UFD0056 Carl Olsson

Peak Face

From *Anomalocaris* to selfies and deepfakes, Carl Olsson charts the history of the biological, cultural, and technological empire of the face, and looks forward to the prospect of a post-facial future

Preface[1]

What follows is a portrait of a dozen trillion faces or more.

Long before anthropogenic modifications of the biosphere made evident the need for a better plan, biological agents had been working to transform the upper layers of the Earth. At different times, different agents have taken centre stage in these terraforming processes. For example, the Great Oxygenation Event two billion years ago was driven by photosynthetic cyanobacteria. The advent of sexual reproduction over a billion years ago also counts as a planetary transformation of the same order.

Around 541 million years ago, an extremely rapid radiation of animal anatomies began. This unique evolutionary event is referred to as the Cambrian explosion. Before this period, most animals lived on the ocean floor and were soft-bodied with comparatively low mobility. A few million years later an abundance of new features and organs including shells, legs, claws, spikes, and fins had begun to proliferate. The diversification of animal life that occurred during this time

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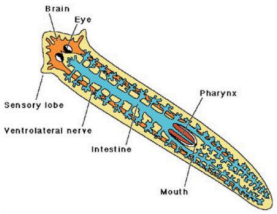
remains a unique event in the history of the Earth and is an explanatory mystery that has vexed biologists, palaeontologists, and climatologists since Darwin.

It is now thought that a higher level of oxygen in the ocean enabled larger bodies and therefore a wider range of possible morphologies, but this can hardly explain why this evolutionary event was so 'explosive'. The changing environment likely created new opportunities for earlier genetic developments to find expression in unprecedented ways, such as through the evolution of limbs and other organs of autonomy. One organisation of organs, a very special mechanism, would become surprisingly important. Oddly enough, it was the face.

The emergence of the face is closely related to the type of symmetry exhibited by animals. Some of the

1. This text is an offshoot of a project conducted by the author along with M.C. Abbott and María Buey González during the second year of 'The Terraforming' at Strelka Institute for Media Architecture and Design in 2021, directed by Benjamin Bratton and Nicolay Boyadjiev. The original project is hosted at <https://peakface.strelka.institute/>, and a version was presented at the Annual Meeting of the American Association of Geographers in 2022. I am responsible for the present twist on a concept that belongs equally to M.C. and María. I would also like to thank Lukáš Likavčan and Thomas Moynihan for their useful comments on earlier drafts, Maya B. Kronic and Amy Ireland for their comments and editing.

biological explanations for the Cambrian explosion include the rise of associative learning, attention schemata, and object-oriented cognition, all developments that occurred in a clade of animals known as *bilaterians*, which includes around 99 percent of the animal species that currently live on the Earth. You yourself (unless you are a faceless web bot reading this text) are an example of a bilaterian. Almost all adult bilaterians exhibit a two-sided symmetry, as opposed for example to the radial symmetry of a sea urchin. They have roughly symmetrical left and right sides and—importantly for the face—this means that they also have front ends and back ends.



It is true that bilateral symmetry predates the Cambrian by several million years, and can be seen already in 550 million year-old fossil imprints left by animals that resemble extant flatworms. Many of the fossilised animals are not just bilaterians, they also show signs of cephalisation—an evolutionary trend in which sensory organs and neural cells become concentrated at the anterior end of an organism. The process of cephalisation is very closely associated with the acquisition of faces, and virtually all animals with faces are to some degree cephalised.[2] Indeed, we might risk describing the face as the superficial correlate of cephalisation—and later, of mind.

The early cephalised animals that were present at the onset of the Cambrian period would have had certain advantages when it came to orientation and feeding that made them well-adapted to the changing environment (and likely made them important agents of change in turn). Simply possessing bilateral symmetry has been linked to advantages in directed motion through swimming or jet propulsion[3] and to efficient nutrient processing.[4] The anterior is also an advantageous location for sensory organs, such as eyes, that help facilitate goal-oriented motion by reinforcing perceptual discontinuity between the animal and its environment: as the vast majority of us can attest, being able to sense where your body ends and the rest of the world begins certainly helps you get around.

Some Cambrian species appear to have evolved more complex brains and nervous systems to support their increasingly advanced abilities to move around the environment. One factor in this development was the ability to cognise images (as explored by Alain Berthoz in *The Brain's Sense of Movement*).[5] Brains are typically very expensive in terms of energy, but the eventual ability to cognise objects on the basis of their images and differentiate between stimuli to form memories appears to have paid off, in that it enabled increasingly effective predation and avoidance of predators.

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The coupling, on the front end of the animal, between perception, ingestion, and attention appears to have triggered a recursive arms race that gave rise to mineralised shells, complex limbs, camouflage, and yet more faces. It is possible, even likely, that the increasing ability of certain animals to 'alienate' themselves from their surroundings developed in simultaneity with the earliest forms of animal-animal predation.[6] Widespread predation required a number of capabilities that had not previously existed. The ability to perceptually differentiate one's own body from its environment and a sufficient degree of self-control to act upon suitable prey is one example[7] that may have required a rudimentary degree of consciousness. Without being able to distinguish

2. And almost all cephalised animals have faces, with notable exceptions including certain species of jellyfish.

3. G. Holló and M. Novák, 'The Manoeuvrability Hypothesis to Explain the Maintenance of Bilateral Symmetry in Animal Evolution', *Biol Direct* 7:22 (2012). DOI:10.1186/1745-6150-7-22.

4. J.R. Finnerty, 'Did Internal Transport, Rather than Directed Locomotion, Favor the Evolution of Bilateral Symmetry in Animals?', *Bioessays* 27:11 (2005), 1174–1180. DOI:10.1002/bies.202992005.

5. A. Berthoz, *The Brain's Sense of Movement* (Cambridge, MA: Harvard University Press, 2006).

6. R. Mackay, 'Perspective, Alienation, Escape: An Introduction' Urbanomic, <https://www.urbanomic.com/document/perspective-alienation-escape-an-introduction>.

7. M. Trestman, 'The Cambrian Explosion and the Origins of Embodied Cognition', *Biological Theory* 8:1 (2013), 80–92.

itself from its environment, an animal risks autophagy—literally eating its own limbs. Others have suggested that the best way to explain the changes that the Cambrian Explosion brought about is in terms of the ability to retain memories, and hence to learn.[8]

Even if these explanations are only partial, the fossil evidence to support the case that widespread animal-animal predation began in the time leading up to the Cambrian Period is convincing. It led to increasingly complex food chains and almost certainly contributed to the (relatively) sudden radiation of animal morphologies similar to those that characterise many of the animals we know today.[9]

If one were to browse through a catalogue of Cambrian fauna and compare them to earlier animals, one would soon find that almost all of the nascent forms of life had one thing in common: they had faces. For example the suspected arthropod *Anomalocaris* can be thought of as the period's answer to the much later *T. Rex*. The forty-centimetre-long soft-bodied creature probably occupied the top of its food chain and, as its name suggests, it looked somewhat like a monstrous shrimp. Fossils indicate that it possessed a clearly defined head with a central plate and two large compound eyes the resolution of which recent evidence suggests might have rivalled that of some modern insect eyes. A triangular mouth was located on the ventral side of the head. *Anomalocaris*'s face would have contributed to highly effective sensing and targeted pursuit of resources. The ancestors of *Anomalocaris* would already have had faces with effective vision,[10] and it may have been this inheritance that set *Anomalocaris* up to become of the very first apex predators in the dawning reality of increasingly complex food chains.

But throughout the analyses and explanations of how these extraordinary changes came about, the role played by the placement of sensory organs at the front-end of animals—the consolidation of the face—appears to have been somewhat neglected. And yet, as we shall see, the face is an important platform that enabled animals to acquire a range of sensory apparatuses that help them interact with, and modify, their environments.

Face Ahead

Bilateral symmetry and cephalisation explain why the face is located where it is, but what is perhaps more important, especially from the point of view of large-scale planetary change, is to go beyond a strictly evolutionary explanation, and to describe the environmental consequences of faces becoming widespread.

Over many million years, most forms of life were forced to adapt to the new abilities that facialised animals had evolved, leading to a thorough exploration of viable morphospace and an accelerating expansion of life onto land and into the air. The space opened up by the face is so extensive, indeed explosive, that one might even be inclined to ask whether bilateral symmetry and cephalisation would be beneficial in any planetary environment, simply by virtue of the laws of physics. Could it be that faces are abundant even among aliens on distant planets because, once a lineage discovers them, they become indispensable, or is our facialised world simply an accident of evolution?[11]

8. S. Ginsburg and E. Jablonka, 'The Evolution of Associative Learning: A Factor in the Cambrian Explosion', *Journal of Theoretical Biology* 266:1 (2010), 11–20.

9. S.J. Gould. *Wonderful Life: The Burgess Shale and the Nature of History* (New York: WW Norton & Company, 1990).

10. D.E. Nilsson, 'Eye Evolution and its Functional Basis', *Visual Neuroscience* 1:2 (2013), 5–20. DOI: 10.1017/S0952523813000035.

11. On this topic, see R. Powell, 'Contingency and Convergence in Macroevolution: A Reply to John Beatty', *The Journal of Philosophy* 106:7 (2009), 390–403, and, by the same author, *Contingency and Convergence: Toward a Cosmic Biology of Body and Mind* (Cambridge, MA: MIT Press, 2020). For a review of historical matters in evolution, see Z.D. Blount, R.E. Lenski, and J.B. Losos, 'Contingency and Determinism in Evolution: Replaying Life's Tape', *Science* 362:6415 (2018).

In either case, here on Earth, the impact of the face upon the articulation of almost every ecosystem can hardly be overestimated.

As a part of its cascading impact on anatomy, the cephalic trend that came to fruition in the Cambrian Explosion was coupled with a facial platform that provided a basis from which other features could evolve in the relevant phyla, including increasingly expensive investments in more and more top-down cognitive control that enabled more and more complex sensory organs. A facial platform is just what it sounds like: face as a platform for evolutionary potential. Following the eyes and mouth, organs for detecting and producing auditory, kinaesthetic, and chemical signals have tended to evolve on, or in proximity to, the front-facing part of the head in many species in different phyla. There are both morphological and economic benefits to these collections. Having organs for sensing and manipulating objects in close proximity to the brain and facing in the same direction is beneficial for coordinating actions with relatively little 'expensive' neural tissue. Granted that many animals in the current biosphere are highly cephalised and that there is some evidence for encephalisation trending upwards over time, it is clear that the combination of cognitive control and sensory organs in close proximity have been adaptive across a wide range of environments.

Understood as a platform, the face does not really exist as anything other than a concentrated compound of sensory organs that are positioned in proximity to a dense grouping of neurons (brains/proto-brains) at the anterior end of an animal. Before it brought itself into being as a determinate 'thing' through social processes in certain mammals, the face remained a 'hidden substrate'[12] or infrastructure that bound sensory organs together. From their humble origins as mere front-ends, faces developed into composites. But these composites played an important role in organising and constraining the physiology of many animals, and, as we have seen, they have played this role continuously for a very, very long time. Nothing, it seems, escapes the face.

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The self-reinforcing enabling and constraining role played by the facial platform may be an example of generative entrenchment. Biologists and philosophers working within the evolutionary developmental (so-called 'evo-devo') paradigm suggest that evolution is prone to weak forms of path dependency and constraint. Developmental processes can 'lock' evolved traits because mutations that impact very basic features like the symmetry of the body often halt development outright or lead to reproductively unsuccessful individuals.[13] But as students of history of technology know, there is another side to platform 'lock-in'. While faces have undoubtedly enabled a new level of behavioural complexity and flexibility, they may also have imposed limitations on the acquisition of future traits, in somewhat the same way that the QWERTY keyboard has become locked in as a near ubiquitous feature of human-computer interaction despite its arbitrariness and arguable inefficiency.

This phenomenon, often observed when platforms become established, is known as path dependency, and it is characterised by the adoption of a standard that becomes ingrained in a system to the extent that, even if the standard later turns out to be inefficient compared to some alternatives, it is too costly to deviate from the chosen path due to its widespread adoption. For instance, changing keyboard layouts would be inconvenient in the short term and would be associated with prohibitive upfront costs. Path dependency can result in systems ending up being constrained by their own constitution, causing their development to plateau without much hope of further improvement.

12. K. Easterling, *Extrastatecraft: The Power of Infrastructure* Space (London: Verso, 2014)

13. C. Schank, W.C. Wimsatt, 'Generative Entrenchment and Evolution', *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association* (1986), 33–60. See also N. Rasmussen, 'A New Model of Developmental Constraints as Applied to the Drosophila System', *Journal of Theoretical Biology* 127:3 (1987), 271–99.

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Could it be that faces result in this type of plateau when it comes to behavioural flexibility and relative autonomy in the environment? Of course, it bears saying that animals with faces do a whole lot of different things. But do they really do that many things compared to what is biologically, or for that matter, physically, possible? If we take a look at plants, fungi, or one of the strains of bacteria—or even animals without faces such as jellyfish and corals—the remarkable thing about faces is how they are correlated with a suite of behaviours that remains surprisingly stable and similar across species, such as directed motion and the behaviours that are enabled by it.

The Facial Age

Although it is of course difficult to make such a judgment, given that we have only one planet as evidence, there is no positive reason to believe that having a face is optimally adaptive on Earth in an absolute sense—and even if it was in the past, that would be no guarantee that it is now—but it is indubitable that the face has proven to be an incredibly resilient platform in a variety of ecological contexts and has been a constant throughout a wide arc of speciation. The catch—because of course there's a catch—is that much of the animal phylum has become stuck in the facial age, for better and for worse. If you happen to have a face, your descendants seem very unlikely to ever lose theirs and go on to reproduce.

If we take a very broad look at look at large-scale transformative events that occurred between the Cambrian and the present time, it makes sense to ask whether any of these events were unrelated to the face. For example, the Azolla event, in which Arctic ferns are thought to have drawn down enough carbon dioxide from the atmosphere to push the Earth into its current 'icehouse' state, qualifies as a life-induced transformative event similar in scale to the ongoing anthropogenic transformation of Earth's biosphere.[14]

It is the face's remarkable persistence and its power as a platform through a long, but bounded period of space and time that makes it so interesting. Despite a succession of mass extinctions and extremely variable climates, the face has remained in place. It seems that once the face has been discovered, it doesn't go away. Time and time again, facial animals have come to occupy prominent places in essentially all ecosystems. Breaking the facial path appears to be very difficult to even imagine, and it may have become even more difficult the longer it is followed, as more features come to depend upon the face-as-platform.

This is because adaptivity is not a one-way process. Just as faces have functioned as adaptive platforms for flexible behaviours throughout different environments, so those environments have been shaped by faces in all sorts of subtle and not so subtle ways. The face is the medium of a mutual capture.

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A Faceless World?

Despite the broad presence of faces throughout the biosphere, however, it is difficult to isolate their influence because they are always embedded in an ecological context. Any attempt at counterfactual thinking about a faceless history quickly lapses into idle speculation because it requires tearing down 500 million years of evolution. But let us give it a shot. Consider a meadow. There are cows. There are different species of grass, flowers, bees, and other insects, and some birds, and surrounding the scene is an electric fence and several shrubs. Perhaps there's a nearby road. Beneath the earth, there

14. J. Zalasiewicz, M. Williams, *The Goldilocks Planet: The 4 Billion Year Story of Earth's Climate* (Oxford: Oxford University Press, 2012).

are earthworms and beetles. Of course, the entire scene is also saturated by microorganisms. Now, try imagining the meadow if faces had disappeared several hundred million years ago. The cows are gone and so are the insects and earthworms. There are no longer any fences or roads—but what about the flowers, shrubs, and grasses—are they missing too?

Probably. At the very least, many of the macroscopic lifeforms inhabiting a faceless world would look nothing like they do now without the presence of earthworms tilling the soil, cows grazing on the grass and flowers, and bees pollinating many of the shrubs—all creatures and activities which, at least in the form we know them, depend on the face. A faceless world may have been completely different, as many of the coevolutionary dependencies of other lifeforms (e.g. insect pollination) would not have developed. Maybe the same roles could have been occupied by other species, but that's a hard maybe to evaluate. It could just as well be the case that certain levels of ecosystem complexity are possible only with faces. In either case, as we've seen, what's truly remarkable isn't just the cascading transformations of animal bodies that were caused by the face during its initial proliferation during the Cambrian Period, but the subsequent constraining effects these transformations came to exert on almost everything.

The Planetary Niche

To understand this, we want to propose a hypothesis that abstracts from the concept of niche construction.[15] In evolutionary biology, work on niche construction emphasises how a species transforms its environment to such an extent that it changes the selective pressures that are exerted upon it and other species around it, such as when a beaver builds a dam and changes the conditions for various river fish. It is an evolutionary feedback mechanism through which organisms inherit pressures exerted by their ancestors (and other organisms). The abstraction we have in mind is a hypothetical quasi-niche—the set of environmental conditions produced by the ubiquity of the face—that extends across the planet, covering the entire biosphere.

15. For an introduction see K. Laland, B. Matthews, and M. W.Feldman, 'An Introduction to Niche Construction Theory', *Evolutionary Ecology* 30 (2016), 191–202. DOI:10.1007/s10682-016-9821-z

The concept of the planetary niche[16] does not suppose environmental homogeneity. It refers to factors that generally remain the same across the heterogeneous environments that make up the biosphere—factors such as the differential strength of Earth's gravitational and magnetic fields and its predictable distance from the sun. The flip side of this coin is that planetary niche construction isn't effectuated by a single species or group of species but by anatomical constants that are present in a differential manner throughout the biosphere.

The wager of this notion is that some such constants can be associated with a determinable range of behaviours that constrain the environment in determinate, but different, ways across virtually all habitats. The face is one such constant, whose presence has shaped many different environments. One curious effect of the ubiquity of faces, then, is that they have become part of the planetary niche alongside the kinds of physical planetary factors mentioned above.

One curious effect of the ubiquity of faces is that they have become part of the planetary niche

The planetary niche hypothesis is not a biological concept. It should be interpreted in an architectural register, as a description of how the biosphere has been constructed and shaped in the past, and how that history places constraints upon its future development

Only One Way Forward

And indeed, the face is a significant factor when one considers the increasingly *directed* manner in which the biosphere has been reconstructed as a result of human cognition. In his widely cited 1945 discussion on the future of the biosphere, Vladimir Vernadsky was on the threshold of realising how the very idea of direction can be traced to the face when he stated that 'the evolution of living matter is proceeding

16. A biological niche is usually defined in relation to a given species and its way of life, but the concept of a planetary niche, as I will use it here, rather captures how planetarity is materially imparted on the conditions of niches in an *absolute* sense.

in a definite direction'.[17] He referred this insight to, on the one hand, Joseph le Conte, and on the other, James Dwight Dana who coined the term 'cephalisation', the relevance of which we discussed above.[18]

Vernadsky's statement is the textbook definition of orthogenesis,[19] the idea that the history of evolutionary variation is oriented in a particular direction (most often, toward the 'perfection' of animal species toward humankind), rather than being entirely contingent. This is, of course, a notion that would be considered defunct by evolutionary biologists after the 'modern synthesis'. But despite this, there may be a way to salvage Vernadsky's insight. If an evolutionary trend is construed in relation to thoroughgoing transformations of the environment on a planet-spanning scale, another kind of directionality may be intelligible, if only retrospectively. To link a phenotypic constant to a series of transformations of the environment is to make, in retrospect, a descriptive claim about the direction of the Earth's transformation rather than about evolution per se, even if the direction in question results from evolutionary factors.

A generous reading of Vernadsky suggests that such an alternate interpretation is present precisely when he proposes that there is an elaboration of a noosphere from out of the biosphere, as a result of humans becoming a 'large-scale geological force'.[20] For Vernadsky, this noosphere, the most recent result of cephalisation, is ultimately a 'reconstruction of the biosphere in the interests of freely thinking humanity as a single totality'.[21] This is a problematic definition because it sits poorly alongside the (ontological) naturalist commitments that Vernadsky espouses: naturalists still struggle to give any coherent descriptions of 'free' thinking alongside their trademark understanding of nature as causally closed. If we want to preserve the insight about directionality, we might therefore attempt to give an alternative definition of the noosphere that does not refer to a 'freely thinking humanity'.

This challenge can be met by introducing a more radical sense in which the noosphere is an orthogenetic concept. We propose that the noosphere should be seen as the large-scale reconstruction of the biosphere in line with the very concept of orthogenesis, or directional progress. That is to say two things. First, the very concept of progress is the higher-level cognitive descendant of the forward-facing mobility of most bilaterians. Second, the use of the concept has had a real impact on the biosphere, guiding its development in ways that would not have occurred without the concept. Orthogenesis, or modern progress, is, in a sense, path dependency acting back on itself.

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The evolutionary path dependency created by the face is not yet directional in the full sense of determinately capturing the development of the biosphere. The ascent of the noosphere, on the other hand, results from the bootstrapping of path dependency into bona fide orthogenesis through the very emergence of the concept of orthogenesis. On this account, orthogenesis is the face asserting its dominance in conceptual terms. The idea of teleology, goal-directedness, is itself a major transformation in evolutionary history that leads to increasing autonomy—and it was enabled by the forward-facing body of the species that had it.

Contrary to a narrative that depends on free thought (whatever that may be), the noosphere is the biogeochemical result of the idea of orthogenesis. From inside the noosphere it is possible to rationalise the history of path dependency as orthogonal, making evolution seem directed in hindsight. The noosphere can thus be thought of as a unilateral distinction of mind from the biosphere; a vector that develops based on a historical trajectory of the biosphere's architecture, but acts upon the latter in return,

17. V.I. Vernadsky, 'The Biosphere and the Noosphere', *American Scientist* 33:1 (1945), 1–12

18. J. D. Dana, 'The Classification of Animals Based on the Principle of Cephalization', *American Journal of Science* 37 (1864).

19. The so-called 'modern synthesis' was the dovetailing of classical Darwinian theory and population-based genetics during the first half of the twentieth century. It remains the basis for the mainstream understanding of evolutionary theory.

20. Vernadsky, 'The Noosphere and the Biosphere'.

21. Ibid.

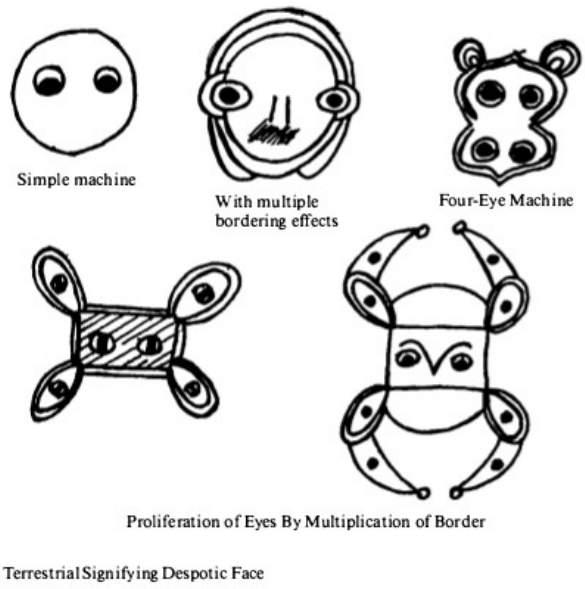
modifying it, quite similarly to how the biosphere first arose from inert geological matter.

The inception of the noosphere occurred by way of cephalisation, in particular via the mammalian brain. But it hardly ended there. The noosphere is far more than a bunch of floating brains-on-sticks, and an analysis must include the morphologies that coexist with brains. Dana did not consider the biosphere-level import of cephalisation, and Vernadsky's corrective was primarily focused on the human perspective and neglected to consider the platforms that made cephalised animals transform the planet in the first place, long before the genus homo had spread across Eurasia.

Evolutionary-developmental dynamics may have imposed constraints on human thinking that are, essentially, facial

The planetary niche hypothesis is a way of tracing the prehistory of the noosphere through the face, one of its most important but often overlooked platforms. The planetary niche has been constrained as a result of feedback between features that are downstream from the face and the planetary conditions that made it so widely successful. The planetary niche hypothesis allows us to change our frame of reference from evolutionary biology to the architecture of the biosphere and its future direction.

On this interpretation, Vernadsky's concept of the noosphere affords us the ability to establish a similar connection between the physical environment and the constraining effects of a platform on the environment via the medium of thought. It also helps us understand that evolutionary-developmental dynamics may have imposed constraints on human thinking that are, essentially, facial, in just the same way that faciality has also constrained how animals forage for food and build their nests. In both cases, there have been significant implications for how the external world has been shaped to accommodate faciality. To make sense of how this process may be changing, we must traverse the phylogenetic tree, contextualise the unusual abilities supported by our own faces, and consider how said abilities have contributed to a directional transformation of the planet.



Gilles Deleuze and Félix Guattari called the face a system of black holes and a white wall to describe the intersection of signifying and subjectifying strata.[22] And the face-as-platform is indeed a black hole, a kind of irresistible attractor which, once it emerged, started to 'capture' everything around it and, indeed, risks forcing everything else to 'make sense' exclusively in terms of the face.[23] But the facialisation of the noosphere goes deeper and is more literal than Deleuze and Guattari wanted to suggest. The subjectifying and semiotic game that, on their account, constitutes the face only continues and overcodes an underlying story: the story of a near-irreversible capture of sense organs which, in some ways, has made the environment gravitate around the image of the face. The story of the face as a platform that welcomes new features forms the background upon which social overcoding can act.

Coordinating between different parts of the body and the environment is crucial for animals that navigate space, a task for which there are many strategies. Most require that animals have a way of encoding and modelling information about their surroundings, something that is achieved through different cognitive frames of reference. Researchers working on animal spatial navigation distinguish between egocentric and allocentric frames of reference that are

22. G. Deleuze and F. Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia* (Minneapolis: University of Minnesota Press, 1987), 167–191 ('Year Zero: Faciality'). See also R. Mackay 'Notes', in J. Chapman. *Pity is Treason* (Falmouth: Urbanomic, 2023).

23. Deleuze and Guattari, *A Thousand Plateaus*, 171.

used in different navigational strategies and utilise distinct neuronal bases.[24] Egocentric frames of reference use a part of the animal's own body as the origin point for representing information about the environment in a directional manner. For example, an egocentric frame of reference originating from the eyes represents information relative to the direction of the gaze. Allocentric frames of reference use an observer-independent framework, typically an object of some kind, to represent space and the relationship between different objects. In other words, when the observer moves within an egocentric frame of reference, the frame moves with them. The opposite is true in the case of allocentric frames of reference, where the frame is independent of the observer's movement. Recent research has, however, shown that the egocentric-allocentric distinction is something of an idealisation, and that the two are often used together, even in tasks that were thought to favour one or the other.

The use of frames of reference is crucial for social communication in many extant species. While there was social activity even prior to the Cambrian period, in the rudimentary sense of interacting with other animals, as evidenced by fossilised claws and spikes for offensive and defensive use,[25] more intricate communicative strategies have become widespread since then. In many primates, faces are important media for communicating. Experiments with monkeys have shown that they possess advanced facial recognition abilities utilising neurons located in the inferior temporal cortex.[26] The monkeys' brains process the faces they perceive piece by piece:

> The retinal image of the face is first broken down into fragments corresponding to the principal channels of the primary visual pathways that dissociate color, shape, movement, and so on; then other neurons reconstruct the facial features. Certain of these neurons are activated by the eyes, others by the hair, still others by the nose, and so on. These features then converge on neurons that respond to faces, but which are also sensitive to behavior, such as the direction of gaze. This ability to detect the direction of gaze is all-important to the monkey; it probably helps to identify the intention of another of its kind: is it friend or foe?[27]

In the process of recognising faces in this bottom-up manner, the monkeys utilise an egocentric frame of reference. But, as Berthoz argues, their ability to recognise a face from different angles hints at the presence of a 'level of abstraction that is independent of the frame of reference in which the visage is perceived'.[28]

The monkeys' ability to perceive faces, and the importance of doing so successfully, confirms what we already know intuitively when looking at ourselves and each other: faces have become social operators. Modern humans' capacities for facial recognition might operate on similar neural principles[29] and have attained a remarkable level of sophistication in support of coordinated social activities; our faces play a crucial role in mediating and constraining our social lives. The environmental consequences of human sociality have been equally far-reaching, and have radically expanded the ways in which the suite of behaviours enabled by the face exert their agency on the physical environment.

Faces, Tools, and Minds

Just consider how bilateral symmetries abound in modern-day transportation systems. This includes cars, roads, airplanes and trains. It would be tempting to conclude from this simple observation of technological prolongations of evolved morphology that bilateral symmetry and an anteroposterior axis

24. T. Wolbers and J.M. Wiener, 'Challenges for Identifying the Neural Mechanisms that Support Spatial Navigation: The Impact of Spatial Scale', *Frontiers in Human Neuroscience* 8:571 (2014). DOI:10.3389/fnhum.2014.00571.

25. P. Godfrey-Smith, *Other Minds: The Octopus and the Evolution of Intelligent Life* (London: William Collins, 2016).

26. L. Chang, D. Y. Tsao, 'The Code for Facial Identity in the Primate Brain', *Cell* 169:6 (2017): 1013-1028.e14. DOI: 10.1016/j.cell.2017.05.011.

27. Berthoz, *The Brain's Sense of Movement*, 109–10, with reference to D. I. Perrett, E. T. Rolls, and W. Caan, 'Visual Neurons Responsive to Faces in the Monkey Temporal Cortex', *Experimental Brain Research* 47 (1982): 342; D. Perrett, A. J. Mistlin, A. J. Chitty, P. A. J. Smith, D. D. Potter, R. Broennimann, and M. H. Harries, 'Specialised Face Processing and Hemispheric Asymmetry in Man and Monkey: Evidence from Single Unit and Reaction Time Studies,' *Behavioural Brain Research* 29(1988): 245–58.

28. Berthoz, *The Brain's Sense of Movement*, 110.

29. N. Kanwisher, G. Yovel, 'The Fusiform Face Area: A Cortical Region Specialized for the Perception of Faces,' *Philosophical Transactions of the Royal Society B: Biological Sciences*, 361:1476 (2006):2109–28. DOI: 10.1098/rstb.2006.1934.

of mobility entail a set of predictable benefits under the determination of planetary conditions such as strong gravity, but this hypothesis would only take us so far.

While there may be something to it, such an analysis would be incomplete if it failed to consider that the same transportation systems have been constructed to accommodate animals—humans—that share the same primary anteroposterior axis of directed mobility and may therefore be expected to optimise their environments for it. In fact, the observation can be extended to most of our technology, since 'almost all everyday objects (tools, furniture, etc.) have a bilateral symmetry, just like animals, and a proximal-distal gradient',[30] giving us a world in which the subtext of signifying-subjectifying faciality is the ubiquity of implements shaped as bilaterians, to fit bilaterians.

In all of this, we also cannot discount the design impact of 'higher-level' facial abilities, such as organs for sight, speech and hearing, which have shaped the worldwide communications infrastructure. The advent of telecommunications has resulted in an interconnected system of interfaces that have been modelled to literally fit the face. Your smartphone is a bizarrely extended mask, passing information through your facial cluster of sense organs. In the broadest sense, most of our interfaces are fitted to our faces.

Your smartphone is a bizarrely extended mask, passing information through your facial cluster of sense organs.

The built environment has not just been shaped to 'fit' the face but has been constructed in its image. The history of self-representation precedes the emoji (the new minimum viable face ☺) by tens of thousands of years. Besides everything else it created, one of the things behavioural modernity brought was an obsession with faces that is leading us toward planetary-scale narcissism. At the Leang Bulu Sipong caves in Indonesia, which date back to at least 40,000 years ago, simple geometries of human-like figures are surrounded by richly detailed illustrations of bison, lions, and warty pigs. There, the human is an almost insignificant observer to a richly detailed interspecies drama. Compare these representations to those of the La Marche caves in France which were made 30,000 years later where human figures dance on the walls as the apparent protagonists of the narrative, and, again, to the current explosion of social media that is intrinsically facial. Earth seems to be undergoing an accelerating facialisation.

To understand planetary-scale facialisation, we need a better grasp of the face as the principal medium for the ability to understand, interpret, and respond to the thoughts of others. These abilities, which figure heavily in so-called theory of mind, reside at the heart of the behavioural modernity that distinguishes homo sapiens from our closest relatives.

The face has been a prominent enabling factor and constraint for our communication and ability to tell what others think

Cognitive scientists have argued that the functions that constitute our ability to develop a Theory of Mind,[31] namely the simulation of others' subjective beliefs and other conscious mental states, are virtually the same functions that enable us to ascribe beliefs to ourselves. The crux of this argument is that we're not first conscious of ourselves as having cognitions, and only later realise that other people are just like us. Instead, it is through social interaction that we attain the ability to ascribe mental states simultaneously to ourselves and to others. To suggest to myself that 'I' think is to exercise the same capacity that allows me to say of you that 'you' think. It is almost unnecessary to emphasise that social interaction does not take place between disembodied subjects or spiritual automata, but is mediated by various physiological means. The face has been a prominent enabling factor and constraint for our communication and ability to tell what others think. Its importance is not limited to the fact that our ears, mouths, and eyes are located on our heads

30. R. Thom, *Structural Stability and Morphogenesis* (Boulder, CO: Westview Press, 1989): 305–6.

31. M.S. Graziano, 'Speculations on the Evolution of Awareness', *Journal of Cognitive Neuroscience* 26:6 (2014), 1300–1304.

and mediate interaction. Rather, our entire body language is aligned with our forward-facing posture. The subjectifying words of the parent 'Look at me when I'm talking to you' act specifically on the child's bilaterian body. The conditions of social facialisation are calibrated in advance by the facial platform. The philosopher Emmanuel Levinas even went so far as to theorise that the face-to-face encounter forms the basis of any ethics. For Levinas, the transcendence of the Other, as one whose very existence places a demand for recognition on the subject, is revealed by the presence of their face, which becomes the carrier of personhood—try having a heartfelt conversation with your back turned to your partner and see what happens.[32]

The determination of thought by its facial conditions goes beyond the face's role as a constraint on social interaction. The history of logic may have its own relation to the bilateral body. The German sociologist Bernd Schmeikal has provided an intriguing argument based on Neolithic stone slabs with four directions. According to Schmeikal, these slabs could be rotated in different directions to represent all sixteen binary truth functions of Boolean algebra. His startling hypothesis is that the logic-slabs had been used as physical implements or toys for learning—possibly even discovering—the rules of reasoning over ten millennia ago.[33]

It is interesting to observe that, owing to its bilateral plan, the human body can perform the same rotational operations that Schmeikal attributed to the Neolithic stone slabs. As Immanuel Kant realised in the late eighteenth century, the chiral distinction between left and right forms an intrinsic part of how humans perceive space and follows as a direct consequence of facing forward. While none of this is to say that the rules of logic come from bilaterian orientation as such, it offers an interesting vision of their discovery and sheds new light on the context of the environment for how mind develops. If the formalisation and vernacular application of something as basic the human mind's ability to make inferences can be traced to the morphology of the human body, it does not seem so far-fetched to suggest that the face contributes to the mental and cognitive ergonomics of human ideas and technological solutions. As we suggested above, the idea of orthogenesis could itself be one example of this, suggesting that the connection between the face and the development of the biosphere in a definite direction goes very deep indeed.

The face has formed the Earth in its image

The Story So Far

The face has formed the Earth in its image. We can summarise the story up until now by dividing it into three parts: First, we encountered the unity of facing, which provided benefits for mobile life under terrestrial conditions. At the time of the Cambrian explosion, many animals possessed light-sensitive spots on one end of their bodies, indicating a preferred direction for movement. This happened in parallel to the trend of cephalisation, i.e. of nervous tissue being clustered on one end of the body.

Secondly, the face attracted additional functional capabilities coming from the consolidation of sensory and expressive organs on and around the forward-facing end of the body. Organs for feeding and photoreceptivity found their locations simultaneously with the entrenchment of directed motion, and in many species they were later joined by other organs. On this level, the face is highly variable platform between species, functioning as a multisensory interface between animals and their surroundings to quite literally structure how these animals perceive their environments.

The third and final level of the hierarchy was a return to unity of the face under the concept of a social operator. This happened when, among certain mammals, the face became an important indicator of internal states, such as emotions or motivations, in a manner that radically augmented the role of the face in receiving and expressing information. In these social worlds, the face has become a discrete entity that can be read as an indicator of personhood and the inner states attributed to persons. It may be that reaching this level served as a condition for the increasingly intensive shaping of the

32. E. Levinas, *Totality and Infinity: An Essay on Exteriority* (Pittsburgh, PA: Duquesne University Press, 1969).

33. B. Schmeikal-Schuh, 'Logic From Space', *Quality and Quantity* 27:2 (1993), 117–37;B. Schmeikal-Schuh, 'The Emergence of Orientation and the Geometry of Logic', *Quality and Quantity* 32:2 (1998), 119–54.

world around the face. By enabling more expansive architectures adapted to bilaterians, and, recently, through the massive-scale circulation of images of faces, the third level has led to the articulation of the noosphere, to put it in Vernadsky's terms.

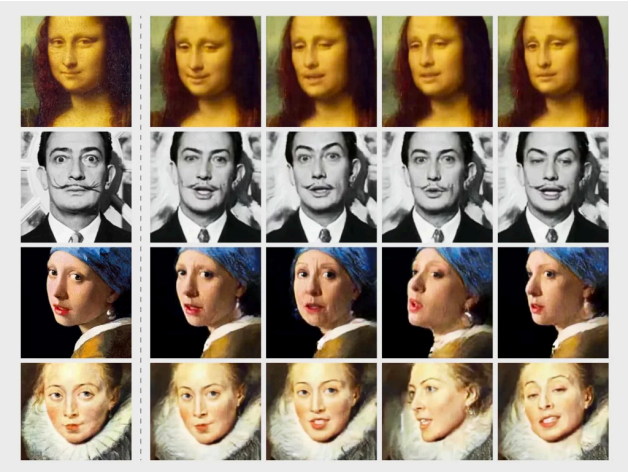
Given how ubiquitous the influence of the face over the bioactive strata of the Earth appears to have become, it may seem that it will last, virtually, forever, and that even imagining an end to faciality is an impossible exercise—and yet 'peak face' maybe in sight.

Traitorous Faces and the Man in the Moon

Here we are. We have crossed nearly half a billion years of faces and have come to live in a world of interfaces constructed like a well-fitted mask—a noosphere built in the face's image. The rate of this 'facialisng' of the Earth is increasing, and the human face, in its role as a social operator, appears to be at the heart of this increase. Every third photo in the United States is a selfie.

Aside from the intensifying effects of social media, emerging technologies are quickly expanding what faces can do and what abstractions and enhancements they can undergo. Machine vision, TikTok filters, and other augmented reality applications are good examples that illustrate the profundity of the transformations underway, and the trends, enthusiasms, and moral panics of the digital age illustrate how such processes call for a shift in how we see ourselves.

The deepfake is one well-known example from recent years that also reveals our heavy reliance on faces as social icons and operators. By using Generative Adversarial Networks (GANs), it has become possible to create false images of faces that are indistinguishable from authentic images; or for that matter, one can now conjure people up from scratch. GANs work by having an algorithm generate (parts of) images, which another algorithm attempts to distinguish from an authentic sample. When the discriminating algorithm can call out the fake, it wins, but when it fails, the generating algorithm scores a mark.[34] By going through this competition, the generative algorithm is trained to produce lifelike images.



To human eyes, deepfakes are difficult to differentiate from authentic images, and although it may be possible to detect forged images of, for example, the president of a country misbehaving, deepfakes are easy and cheap to produce and distribute. These low barriers to entry mean that deepfakes pose an increasingly credible 'epistemic threat'[35] to public life, where a combination of trickery and intense suspicion against any and all depictions of faces permeates social exchange—for example, by eroding the authoritative power of visual recordings as 'backstops'[36] in public discourse.

Other technologies similarly suggest that the fidelity of the face's social function may be decreasing even as facial images continue to proliferate. We might consider the tendency to anthropomorphise cars and personal-assistant robots, or how cuteness is rapidly becoming adaptive among non-human mammals.

34. A. Creswell, T. White, V. Dumoulin, K. Arulkumaran, B. Sengupta and A. A. Bharath, 'Generative Adversarial Networks: An Overview', *IEEE Signal Processing Magazine* 35:1 (2018) 53–65.

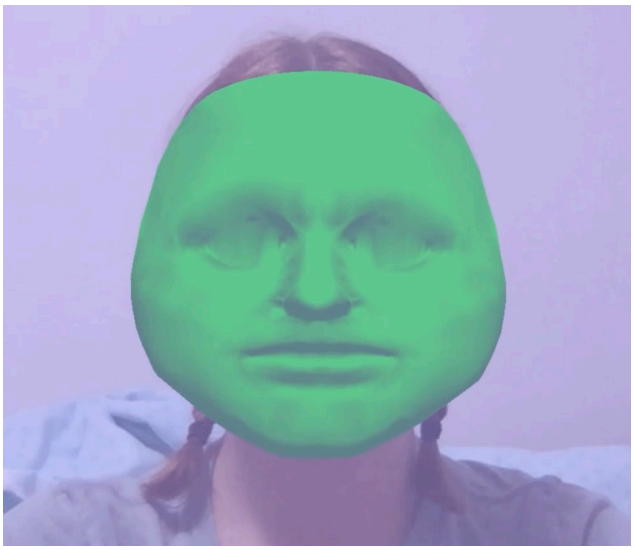
35. D. Fallis, 'The Epistemic Threat of Deepfakes', *Philosophy & Technology* 34:4 (2020). 1-21.

36. R. Rini, 'Deepfakes and the Epistemic Backstop', *Philosophers* 20:24 (2020).

Given the constraining role of the face in the evolution of human sociality, it is no exaggeration to say that life has often depended on our capability to recognise and read the nuances of faces (think of the monkeys that seemed able to differentiate friends from foes), but now images with pseudo-features of human faces are proliferating with unprecedented intensity. So-called Chernoff faces can be used to represent data by utilising human face processing to display multivariate information in an intuitively accessible way.[37] By attaching variables to different features of a humanlike image, such as eye size, nose length, or emotional expression, it is possible to create graphs that convey the overarching sense of data that would have been difficult to interpret through other means because of its high number of variables. Augmented reality is becoming widespread through filters that are fitted on top of face recognition 'meshes' in real-time. These virtual masks are now quite literally serving as models for broader implementation of augmented reality, having provided an opportunity to develop the technology in question by making it appealing to the online public's vanity, narcissism, sense of fun, and thirst for novel social interaction at a distance (all already deeply attuned, of course, to the face).

Faces on toasters? Faces on toilet seats? Puppies bred to have faces like cute human toddlers?

We might then wonder what an extreme projection of these appropriations of humans' biotic face recognition system could lead to in the future. Faces on toasters? Faces on toilet seats? Puppies bred to have faces like cute human toddlers? Perhaps some prodigious artist will eventually carve a giant face into the moon?[38] Whatever the case may be, the terrestrial habitat may continue to shape and be shaped by our preference for faces. Without even mentioning genetics, the moulding of the biosphere to suit human face recognition already constitutes a form of applied biohacking, captivating our minds. There is something uncanny about these visions where almost everything comes to look like a face,



be it the horror story of ubiquitous deepfakes or the weirdness of a literal man in the moon. Seen from the perspective of Levinas's emphasis on the transcendent qualities hosted by human faces, either future would be a world where everything is built to resemble an Other in order to elicit emotional and cognitive responses through apparent face-to-face encounters. And increasingly, this does indeed seem to be happening—but is such a narcissistic world likely to last?

Peak Face

Even considering the increasing amount of resources being spent on self-representational efforts in absolute terms, in the form of social media and new technologies trained on the human image, it seems likely that the noosphere could reach something like *peak face*, a point beyond which both self-representation and cephalisation decline as social processes discover alternative platforms. But how could this be possible, given everything we have said so far about path dependency and orthogenesis?

Peak face is not the end of the face, although it might be that too. Instead, the prospect suggests that the face will reach an apex of influence as a determinant of the planetary niche. After peak face, the defining terms for the architecture of the Earth's surface will change.

The irony is that such a turning point may occur through the deployment of the very technologies that have driven the proliferation of selfies and other forms of facial representation and self-representation. And it may not come about solely through a

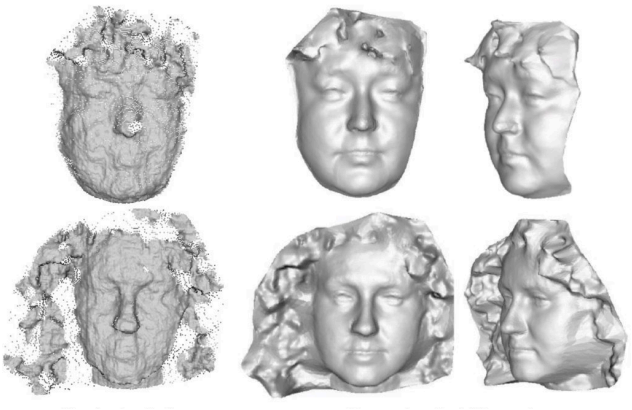
37. H. Chernoff, 'The Use of Faces to Represent Points in K-Dimensional Space Graphically', *Journal of the American Statistical Association* 68:342 (1973), 361–68. DOI:10.2307/2284077

38. See Mackay, 'Notes', in Chapman, *Pity is Treason*.

deterritorialisation of social fidelity from the face, but through something more comprehensive: a gradual migration of functions away from the face. Many of the functions that faces perform in the planetary niche would be taken over by other features and forms, and some would no longer be necessary at all. The loss of facialisation may happen as a result of the face becoming a vestigial form as it already is, for example, in the world of banking where financial credit depends more on digital credentials than on face-to-face confirmation of one's identity or the production of photo id on demand. The thorough obsolescence of the face would be extraordinarily unlikely to occur naturally among animals because of the deep entrenchment of the face as a platform in everything from feeding to basic orientation. Any large-scale disappearance of faces would almost certainly need to transpire in the merely contingently facialised noosphere; in a phylum that may have been enabled by the face, but does not any longer need the face.

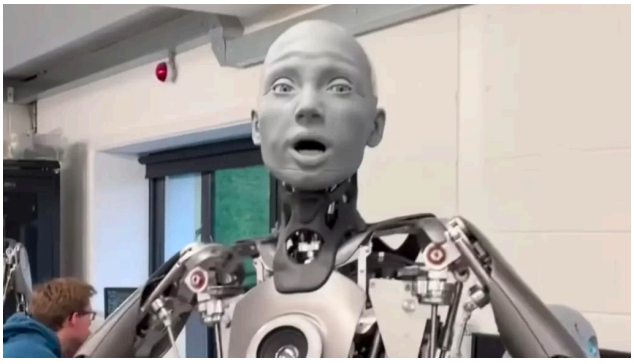
While the face may have been unusually effective at moulding the world to fit its image, we have already seen that we are no longer alone in being fixated on our faces. The real revolution of facial recognition algorithms in computer vision and generative AI is their facelessness. The story of modern technology is the story of the facial platform being sublimated. On the face of things, this seems contradictory, in that the increased use of technologies that process faces might be thought to indicate an intensification of narcissism rather than its demise. But the application of algorithmic systems to faces is arbitrary, in the sense that algorithms process faces very differently from the evolutionarily entrenched facial recognition of humans.

For example, the technique known as face hallucination transforms a low-resolution image of a face into a high-definition one by an automated process of filling in the gaps. It does so based on normalised patterns extracted from a database of faces. From this perspective, faces are not simply pieced together and assigned meaning, they're quite literally made recognisable. The transcendence that Levinas thought was the very ground for ethics is simply missing, meaning that you're not that different from the man on the moon anymore, or, for that matter, any other object. Faces are simply images that meet certain criteria without any of the social functions being accounted for, perceived by things



The entire world has been turned into a well-fitted mask for the human face. The world is a Facehugger. And now we are seeing signs that this technological mask can also expropriate the functions that have until now been monopolised by the face.

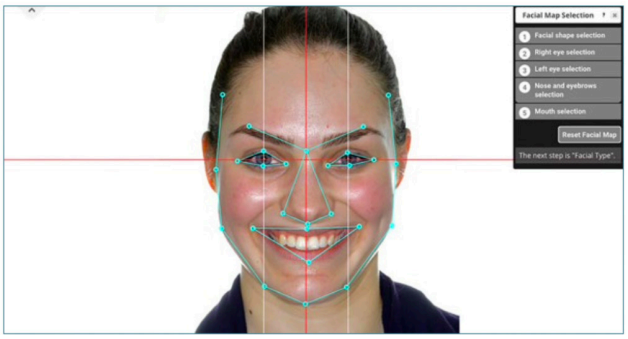
that certainly do not utilise the facial platform.
The entire world has been turned into a well-fitted mask for the human face. The world is a Facehugger. And now we are seeing signs that this technological mask can also expropriate the functions that have until now been monopolised by the face. The progressive externalisation of computation, vision, and depiction from the face might be viewed abstractly as so many surgical instruments intensely probing the face from all angles, dissecting it, tugging and cutting at it from every direction at once, in a frenzied coup against its hegemony: peak face—followed by a sudden descent.



Already implied in this abstract view is a positive account of how machine vision sees us, in its agnosticism. It sees us, and our faces, as one object among others. Bratton has argued that the recognition of such a vision of the human produces an

'inverse uncanny valley'[39] effect. No longer are we weirded out by the strangeness of the almost human other, instead we are struck by the 'offness' of seeing ourselves as seen by a machine. This effect serves to reduce transcendence even in human-human recognition, which is to say that machine vision effectively induces an allocentric frame of reference for the seeing of oneself and one's peers: an 'autoallocentric' frame of reference for which Rimbaud's *Je est un autre* remains the best slogan.

We have suggested that the physical constitution of a planet's habitable zone is constraining its trajectory. Evolution is prone to phenotypic path dependency. Morphology has implications for architecture and for thought. Further, these insights apply to evolutionary-developmental dynamics as well as to the adaptive feedback created by the truly orthogenetic construction of the noosphere on top of these dynamics to accommodate synthetic animal-machine cognition. And now the face is being rendered vestigial with the rise of computational capacities that may lead to a defacialisation of the noosphere. The consequence, should this process continue, is likely to be a completely different architecture, at odds with the thoroughly facialised environment of today.



Even as an increasing amount of processing power is spent recognising and modelling faces, we should understand that the face could be close to losing its hegemony over social cognition and the large-scale architectural agency that comes with it. Possibly the greatest change to come will be the continued development of faceless social cognition for a world of increasingly morphodiverse and neurodiverse intelligence, which is to say that animals constrained by faces are giving rise to kinds of computational embodiment that currently operate within, but are essentially unconcerned with and unconstrained by, the limits of our planetary niche, and are slowly but surely forcing us to adapt to them and to their refitted planetary niche.

39. B.H. Bratton,'The Inverse Uncanny Valley: What We See When AI Sees Us'. Paper presented at *The Uncanny Valley: Being Human in the Age of AI*, San Francisco, 2021, <https://www.youtube.com/watch?v=2E3kQqrHwqo>.

Faceless Prospects

The face began in the unity of directed motion, developed into a sensory composite that enabled subjective awareness in the process of distinguishing one's own body from the environment, and eventually coalesced into a social operator in a small number of lineages which have had transformative effects upon almost all terrestrial habitats. What we are now seeing is that other distributions of perceptual 'organs' and other structures of information processing are taking on roles that faces had previously captured. To understand this is to understand that the face's role as a driver of articulating the noosphere may be nearing its end. The human, at the end of the day, may well become known as the species that defaced the world.

The new arrangement of the noosphere that has been created to suit faces need not resemble how machinic intelligent systems would organise their environments at all. We know that the physical arrangements of the planet's surface are being remade to suit the sensing, modelling, and acting that is most efficient for machine intelligence. That this is being done by animals for their own comfort and for the display of their faces is ironic.[40] While the face has been an efficient platform for animals, given the physical parameters of the planet there's no intrinsic reason to believe that a mechanical or hybrid phylum would maintain the same relationship to faces or even be impacted by faces in the way that plants and fungi have been. What may follow after peak face could be a post-facial radiation of forms rivalling that of the Cambrian

40. [The irony that a social-computational infrastructure apparently obsessed by the processing of faces could be the vector of defacialisation...isn't this one possible interpretation of what D&G mean when they say that 'the face has a great future, but only if it is destroyed, dismantled' in a defacialisation that 'frees something like probe-heads' (Deleuze and Guattari, *A Thousand Plateaus*, 190)? 'Probe-head' here is *tête chercheuse*, literally a homing device, presumably calibrated to criteria that have little in common with the signifying-subjectifying function of the face. Perhaps we could update the translation today by saying that the face is acting as the 'search engine' of a defacialising war machine—ed.]

explosion, with similar consequences for the histories of life and of the Earth. The problem that the coming of 'peak face' highlights is that responding to these questions in any meaningful way is likely to be woefully difficult for thinkers whose cognitive ergonomics have been sculpted by their own faces for more than 450 million years of evolutionary history. And yet, we could also see it as an opportunity.

The defacement of the world may be a chance to save ourselves from the constraints of the facial platform. Soon we might be able to look in the mirror and ask ourselves, earnestly, 'Do we really need this?'

To borrow a phrase from Benedict Singleton, the defacement of the noosphere can be construed as a way of approaching 'maximum jailbreak'[41] here on Earth, a vector along which intelligence can escape from thoroughly entrenched constraints on animal morphology and architecture. This is how the prospect of peak face brings the orthogenetic articulation of the noosphere to a close: from the perspective of a post-facial future, the face may turn out to have been a directional operator that ultimately served to break free of the concept of direction.

But the negative answer does not have to be coupled with a dystopian fantasy of AI takeover or the elimination of all bilaterian life. In the very long run, another version of events may involve a careful art of *developmental lock-picking* or jailbreaking in which the human genome is gradually modified to reconfigure something as deeply entrenched as our basic symmetry, whether by direct genetic engineering or by technologically-enabled speciation in fabricated habitats intended to guide evolution. An off-planet location with less gravitational influence would be helpful in such an endeavour, for instance, allowing our distant descendants to approach a spherical form that would make all directions perfectly equal.[42]

If facing forward has impacted our conceptual repertoire and our civilisational history on a fundamental level, perhaps this post-peak-face *homo sphera* would realise a faceless democratic ideal equally accommodating to all directions of thought.

41. B. Singleton, 'Maximum Jailbreak', in R. Mackay and A. Avanessian, *#accelerate: The Accelerationist Reader* (Falmouth: Urbanomic, 2014).

42. This far-flung future, then, might ensure the spinally traumatised bilaterian human's triumphant return to the radial bliss of the faceless echinoderm—a jellyfish-regression dreamt of by various speculative pseudo-evolutionary theorists: see T. Moynihan, *Spinal Catastrophism: A Secret History* (Falmouth: Urbanomic, 2019), 95–102, 122,139–147, 151, 174. The fantasy of a spherical future only takes their dream to its geometrical conclusion.