ENCYCLOPEDIA OF BIOMETRICS

Anatomy of the Face

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SYNONYMS

Anatomic, structural and functional anatomy

DEFINITION

Facial anatomy – The soft-tissue structures attached to the bones of the facial skeleton, including epidermis, dermis, subcutaneous fascia, and mimetic musculature.

MAIN BODY TEXT

I. Introduction

Face recognition is a leading approach to person recognition. In well-controlled settings, accuracy is comparable to that of historically reliable biometrics including fingerprint and iris recognition (Phillips et al., 2007). In less-controlled settings, accuracy is attenuated with variation in pose, illumination, and facial expression among other factors. A principal research challenge is to increase robustness to these sources of variation, and to improve performance in unstructured settings in which image acquisition may occur without active subject involvement.

Current approaches to face recognition are primarily data driven. Use of domain knowledge tends to be limited to the search for relatively stable facial features, such as the inner canthi and philtrum for image alignment, or the lips, eyes, brows, and face contour for feature extraction. More explicit reference to domain knowledge of the face is relatively rare. Greater use of domain knowledge from facial anatomy could prove useful in improving the accuracy, speed, and robustness of face recognition algorithms. Data requirements could be reduced, since certain aspects need not be inferred, and parameters might be better informed. This chapter provides an introduction to facial **anatomy** that may prove useful toward this goal. We emphasize facial skeleton and musculature, which bare primary responsibility for the wide range of possible variation in face identity.

II. Morphological Basis for Facial Variation Among Individuals

1. The Skull

It has been suggested that there is more variation among human faces that in any other mammalian species except for domestic dogs (Enlow & Gans, 1996) . To understand the factors responsible for this variation, it is first necessary to understand the framework of the face, the skull. The bones of the skull can be grouped into three general structural regions: the *dermatocranium*, which surrounds and protects the brain; the *basicranium*, which serves as a stable platform for the brain; and the *viscerocranium* (facial skeleton) which houses most of the special sensory organs, the dentition, and the oronasal cavity (Schwartz, 2007). The facial skeleton also serves as the bony framework for the **mimetic musculature.** These muscles are stretched across the facial skeleton like a mask (Fig. 1). They attach into the dermis, into one another, and onto facial bones and nasal cartilages. Variation in facial appearance and expression is due in great part to variation in the facial bones and the skull as a whole (Enlow & Gans, 1996).

Fig. 1 about here

The viscerocranium (Fig. 2) is composed of 6 paired bones: the maxilla, nasal, zygomatic (malar), lacrimal, palatine, and inferior nasal concha. The vomer is a mid-line, unpaired bone and the mandible, another unpaired bone, make up the 13th and 14th facial bones (Schwartz, 2007). While not all of these bones are visible on the external surface of the skull, they all participate in producing the ultimate form of the facial skeleton. In the fetal human there are also paired premaxilla bones, which fuse with the maxilla sometime during the late fetal or early infancy period (Enlow & Gans, 1996). Separating the bones from one another are sutures. Facial sutures are fairly immobile fibrous joints that participate in growth of the facial bones, and they absorb some of the forces associated with chewing (Enlow & Gans, 1996). Variation in the form of these bones is the major reason that people look so different (Enlow, 1990).

Fig. 2 about here

While there are many different facial appearances, most people fall into one of three types of head morphologies: *dolicocephalic*, meaning a long, narrow head with a protruding nose (producing a leptoproscopic face); *mesocephalic*, meaning a proportional length to width head (producing a mesoproscopic face); and *brachycephalic*, meaning a short, wide head with a relatively abbreviated nose (producing a *euryproscopic* face) (Fig. 3).

Fig. 3 about here

What accounts for this variation in face shape? While numerous variables factor into this variation, it is largely the form of the cranial base that establishes overall facial shape. The facial skeleton is attached to the cranial base which itself serves as a template for establishing many of the angular, size-related, and topographic features of the face. Thus, a dolicocephalic cranial base sets up a template for a long, narrow face while a brachycephalic cranial base sets up a short, wide face. A soft-tissue facial mask stretched over each of these facial skeleton types must reflect the features of the bony skull. While most human populations fall into a brachycephalic, mesocephalic, or dolicocephalic head/face shape, the variation in shape within any given group typically exceeds variation between groups (Enlow & Gans, 1996). Overall, though, dolicocephalic forms tend to predominate in the northern and southern edges of Europe, the British Isles, Scandinavia, and sub-Saharan Africa. Brachycephalic forms tend to predominate in central Europe and China and mesocephalic forms tend to be found in Middle Eastern countries and various parts of Europe (Enlow, 1990). Geographic variation relates to relative genetic isolation of human populations following dispersion from Africa approximately 50,000 years ago.

Variation in facial form also is influenced by sex, with males tending to have overall larger faces. This dimorphism is most notable in the nose and forehead. Males, being larger, need more air in order to support larger muscles and viscera. Thus, the nose as the entrance to the airway will be longer, wider, and more protrusive with more flaring nostrils. This larger nose is associated with a more protrusive, sloping forehead while female foreheads tend to be more upright and bulbous. If a straight line is drawn in profile that passes vertically along the surface of the upper lip, the female forehead typically lies far behind the line with only the tip of the nose passing the line. Males, on the other hand, tend to have a forehead that is closer to the line and they tend to have more of the nose located beyond the line (Enlow & Gans, 1996; Mooney & Siegel, 2002). The protruding male forehead makes the eyes appear to be deeper set with less prominent cheek bones than in females. Overall, the female face, because of the less protrusive nose and forehead, appears to be flatter than males. Males are typically described as having deep and topographically irregular faces.

What about the variation in facial form with change in age? Facial form in infants tends to be brachycephalic because the brain is precocious relative to the face, which causes the dermatocranium and basicranium to be well-developed relative to the viscerocranium. As people age into adulthood, the primary cue to the aging face is the sagging soft-tissue: the **collagenous** fibers and **proteoglycans** of the dermis decline in number such that dehydration occurs. Additionally, subcutaneous fat deposits tend to be reabsorbed, which combined with dermal changes yields a decrease in facial volume, a skin surplus (sagging of the skin), and wrinkling (Enlow, 1990).

2. Musculature & Associated Soft Tissue

Variation in facial appearance among individuals is also influenced by the soft tissue structures of the facial skeleton: the **mimetic musculature**, the superficial **fasciae**, and adipose deposits. All humans generally have the same mimetic musculature (Fig. 4). This plan does vary, however. For instance, the risorious muscle, which causes the lips to flatten and stretch laterally, was found missing in 22 of 50 specimens examined (Pessa, Zadoo, Adrian et al., 1998). Recent work (Waller, Cray, & Burrows, Under review) has shown that the most common variations involve muscles that are nonessential for making five of the six universal facial expressions of emotion (fear, anger, sadness, surprise, and happiness). The sixth universal facial expression, disgust can be formed from a variety of different muscle combinations, so there are no ‘essential’ muscles. The most variable muscles are the risorius, depressor septi, zygomaticus minor, and procerus muscles. Muscle that vary the least among individuals were found to be the orbicularis oris, orbicularis occuli, zygomaticus major, and depressor anguli oris muscles, all of which are necessary for creating the aforementioned universal expressions.

Fig. 4 about here

In addition to presence, muscles may vary in form, location, and control. The bifid, or double, version of the zygomaticus major muscle has two insertion points rather than the more usual single insertion point. The bifid version causes dimpling or a slight depression to appear when the muscle contracts (Pessa, Zadoo, Adrian et al., 1998; Pessa, Zadoo, Garza et al., 1998; Sato, 1968). The platysma muscle inserts in the lateral cheek or on the skin above the inferior margin of the mandible. Depending on insertion region, lateral furrows form in the cheek region when the muscle contracts. Muscles also vary in the relative proportion of slow- to fast twitch fibers. Most of this variation is between muscles. The orbicularis occuli and zygomaticus major muscles, for instance, have relatively high proportions of fast twitch fibers relative to some other facial muscles (Goodmurphy & Ovalle, 1999). For the orbicularis oculi, fast twitch fibers are at least in part an adaptation for eye protection. Variation among individuals in the ratio of fast to slow twitch fibers is relatively little studied, but may be an important source of individual differences in facial dynamics. Overall, the apparent predominance of fast-twitch fibers in mimetic musculature indicates a muscle that is primarily capable of producing a quick contraction but one that fatigues quickly (slow-twitch fibers give a muscle a slow contraction speed but will not fatigue quickly). This type of contraction is consistent with the relatively fast neural processing time for facial expression in humans (Burrows, In press).

A final source of variation is cultural. Facial movements vary cross-culturally (Schmidt & Cohn, 2001) but there is little literature detailing racial differences in mimetic muscles. To summarize, variation in presence, location, form, and control of facial muscles influences the kind of facial movement that individuals create. Knowledge of such differences in expression may be especially important when sampling faces in the natural environment in which facial expression is common.

While there are no studies detailing individual variation in the other soft tissue structures of the face, these may also affect facial appearance. The facial soft-tissue architecture is a layered arrangement with the *epidermis* and *dermis* being most superficial, followed by the subcutaneous fat, superficial *fascia*, mimetic musculature, and deep facial fascia (such as the parotid/masseteric fascia) and the buccal fat pad (Larrabee & Makielski, 1993). The superficial fascia mainly consists of the *SMAS* (the superficial musculoaponeurotic system). This is a continuous fibromuscular fascia found in the face that invests and interlocks the mimetic muscles. It sweeps over the parotid gland, up to the zygomatic arch, across the cheeks and lips and down to the region of the platysma muscle. This sheet is also attached to the deep fascia of the face and the dermis (Larrabee, Jr. & Makielski, 1993). The collagen fibers found throughout the SMAS deteriorate with age, contributing to the sagging facial appearance during the aging process. In addition, fat deposits in the facial region, especially the buccal fat pad located between the masseter muscle and the orbicularis oris muscle, also breaks down with age and contributes to the sagging (Larrabee & Makielski, 1993).

Contributing to change with age are the cumulative effects of individual differences in facial expression. When facial muscles contract, facial lines and furrows appear parallel to the direction of the contraction. With aging, the elasticity of the skin decreases, and those expressions that occur frequently leave their traces; facial lines, furrows, and pouches become etched into the surface as relatively permanent features.

3. Asymmetry

Faces are structurally asymmetric, often with one side larger than the other. Structural asymmetry, approximated by distance from facial landmarks to center points, ranges from 4% to 12% average difference, depending on the landmark measured (Ferrario, Sforza, Ciusa, Dellavia,

& Tartaglia, 2001). The right side tends to be larger, and facial landmarks on the right side tend to be rotated more inferiorly and posteriorly than those on the left (Ferrario et al., 2001). Facial asymmetry is perceptually salient (Fig. 5) and can result from multiple factors. These include genetic variation, growth, injury, age, and depending on type of asymmetry, sex.

Recent evidence suggests that individual differences in asymmetry may be a useful biometric. When asymmetry metrics were added to a baseline face recognition algorithm, Fisher-Faces, recognition error in the FERET database decreased by close to 40% (Liu, Schmidt, Cohn, & Mitra, 2003). These findings are for 2D images. Because some aspects of asymmetry are revealed only with 3D measurement, error reduction may be greater when 3D scans are available.

Another factor that may contribute to the appearance of asymmetry is facial expression. While most of the variation in asymmetry at peak expression is accounted for by structural asymmetry (i.e., basal or intrinsic asymmetry at rest) (Schmidt, Lui, & Cohn, 2006), movement asymmetry contributes small but significant variance to total asymmetry. A function of movement asymmetry may be to attenuate or exaggerate apparent asymmetry. The influence of facial expression in face recognition has been relatively little studied.

Fig. 5 about here

III. Evolution of Human Face Forms

The first recognizable human ancestor was *Australopithecus*. The gracile (slender or slight) australopithecines, such as *A. africanus*, are directly ancestral to *Homo* and modern humans. The craniofacial skeleton of the gracile australopithecines is characterized by having relatively large brains when compared to modern apes (but smaller than *Homo*) and massive molar teeth with large jaws. Large jaws need large muscles to move them, which in turn leave large muscle markings such as the sagittal crest and a flaring mandibular angle. Powerful chewing stresses were dealt with in the facial skeleton by placing anterior pillars on either side of the nasal apertures. These anterior pillars were massive vertical columns supporting the anterior part of the hard palate. Any facial mask stretched over this facial skeleton would have been influenced in appearance by these bony features. Overall, australopithecines had a dolicocephalic head with a prominent, prognathic "snout" relative to modern humans (Tattersall & Schwartz, 2000).

In *Homo erectus*, the "snout" is greatly reduced as are the molars (Fig. 6). The sagittal crest and anterior pillars thus disappear and the head shape becomes more brachycephalic as in modern humans, due to the dramatic increase in brain size. The nasal aperture becomes much wider, and the nares in this species attain the downward facing posture as in modern humans. A prominent brow ridge develops in *H. erectus* that is lost in modern humans (Tattersall & Schwartz, 2000).

Fig. 6 about here

Neanderthals, *H. neanderthalensis*, are the most recent fossil human. Their brain size was actually larger than that of modern humans. Neanderthals are generally characterized by an enormous nasal opening, a reduced snout relative to *H. erectus* but larger than in modern humans, and a swollen, "puffy" appearance to the face in the region of the malar bones (Tattersall & Schwartz, 2000).

What might the face have looked like in each of these fossil humans? What might their facial expression repertoire have been? Facial musculature does not leave muscle markings behind on the bones so we can't say with any degree of certainty. However, since the mimetic musculature in primates follows a very conservative pattern from the most primitive strepsirhines through humans (Burrows, In press), it is logical to assume that mimetic musculature in fossil humans was very similar to our own and to chimpanzees, our closest living relative.

IV. Conclusions

Variation in facial appearance among human individuals is considerable. While the mimetic musculature produces facial movements, of which facial expressions of emotion are best known, it is not the major source of this variation. The major source is in the facial skeleton itself. Three representative head types have been identified, dolico-, meso-, and brachycephalic. These types correspond to geographic dispersion of human populations over the past 50,000 years or more. Within each of these types, there is considerable variation, which is likely to increase in light of demographic trends. Such individual differences in facial anatomy have been relatively neglected in face recognition research. Asymmetry is a recent exception. Preliminary work in 2D images suggests that inclusion of asymmetry metrics in algorithms may significantly reduce recognition error. Because many asymmetry metrics are 3D, their relative utility may be even greater where 3D imaging is feasible. Asymmetry, of course, is only one type of individual variation in facial anatomy. Others have yet to be explored. The anatomical record suggests that such work could be promising.

Fossil humans had facial skeletons drastically different from contemporary humans, *Homo sapiens*. In general, human facial skeletons have evolved from a long, narrow form with a prominent “snout” to one in which the face is more “tucked under” the braincase. Facial expression and face recognition are major components of communication among humans. Understanding how the human facial form has evolved provides a window for an understanding of how and why we place so much emphasis on the face in recognition of individual identity.

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RELATED ENTRIES

DEFINITIONAL ENTRIES

Mimetic Musculature – Muscles of facial expression or facial muscles. These muscles are differentiated from other musculature of the head by their innervations via the seventh cranial nerve, the facial nerve.

Fascia – A connective tissue structure that covers, supports, and separates muscles and/or connects dermis to muscles.

Brachycephalic – Head form characterized by an anteroposteriorly short and mediolaterally wide skull.

Dolicocephalic – Head form characterized by an anteroposteriorly long and mediolaterally narrow skull.

Mesocephalic -- Head form that is intermediate between brachycephalic and dolicocephalic forms.

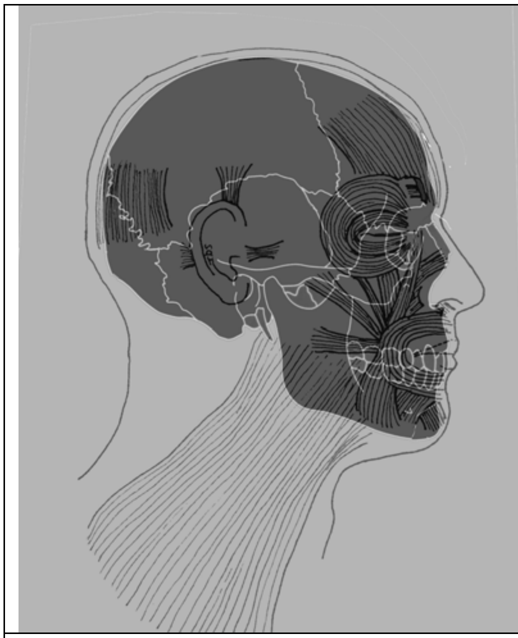


Fig. 1. Mimetic musculature and underlying facial skeleton.

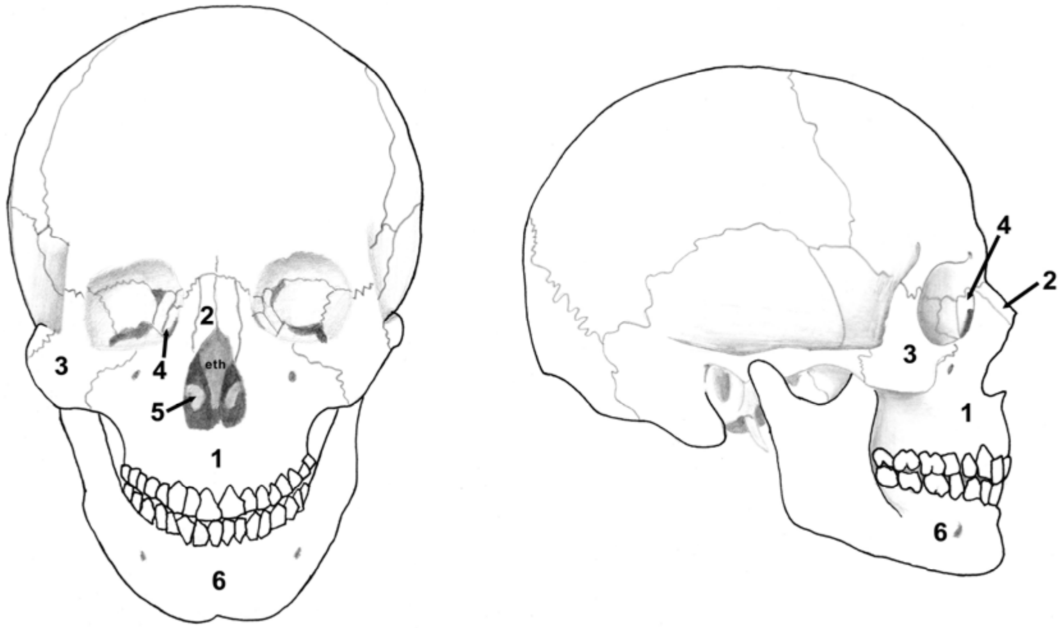


Fig. 2. Frontal view (left) and side view (right) of a human skull showing the bones that make up the facial skeleton, the viscerocranium. Note that only the bones that compose the face are labeled here. Key: 1 – maxilla, 2 – nasal, 3 – zygomatic (malar), 4 – lacrimal, 5 – inferior nasal concha, 6 – mandible. The vomer is not shown here as it is located deeply within the nasal cavity, just inferior to the ethmoid (eth). While the maxilla is shown here as a single bone it remains paired and bilateral through the 20's and into the 30's (Enlow & Gans, 1996). The mandible is shown here as an unpaired bone as well. It begins as two separate dentaries but fuses into a single bone by 6 months of age (Enlow & Gans, 1996). Compare modern humans, *Homo sapiens*, with the fossil humans in Figure 4, noting the dramatic enlargement of the brain and reduction in the "snout".

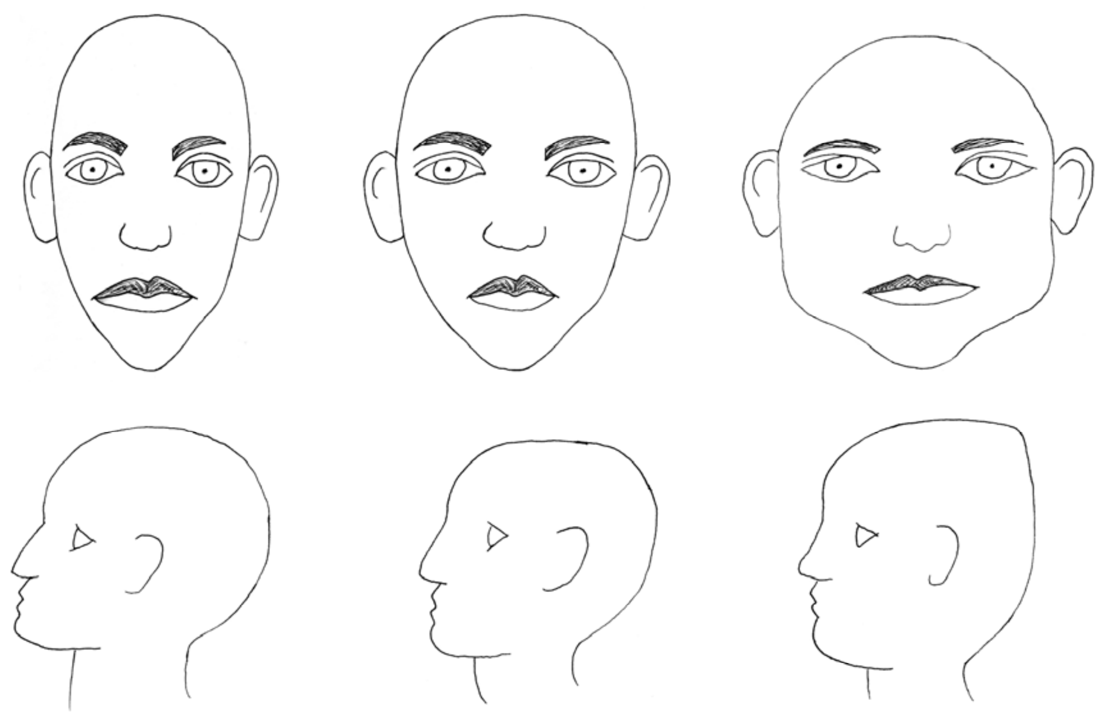
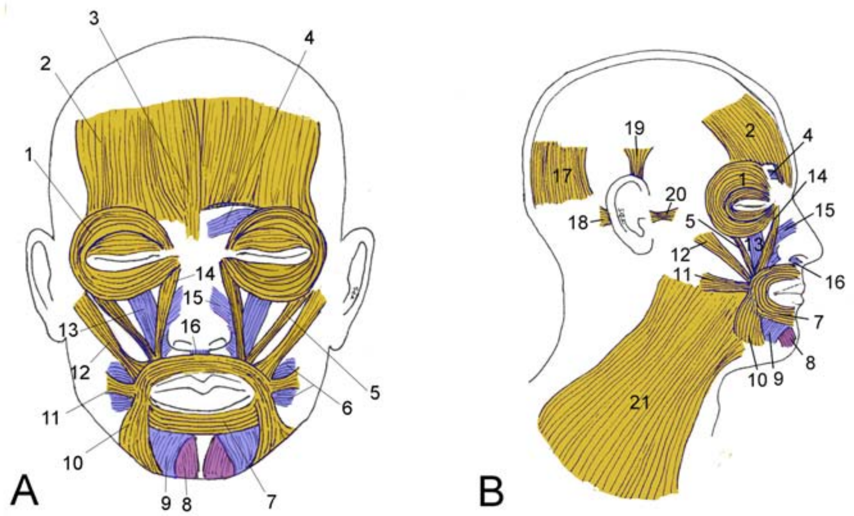


Fig. 3. Representative human head shapes (top row) and facial types (bottom row). Top left – dolicocephalic head (long and narrow); middle – mesocephalic head; right – brachycephalic head (short and wide). Bottom left – leptoproscopic face (sloping forehead, long, protuberant nose); middle – mesoproscopic face; right – euryproscopic face (blunt forehead with short, rounded nose).



(Waller et al., Under review)Fig. 4. Human mimetic musculature in (A.) frontal and (B.) right side views. Key: 1 – orbicularis occuli m., 2 – frontalis m., 3 – procerus m., 4 – corrugator supercilli m., 5 – zygomaticus minor m., 6 – buccinator m., 7 – orbicularis oris m., 8 – mentalis m., 9 – depressor labii inferioris m., 10 – depressor anguli oris m., 11 – risorius m., 12 – zygomaticus major m., 13 – levator labii superioris m., 14 – levator labii superioris alaeque nasi m., 15 – nasalis m., 16 – depressor septi m., 17 – occipitalis m., 18 – posterior auricularis m., 19 – superior auricularis m., 20 – anterior auricularis m., 21 – platysma m. Color coding represents depth of musculature with muscles colored yellow being the most superficial, muscles colored blue being intermediate in depth, and muscles colored purple being the deepest. Note that the buccinator m. (#6) is not considered to be a mimetic muscle but it is included here as a muscle located on the face that is innervated by the facial nerve.

Fig. 5. Left: original face images taken under balanced bilateral lighting. Middle: a perfectly symmetrical face made of the left half of the original face. Right: a perfectly symmetrical face made of the right half of the original face. Notice the difference in nasal regions in both individuals caused by left–right asymmetry of the nasal bridge. (Liu et al., 2003)**.** © Elsevier.

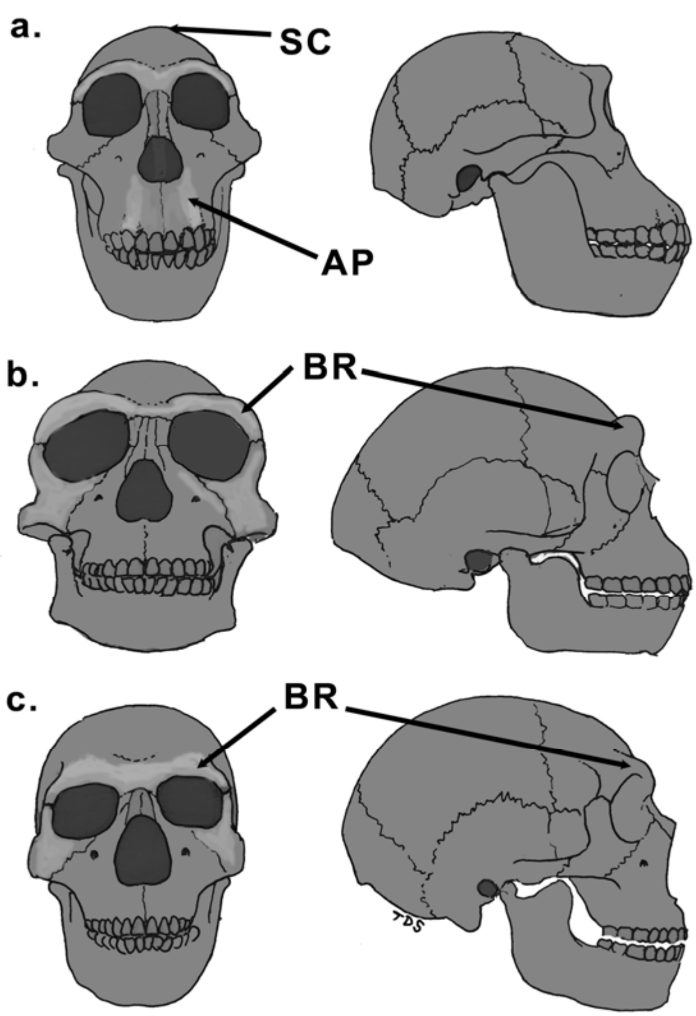


Fig. 6. Frontal (left) and right views (right) of fossil humans. a.) *Australopithecus africanus*, b.) *Homo erectus*, c.) *H. neanderthalensis*. Abbreviations: AP: anterior pillar; SC: sagittal crest; BR: brow ridges. Note the relatively small neurocranium in *A. africanus* and the relative states of dolicocephaly and leptoproscopy, reflecting the small brain. Note also the anterior pillars and massive jaws. While a brow ridge is present in this species, it is relatively small compared to *Homo*. In *H. erectus*, note the enlarging neurocranium and wider face with a reduced "snout", reflective of the enlarging brain in this species relative to *A. africanus*. Additionally, the anterior pillars have disappeared and the size of the jaw is reduced but the brow ridges enlarge. Similarly, *H. neanderthalensis* has an even larger brain and greater reduction of the "snout" relative to *H. erectus*. © Tim Smith

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