off roughly 9 to 13 million years ago (Hobolth et al., 2011), and great apes today spend significantly less time "hanging out" in trees than orangutans, we can deduce that the palmaris longus muscle started becoming vestigial around that time.

This phenomena is testament to (1) the inability for mutation to effectively eliminate a single trait even over millions of years, (2) the absence of a genetic drift event in our past that successfully wiped out the trait, and (3) the fact that those without the palmaris longus muscle have not reproduced at a higher rate than those who do have the trait.

Fun fact: Newborn babies can support their own weight using only their hand strength. The palmar grasp reflex – allowing a baby to firmly grasp e.g. a horizontal bar, without letting go – is inherited from our ancestors, and a matter of survival when newborns had to hold on their mothers. At the age of 3 months, babies usually lose this ability.

Figure 11: Palmaris

Source: unknown

Figure 12: Palmaris

Source: John Grainger

6.3 Cranial capacity

6.3.1 Subject introduction

ask class:

Have you ever wondered how you fit through the inlet of your mother's pelvis, which on average measures 11cm inches? Imagine trying to squeeze your head through crevice two-thirds its size. "How?" you ask?

Present: Helping your head mold through your mother's pelvis – provided you had a vaginal delivery – are the sutures on your head. Think of your head skull as a ball with 6 "tectonic plates" that had to squeeze through a ring that was smaller in size.

The human skull is made up of six cranial (skull) bones – frontal bone, occipital bone, two parietal bones and two temporal bones (see Figure 13). These bones are held together by strong, fibrous, elastic tissues called *sutures*.

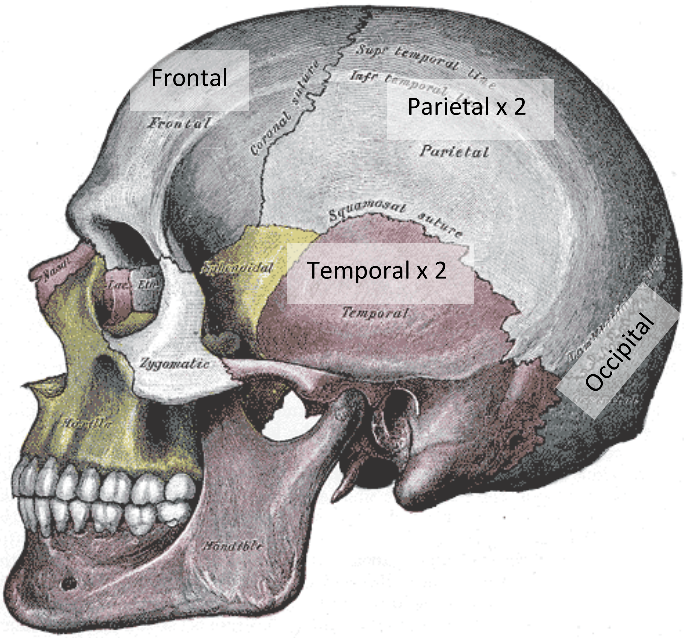

Figure 13: Bones of the cranium

Source: Gray, 1918

Nature developed an ingenious way to allow a sphere (head) that is larger than a circle (birth canal) to pass through it: Between these sutures, at birth, an infant's head has soft spots – fontanels – where the bony plates have not yet fused. The fontanels persist until approximately 18 months after birth, allowing the skull to expand and make room for brain growth. Between the bone plates are sutures, essentially the junction between the fontanels (Figure 14). The “flexible skull” is part of an adaptive solution to make an even large-brained baby fit through a relatively narrow birth canal.

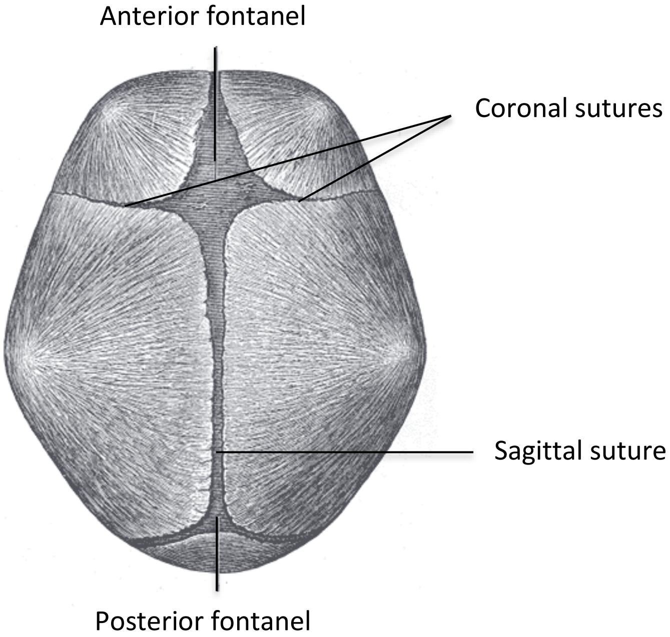

Figure 14: Fontanels and sutures in an infant

Source: Gray, 1918

A female’s “birthing hips” do not do the job alone. In fact, the head of baby is so malleable; it can be shaped into a cone (head binding). An example from Peru is depicted in Figure 15. Note the large fontanel indentation.

Figure 15: Bound head, Peru

Do other animals have soft heads and sutures to assist with birth, or is that unique to our species? Apes, dogs, cats and even mice are born with fontanels that close over the next few weeks or months. While these other species do have "soft heads," none are as dramatic as those found in humans: compared to apes and monkeys, the human skull can be compressed more intensely during birth and also allows for more growth until adulthood.

Table 6: Fontanel specs

	humans	other great apes	monkeys
fontanel at birth	Large fontanels at birth	Fontanels are small but still present at birth	Fontanels are nearly or completely closed at the time of birth
fontanel fusion	All fontanels fused by the fifth year of life	Fontanels close soon after birth	
suture fusion	Sutures remain capable of growth until early adulthood	Sutures fuse in childhood	
brain volume at birth	In human infants, the brain is only about 25% of its adult volume at birth	Neonates have brain volumes that average about 40% of the adult volume	

Not only is an infant’s cranium soft and pliable. The mother’s pelvis, too, is altered specially for birth. The pelvic bones are held together by ligaments between their joints. During pregnancy, the female body produces a hormone called “relaxin,” which softens the ligaments, allowing the pelvis to “stretch” and make sufficient room during birth, especially between the pubic arch (see Figure 16).

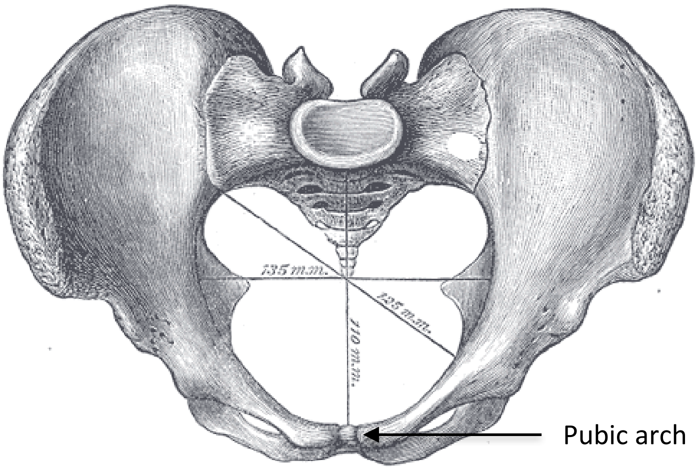

Figure 16: The Pelvis

Source: Gray, 1918

The sutures remain flexible in childhood, allowing the brain to grow quickly. As soon as the fontanelles and sutures completely turn into bone, the braincase can no longer expand. Without flexible sutures and fontanels, it would not be possible to create enough space to make way for a growing brain. And especially humans need the post-partum “headspace”: while “chimpanzees are born with about half their adult brain weight, humans with a quarter” (Hogervorst et al., 2009).

6.3.2 Discovery lab

ask class: *Sutures are the edges of skull plates. Can you identify the following sutures on the following six species?*

Show and tell: Record a “yes” or “not visible” for the presence of absence of sutures.

Table 7: Pelvic inlet vs. cranial capacity

Species	***sagital suture***	***coronal suture***	***lambdoid suture***
Homo sapiens	*yes*	*yes*	*yes*
Homo neanderthalensis	*yes*	*not visible*	*yes*
Homo erectus	*yes*	*yes*	*yes*
Homo habilis	*barely visible*	*not visible*	*not visible*
Australopithecus afarensis	*not visible*	*yes*	*not visible*
Ardipithecus ramidus	*not visible*	*not visible*	*not visible*

6.3.3 Discussion & short lecture

ask class: *Based on the data you collected, what did you observe?*

Answer: Not all sutures on the skull casts of the species under observation are readily identified. Obscured sutures are also a function of fossilization or having been lost in the process of skull reconstructions. At least with our ancestor *H. erectus*, the suture marks are clearly visible.

Present: How does our head/pelvic inlet ratio compare to that of other great apes? Humans have much a larger brain than other apes – it is 3 to 4 times larger than those of chimpanzees, our nearest relative (Gibson, 2002). Especially in relative terms (body/head ratio), humans have a uniquely large head in the animal kingdom. Yet also our head/pelvic inlet ratio is also much smaller compared with other species, as illustrated in Figure 17.

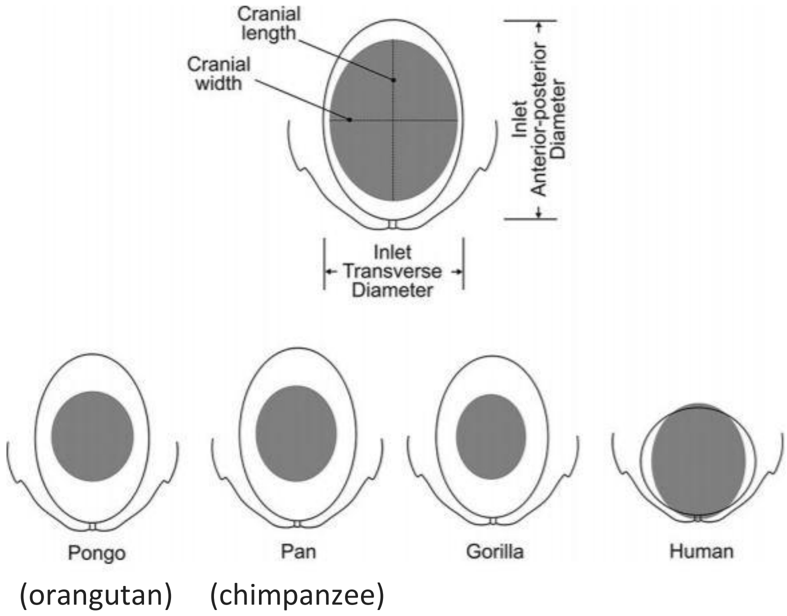

Figure 17: Relationships between the fetal head and maternal pelvis in higher primates

Source: Wittman & Wall, 2007

ask class: *At what point did an increasing cranial size become a problem?*

In our *Be a Paleoanthropologist For a Day!* Lab, we observed that cranial capacity grew with the evolution of the Homo lineage. A large brain was only a relatively "recent" innovation in hominin history: especially with the emergence of *Homo erectus* around 2 million years ago, hominids saw a dramatic increase in brain size such that obstetric constraints likely contributed to hominin pelvic morphology (Simpson et al., 2008).

As shown in Figure 18, *H. sapiens* and *H. erectus* have the largest variation in brain size, followed by *H. heidelbergensis* and *H. neanderthalensis* (Bruner, 2016).

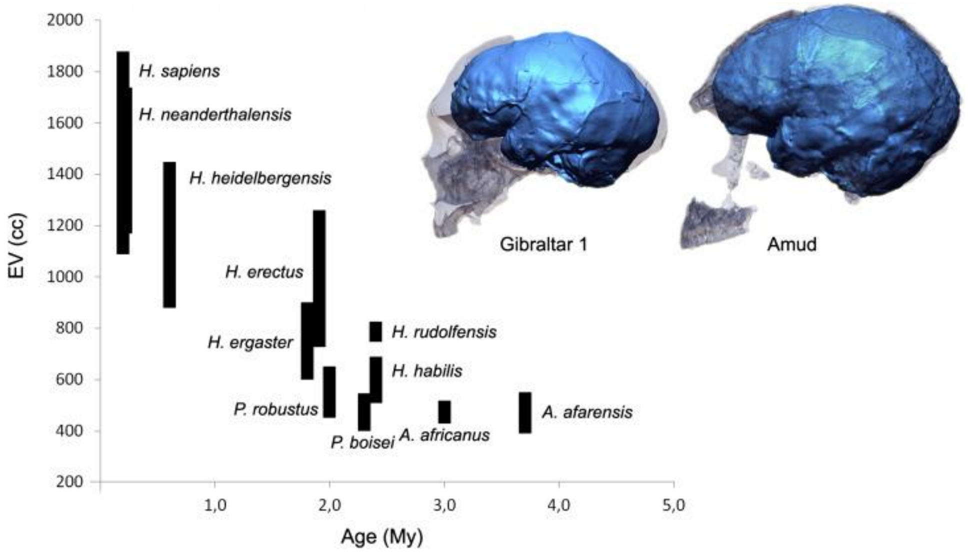

Figure 18: **Comparison of species, plotting their endocranial volume (EV) with first appearance in the fossil record (My: million years)**

Source: Bruner (2016), original data from de Sousa & Cunha, 2012

Juxtaposing pelvic inlet (measured in millimetre) and cranial capacity (measured in cm^3), Figure 19 shows that even while the cranial capacity experienced explosive growth within the *Homo* genus, the pelvic inlet size did not budge much between the species.

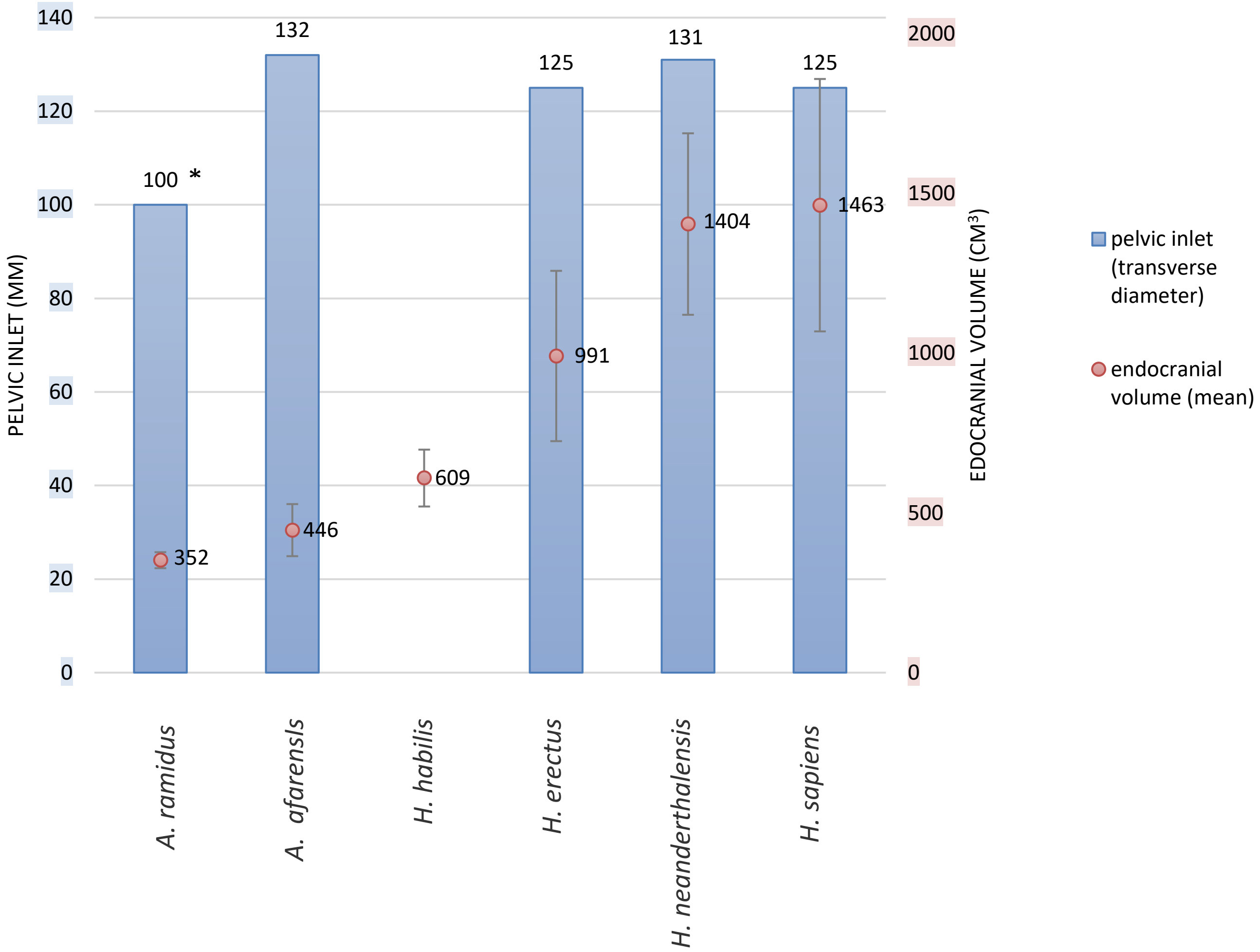

Figure 19: Pelvic inlet vs. cranial capacity

* Approximate measurement. Given the absent sacrum in the A. *ramidus* fossil, the sacrum of Lucy (*A. afarensis*) is drawn on for the purposes of a ballpark figure.

Source: Endocranial volume:
A. ramidus: Suwa et al. (2009)
all other species: de Sousa & Cunha (2012)
Pelvic inlet (traverse diameter):
A. ramidus: Lovejoy et al. (2009)
A. afarensis (AL288-1): Tague & Lovejoy (1986)
H. erectus (Gona pelvis BSN49/P27): Simpson et al. (2008)
H. neanderthalensis (Tabun pelvis): Weaver & Hublin (2009)
H. sapiens: Wells et al. (2012)

ask class: *Why do humans not simply have a larger pelvic inlet to allow for larger heads?*

The pelvis is adapted for bipedal locomotion. An efficient gait does not enable a much larger pelvic inlet, i.e. the “exit” through which the baby has to pass during birth. While allowing for an increased head and brain size would have presented clear evolutionary advantages, a competing evolutionary pressure is the size of a bipedal female’s hips. Her locomotion, e.g.

running ability and efficiency, was a survival factor for the mother, or to-be mother. This is what is referred to as the human “obstetric dilemma” – the “shrunken dimensions of the human birth canal mandated by the mechanical requirements of upright bipedal locomotion and the evolution of progressively larger human brains” (Wittman & Wall, 2007).

ask class: *Is a large cranial capacity an issue for childbirth today?*

Yes. *Homo sapiens* play with fire, literally and figuratively. Figuratively, in the sense that our species pushed big brains to the max to the point such that it would even endanger our very survival during birth. Indeed, “big” brains also came with a “big” challenge – fitting through the pelvic inlet of the mother.

For most of our history before the advent of modern medicine (which began in the late 18th century), pregnancy and childbirth were dangerous for both baby and mother. At least every 100th birth, on average, resulted in the mother’s death from pregnancy-related causes (Hanson, 2010). Among these deaths, 20% to 30% are attributable to the complications of cephalopelvic disproportion (CPD), a medical condition complicating birth in which a baby cannot safely pass through the birth canal due to the mother’s pelvis being too small, or as the baby’s head is too large (Abou-Zahr et al., 1996; Kwast, 1992; Nkata, 1997; Smith et al., 1986).

Fortunately, CPD is relatively rare, as during labor, the baby’s head molds and the pelvis joints spread, creating sufficient room for the baby to pass through the pelvis. According to the American College of Nurse-Midwives (ACNM), CPD occurs in 1 out of 250 pregnancies (Scott et al., 2003). One study performed in Malawi among 1,523 women delivering, the incidence of CPD was 2.3% (Brabin et al., 2002). We therefore must take note that mother nature is still, every now and then, pushing the envelope regarding upper-bound variation in cranium size.

To identify fetuses whose heads are too big for their mother's pelvis, pregnant women may undergo pelvimetry, which involves measuring the mother’s pelvis through radiological pelvimetry [X-ray, computerized tomography (CT) scan or magnetic resonance imaging (MRI)] and clinical examination of the woman. More research is however needed to determine whether pelvimetry significantly improves pregnancy outcomes (Pattinson et al., 2017).

ask class: *Is pelvic size a limitation for cognition?*

Cognition bestows to its owner an undisputed (evolutionary) advantage. While absolute or relative size of the brain, cortex, prefrontal cortex and degree of encephalization certainly plays a role in basic information-processing capacity, “factors that correlate better with intelligence are the number of cortical neurons and conduction velocity” (Roth & Dicke, 2005). Cognitive function is further modulated by the physical size of the animal (which can be controlled through the encephalization quotient -- EQ), brain folding (gyrification), neurologic complexity, as well as cranial blood flow.

Furthermore, the absolute cranial size has decreased in Homo sapiens since the beginning of our species: “Modern humans reached their maximum endocranial volume soon after their phylogenetic origin, approximately 100–150 thousand years ago (ka)” (Bruner, 2016).

Thus, the answer to the question is Yes and No. While cranial capacity alone is not the sole factor of cognitive outcomes, a certain size is required to potentiate its higher functions. But future favorable mutations in the brain could enhance cognition without also requiring more space.

"Fun" fact: In the 17th and 18th centuries, when a fetus could not fit through – or would get stuck in – the pelvis, the cartilage between the pubic arch was divided in order to widen the pelvis to create more space for the birth. This procedure, known as a "symphysiotomy", was originally performed using a small knife and saw. In the 1780s, in a bid to make the removal of the pelvic bone easier, two doctors (John Aitken and James Jeffray) invented the chainsaw. Symphysiotomies were widely replaced by caesarian section starting in the 19th century.

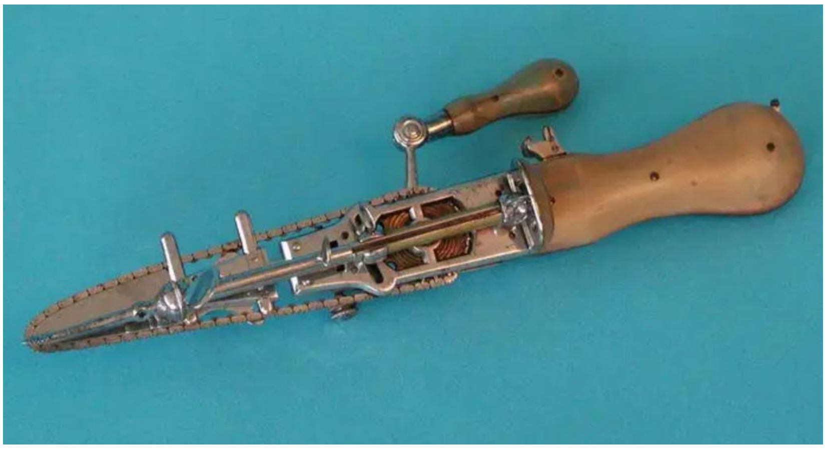

Figure 20: Obstetric chainsaw, invented in 1780

Source: Sabine Salfer / Wikicommons

6.4 Auricular muscles

6.4.1 Subject introduction

ask class:

Classroom primer questions: *Have you ever observed cat or dog orienting their ears toward a sound, for example when it is loud or interesting to them?*

For that movement, they use muscles around their ear. Dogs, cats and horses, for example, also use these muscles to engage in non-verbal communication.

In humans, the Auricular muscles (“of or relating to the ear or to the sense of hearing”) control movement of the visible part of the ear. Yet, we do not use them much. As humans have good latitudinal head movement – i.e. able to turn the head left and right covering approximately 180 degrees in total – we do not depend on the auricular muscles to rotate the ear. Some humans can wiggle their ears, but that is the best we can do.

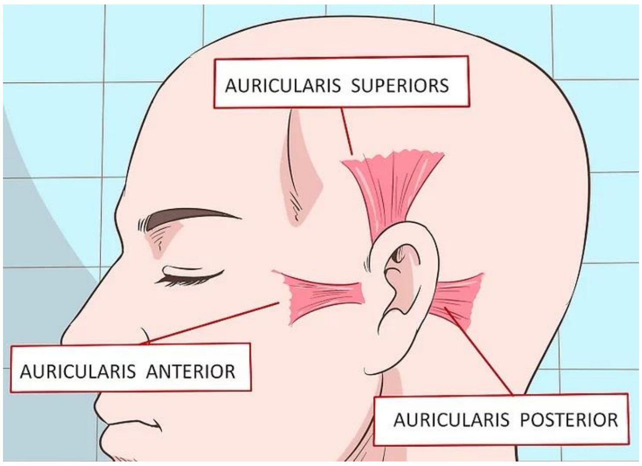

Figure 21: Auricularis muscles

Source: WikiHow, 2020

6.4.2 Discovery lab

ask class:

Ask the class:

a) *Who of you can wiggle their ears?*
b) *Have you ever noticed your ears twitch after hearing an unexpected sound or noise beside or behind you (especially observable in a quiet room)?*

Then announce the following: One can learn how to wiggle one’s ears (in most cases). Have students follow this wiki tutorial to learn how: https://www.wikihow.com/Wiggle-Your-Ears

After having given students 5-10 minutes to follow the step-by-step guide, ask them if any of them could now wiggle their ears.

6.4.3 Discussion & short lecture

Take a tally of the answers to questions a) and b) above. If in either case a student answered yes, it means their body is still “making use” of their auricular muscles.

ask class:

What advantage and disadvantage might ear movement have?

A clear advantage would be the ability to locate the source of a sound, especially vital e.g. at night, where vision is impaired. The ability to detect location of the noise and react quickly could mean a matter of life or death.

ask class:

Are auricular muscles already vestigial?

It appears that apes, including great apes (which includes *Homo sapiens*) never used their auricular muscles to locate sounds (Yerkes & Yerkes, 1929). “Given that the lesser apes (gibbons and siamangs) branched off from Old World monkeys about 25 million years ago (Gibbs et al., 2007), we can surmise that our [ear-orienting] system had become vestigial at least by that point in time” (Hackley, 2015).

Although vestigial, our ear musculature is not completely fallen into disuse: it “exhibits systematic activation during standard laboratory tests of attention” (Ibid).

ask class: *Why did the auricular muscles become vestigial?*

The evolutionary trajectory, in what would become the great ape lineage, went from forward-facing ears (necessitating rotation) to ears located at the side of the head. Over the period of fifty to thirty million years ago, ears became “shorter, wider, and more laterally positioned” (Hackley, 2015). As shown in Figure 22, the size of the ears “relative to that of the head decreased, the associated musculature degenerated, and they became less mobile” (Ibid).

An increased ability to rotate the head, in combination with increasingly upright locomotion in trees or on the ground (unlike the head position of quadruped, e.g. dog or cat) worked to diminish ear size and mobility in primate evolution. An additional driving force behind these changes may have been the switch from a predominantly nocturnal to day-time lifestyle, “in which vision played an increasingly greater role than audition” (Heffner, 2004).

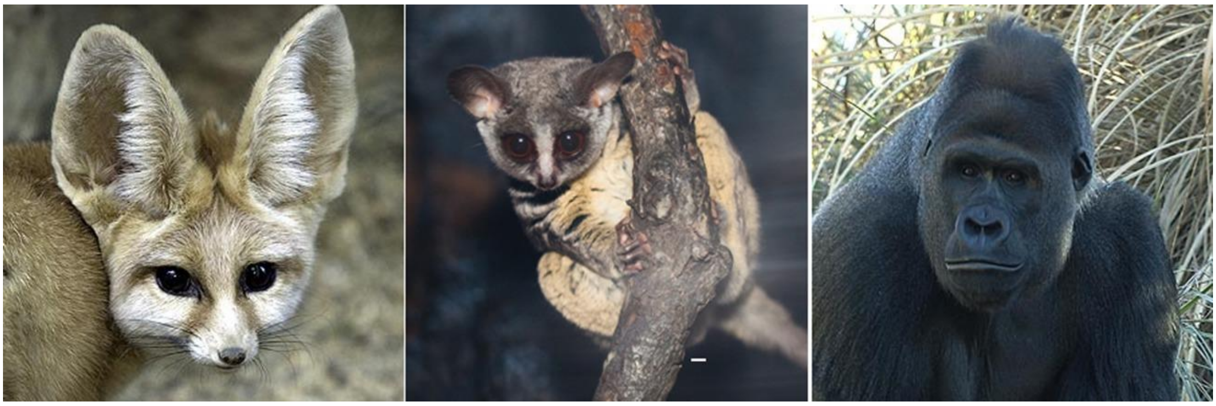

Figure 22: From left to right: the nocturnal fennec fox, the nocturnal moholi bushbaby, the diurnal western lowland gorilla

Source: Lincoln Park Zoo, Chicago, IL

Fun fact: People with moving ear syndrome, in which their ears may twitch or spasm, are treated with botulinum toxin injections (“Botox”) – a type of bacteria in which the affected muscles are temporarily paralyzed.

6.5 Hair

6.5.1 Subject introduction

ask class: *Why on earth are humans the only naked species that require clothing? What happened to the convenience of having fur? Every other animal either has feathers, scales or fur.*

No, our species did not lose its hair through continuous shaving (Figure 23) or laser hair removal. There are three competing hypotheses:

1. The *Aquatic-ape hypothesis* posits that early hominins, six to eight million years ago, may have led a semiaquatic lifestyle, hunting in shallow waters. The recent discovery that many Gibraltar Neanderthal specimens suffered from *surfer's ear* means that hominins did do some swimming (Rhys-Evans, 2020).

2. The *Parasite reduction hypothesis* argues that fur provides an attractive hiding place for ectoparasites, such as ticks, lice, mosquitos and biting flies (Pagel & Bodmer, 2003). Not only do these critters cause an annoying itch, more importantly, they transmit a large number of diseases. Among those malaria, sleeping sickness, West Nile and Lyme disease, which can even be deadly. The loss of fur could have reduced the amount of parasites to which humans would have been exposed, reducing infectious diseases and thereby presenting a survival advantage.

3. The *Sweating hypothesis* holds that body temperature control became crucial when humans began to adapt to life in the hot savannah. Walking upright (bipedalism) – which evolved before the loss of hair – exposes the head to more heat, and the bigger brains were especially in danger of overheating. Too much heat is, in particular, a concern when running long distances to hunt. Out on the open there was more game to hunt, and as humans started to eat more meat, the savannah provided the prey humans were after.


Figure 23: Not how it happened!

Source: Marco Melgrati

6.5.2 Discovery lab

Provide the following instructions: Under adequate lighting, examine your hands for dorsal phalangeal hair distribution applying the modified Bernstein (1949) classification, and note your results:

0: no hair on any of the phalanges.
1: hair present on the thumb.
2: hair present on the index finger.
3: hair present on the middle finger.
4: hair present on the ring finger.
5: hair present on the little finger.
45: hair present on the ring and little fingers.
345: hair present on the middle, ring and little fingers.
234: hair present on the index, middle and ring fingers.
etc.

Then tally the results among students in the table below.

Table 8: Distribution of proximal phalangeal hair

combinations	*absolute #*	*%*
12345		
2345		
345		
234		
34		
23		
45		
4		
0 (absent)		
other combination		

6.5.3 Discussion & short lecture

Discuss the lab results: While the degree of hair distribution demonstrates some variation between ethnicities and populations, there are also commonalities (discuss class results). Humanity does not have one uniform hair type or density of hair, which is also a function of the environment in which populations live.

ask class:

Which of the theories to explain fur loss do you agree with and why?

- The “aquatic-ape theory” is not widely accepted among scientists. There are plenty of aquatic animals out there, which have perfectly water-adapted fur. No aquatic mammals lost their hair except cetaceans who went fully aquatic over millions of years.
- The “parasite theory” doesn’t explain why so many other primates still kept their hair. Even mammals in the hottest and most arachnid-infested climates retain their fur. If this particular selective pressure were so specific, we would expect it to come up in mammals over and over again, especially because an adaptation is “losing something” is easy to get to.
- The “sweating hypothesis” is the most widely accepted theory, with genetic (human and parasite) evidence of when humans lost their hair, as well as behavioral evidence. Upright walking, running, and sweating was a perfect combination for losing our hair.

Our largely hair-free body is a product of adapting to the African savanna over a million years ago. Ridding the species of its hair coat over the generations is inversely related to a simultaneous development which proved most useful in a hot climate: sweating. The lack of fur and the ability to keep the body cool by sweating allowed Homo to run and cool itself at the same time, whereas the prey we were chasing developed hyperthermia. This is a key point: While we could have hardly produced their physical exhaustion, we had a competitive advantage by staying cooler while running, and not over-heating.

When other animals remain in the shade during the hot midday hours, humans were able to hunt. As a matter of fact, *endurance hunting* is still practiced to this day e.g. by the San 'Bushmen' (see Figure 24). This practice involves a combination of running, walking and tracking the prey until it is exhausted and/or overheats (taking advantage of slow-twitch muscles, which allow for greater endurance, but less useful for sprints).

Mathematical models show that humans would not have been able to lose enough heat hunting in the savannah had we kept our fur (Ruxton & Wilkinson, 2011; Wheeler, 1992). Yet our 2-4 million sweat glands allow for a marathon distance to be traversed – *hakuna matata* – even in the hot sun.

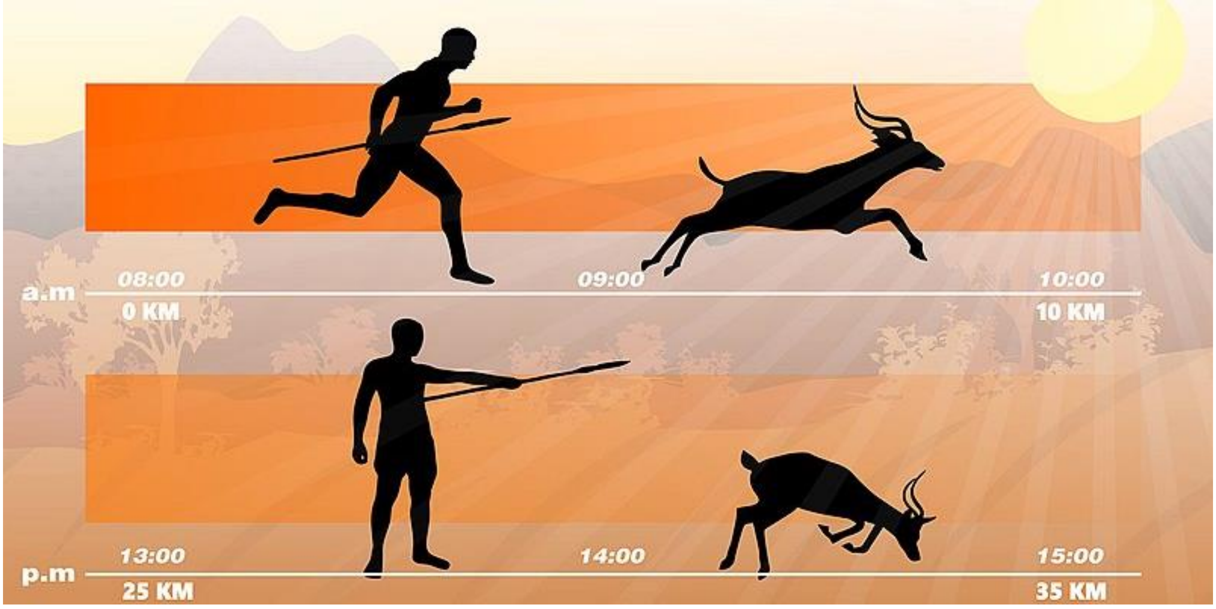

Figure 24: Timelapse of endurance hunting (2-7 hours and ca. 30 km later)

Source: Fiann Paul, TEDx talk

The connection between the loss of hair and sweat gland development can even be observed on a genetic level. Scientists have found genetic regulation factors in mice, which increase the amount of sweat glands and at the same time decrease the hair follicle production – and vice versa (Kamberov et al., 2015). In other words, you cannot have it all: sweat pores AND hair glands. Nor do you want it all. Their development in the body is in fact mutually exclusive.

ask class: *When did we shed our fur? Take a guess.*

And how would we know? Lice to the rescue. Yes, that is correct: *Pediculus humanus* comes in two forms – head and body lice – which are morphologically similar, but specialized to a particular “ecologically niche” of the body. Body lice attach to clothing and move onto the skin to feed once or twice a day, head lice are confined to the scalp and feed more frequently. Scientists compared the genes of head and body lice, found out that they diverged 1.18 million years ago (Reed et al., 2004). Such a divergence, it could be reasoned, would come about when hominins lost their chest hair.

A second relevant study investigated genes coding for skin tone and identified a gene (*MC1R*) associated with darker skin color. This would only be needed if skin became (near) naked, as fur-free skin is pink (Rogers et al., 2004). When did this gene emerge? 1.2 million years ago, which corresponds, almost exactly, with the date of the lice divergence.

Losing fur, however, would have necessitated a fur-ersatz, especially to provide the required warmth at night. Whereas mastery over fire has only been demonstrated at the 1 million years ago mark, it should not be ruled out that earlier fire sites would not still be found. Even without fire, consuming cooked food would have provided *Homo erectus* the necessary additional calories for body heat control (ibid).

ask class: *Why do you think we kept some of our "fur"?*

We still have hair in our armpits, pubic hair, and hair on our head. The hair on our head – aside – from looking good, reduces the exposure to direct sunlight, which causes skin cancer (Lesage et al., 2013).

ask class: *Speaking of "looking good," in our current culture, is hairlessness in some body regions a factor for sexual selection?*

Fun fact: Goose bumps are a reflex, and, in humans, indicative that our hair is in fact largely vestigial. The "pilomotor reflex" occurs when the tiny muscle at the base of a hair follicle contracts, pulling the hair upright. In birds or mammals with feathers, fur or spines, this creates a layer of insulating warm air, or larger appearance to put off a would-be predator. But since human hair is incapable of either of these functions, this reflex is only used to give us the "chills."

7 Final discussion

Future physiology: Address the class with concluding questions regarding what they would predict.

ask class: *1. Will the palmaris longus muscle completely disappear in the human population over time?*

Nathan Lents explains: "*Evolution has a tendency to 'clean up' unused structures and genes. It is not so much that natural selection FAVORED the removal of these vestigial structures. Natural selection did not specifically PERSERVE them, and so they eventually fell victim to one of those scattershot mutations that was later fixed in the population. In a sense, the biologist Jean-Baptiste Lamarck was correct that 'if you don't use it, you lose it,' but through attrition, not selection. That is a subtle difference and it has the same effect as selection, but the mechanism is different (and therefore a rather common misconception). What we've learned* *is that the loss of some functionality that is no longer needed is not really due to natural selection AGAINST that trait, because there is not really a survival advantage in those cases.*

"Instead, what happens is that the randomness of mutations is akin to the body being hit with a 'mutation scattershot' periodically. And, if natural selection does not WEED OUT the mutations, they add to the general genetic diversity. Then some of those scattershot mutations get fixed in the population by genetic drift – meaning, sampling error due to small population size. This is the mechanism that best applies to the loss of the palmaris muscle, for example. Even though we do not need it, there is no specific advantage in losing it." It gets lost only randomly in specific individuals, and then with nothing to maintain it, that loss could be eventually reflected in the population in the event of genetic drift. However, as genetic drift is an unlikely scenario in our modern, gene-flow enabled civilization, many populations will retain the trait for time to come.

ask class: *2. Will our wisdom teeth someday disappear?*

Nathan Lents explains: "With the advanced state of medical science in most parts of the world, natural selection is no longer working in the human population in the same manner as it did, say, even just a few hundred years ago. We do not live and die based on the status of our bodies anymore. And same with reproduction: Yes, different populations are reproducing at different rates, and yes this affects the future gene pool and so it is evolution, but those differential rates are not due to anything relevant to their genetics or physiology (that we know of). It is therefore very hard to imagine that the disappearance of the third molar will continue (except perhaps in populations with literally no access to medical care). For that to happen, those without the third molar would have to reproduce at least at a higher rate than those who do, and without any gene flow taking place between both populations, and that is just not something I would expect to see."

"The crowding of teeth (and also malocclusion) that is common in the human of today is because we do not spend as much time chewing hard foods. Our ancestors spent hours every day chewing tough, low-quality foods such as uncooked roots, and this mechanical stress sends biochemical signals that promote the growth of the mandible, in both length and depth. The loss of those signals is why many people have crowded teeth now."

ask class: *3. Will our Auricularis muscles someday disappear?*

As we learned, the Auricularis muscles have been around at least 25 million years on in the lineage that led to us. They therefore tell a similar story as the *palmaris longus muscle.* Since these traits are neither advantageous nor disadvantageous, and with no clear evaluation pressure bearing down upon it, for this trait to be lost would be the following mechanisms would have to kick in:

1. random mutation (to genetically produce agenesis), followed by
2. genetic drift (to embed the agenesis in the particular population), followed by
3. isolation of population.

In sum, while, hypothetically, the palmaris could disappear, since genetic drift is not generally observed in our currently globalizing world, it is not very likely scenario.

ask class: 4. *Will our hair someday disappear?*

Derived from our time in the African savanna over 1 million years ago, natural selection favored sweat glands rather than fur. Hence our much-reduced fur compared to the other great apes. Regarding the hair that remains, sexual selection is a driver for, at least, a full head of hair (currently an attractive trait across most cultures).

ask class: *5. Will large baby heads disappear?*

No. The large fetal cranium in *H. sapiens* is able to pass through the female pelvis thanks to sutures and fontanelles, and the elastic, expandable pelvis of the mother. But even so, sadly, to this day mothers and fetuses still die in childbirth due to complications arising from cephalopelvic disproportion (CPD). In countries with poor health infrastructure, maternal mortality remains an issue – and such populations would continue to be subjected to some degree of natural selection. However, in populations with good health care, cesarians may be employed in the event of obstetric complications involving CPD. As such, CPD would no longer impact the fitness outcomes in the evolutionary sense, and an infant's head that was too large at birth would no longer be controlled for by "mother nature."

Further discussion questions:

ask class: *Are there still evolutionary pressures being exacted on our populations today, in spite of technological and medical advances?*

ask class: *Imagine we were living in the early middle ages. How would evolutionary pressures have affected these 5 traits back then?*

ask class: *Imagine in 1000 years from now, and humans were living in an apocalyptic environment. Which traits will have become (more) vestigial?*

8 Student worksheet

1. Wisdom teeth

Record your answers (*maxillary angle* is provided):

species	***arch circumference (in cm)***	***maxillary angle***
Homo sapiens		54
Homo neanderthalensis		54
Homo erectus		51
Homo habilis		44
Australopithecus afarensis		35
Ardipithecus ramidus		35

2. Palmaris longus muscle

Do you have the palmaris longus muscle/tendon? Circle one: yes no

3. Cranial capacity

Record a "yes" or "not visible" for the presence of absence of sutures:

species	**sagital suture**	**coronal sutures**	**lambdoid suture**
Homo sapiens			
Homo neanderthalensis			
Homo erectus			
Homo habilis			
Australopithecus afarensis			
Ardipithecus ramidus			

4. Auricular (ear) muscles

Can you wiggle your ears, or have you ever noticed your ears twitch after hearing an unexpected sound or noise beside or behind you (especially observable in a quiet room)?

Circle one: yes no

5. Hair

Note your distribution of proximal phalangeal hair (according to the Bernstein classification):

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