
BROCA'S BRAIN*

Carl Sagan

'They were apes only yesterday. Give them time.'

'Once an ape — always an ape.' . . .

'No, it will be different. . . . Come back here in an age
or so and you shall see. . . .'

The gods, discussing the Earth, in the motion picture version of H. G. Wells,
The Man Who Could Work Miracles (1936)

IT was a museum, in a way like any other, this Musée de l'Homme, Museum of Man, situated on a pleasant eminence with, from the restaurant plaza in back, a splendid view of the Eiffel Tower. We were there to talk with Yves Coppens, the able associate director of the museum and a distinguished paleoanthropologist. Coppens had studied the ancestors of mankind, their fossils being found in Olduvai Gorge and Lake Turkana, in Kenya and Tanzania and Ethiopia. Two million years ago there were four-foot-high creatures, whom we call *Homo habilis*, living in East Africa, shearing and chipping and flaking stone tools, perhaps building simple dwellings, their brains in the course of a spectacular enlargement that would lead one day — to us.

Institutions of this sort have a public and a private side. The public side includes the exhibits in ethnography, say, or cultural anthropology: the costumes of the Mongols, or bark cloths painted by Native Americans, some perhaps prepared especially for sale to *voyageurs* and enterprising French anthropologists. But in the innards of the place there are other things: people engaged in the construction of exhibits; vast storerooms of items inappropriate, because of subject matter or space, for general exhibition; and areas for research. We were led through a warren of dark, musty rooms, ranging from cubicles to rotundas. Research materials overflowed into the corridors: a reconstruction of a Paleolithic cave floor, showing where the antelope bones had been thrown after eating. Priapic wooden statuary from Melanesia. Delicately painted eating utensils. Grotesque ceremonial masks. Assagai-like throwing spears from Oceania. A tattered poster of a steatopygous woman from Africa. A dank and gloomy storeroom filled to the rafters with gourd woodwinds, skin drums, reed panpipes and innumerable other reminders of the indomitable human urge to make music.

Here and there could be found a few people actually engaged in research, their sallow and deferential demeanours contrasting starkly with the hearty bilingual

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competence of Coppens. Most of the rooms were evidently used for storage of anthropological items, collected from decades to more than a century ago. You had the sense of a museum of the second order, in which were stored not so much materials that might be of interest as materials that had once been of interest. You could feel the presence of nineteenth-century museum directors engaged, in their frock coats, in *gonio-métrie* and *craniologie*, busily collecting and measuring everything, in the pious hope that mere quantification would lead to understanding.

But there was another area of the museum still more remote, a strange mix of active research and virtually abandoned cabinets and shelves. A reconstructed and articulating skeleton of an orangutan. A vast table covered with human skulls, each neatly indexed. A drawer full of femurs, piled in disarray, like the erasers in some school janitor's supply closet. A province dedicated to Neanderthal remains, including the first Neanderthal skull, reconstructed by Marcellin Boule, which I held cautiously in my hands. It felt light-weight and delicate, the sutures starkly visible, perhaps the first compelling piece of evidence that there once were creatures rather like us who became extinct, a disquieting hint that our species likewise might not survive forever. A tray filled with the teeth of many hominids, including the great nutcracker molars of *Australopithecus robustus*, a contemporary of *Homo habilis*. A collection of Cro-Magnon skull cases, stacked like cordwood, scrubbed white and in order. These items were reasonable and in a way expected, the necessary shards of evidence for reconstructing something of the history of our ancestors and collateral relatives.

Deeper in the room were more macabre and more disturbing collections. Two shrunken heads reposing on a cabinet, sneering and grimacing, their leathery lips curled back to reveal rows of sharp, tiny teeth. Jar upon jar of human embryos and foetuses, pale white, bathed in a murky greenish fluid, each jar competently labelled. Most specimens were normal, but occasionally an anomaly could be glimpsed, a disconcerting teratology – Siamese twins joined at the sternum, say, or a foetus with two heads, the four eyes tightly shut.

There was more. An array of large cylindrical bottles containing, to my astonishment, perfectly preserved human heads. A red-mustachioed man, perhaps in his early twenties; originating, so the label said, from Nouvelle Calédonie. Perhaps he was a sailor who had jumped ship in the tropics only to be captured and executed, his head involuntarily drafted in the cause of science. Except he was not being studied; he was only being neglected, among the other severed heads. A sweet-faced and delicate little girl of perhaps four years, her pink coral earrings and necklace still perfectly preserved. Three infant heads, sharing the same bottle, perhaps as an economy measure. Men and women and children of both sexes and many races, decapitated, their heads shipped to France only to

moulder – perhaps after some brief initial study – in the Musée de l'Homme. What, I wondered, must the loading of the crates of bottled heads have been like? Did the ship's officers speculate over coffee about what was down in the hold? Were the sailors heedless because the heads were, by and large, not those of white Europeans like themselves? Did they joke about their cargo to demonstrate some emotional distance from the little twinge of horror they privately permitted themselves to feel? When the collections arrived in Paris, were the scientists brisk and businesslike, giving orders to the draymen on the disposition of several heads? Were they impatient to unseal the bottles and embrace the contents with calipers? Did the man responsible for this collection, whoever he might be, view it with unalloyed pride and zest?

And then in a still more remote corner of this wing of the museum was revealed a collection of grey, convoluted objects, stored in formalin to retard spoilage – shelf upon shelf of human brains. There must have been someone whose job it was to perform routine craniotomies on the cadavers of notables and extract their brains for the benefit of science. Here was the cerebrum of a European intellectual who had achieved momentary renown before fading into the obscurity of this dusty shelf. Here a brain of a convicted murderer. Doubtless the servants of earlier days had hoped there might be some anomaly, some telltale sign in the brain anatomy or cranial configuration of murderers. Perhaps they had hoped that murder was a matter of heredity and not society. Phrenology was a graceless nineteenth-century aberration. I could hear my friend Ann Druyan saying, 'The people we starve and torture have an unsociable tendency to steal and murder. We think it's because their brows overhang.' But the brains of murderers and savants – the remains of Albert Einstein's brain are floating wanly in a bottle in Wichita – are indistinguishable. It is, very probably, society and not heredity that makes criminals.

While scanning the collection amid such ruminations, my eye was caught by a label on one of the many low cylindrical bottles. I took the container from the shelf and examined it more closely. The label read *P. Broca*. In my hands was Broca's brain.

PAUL BROCA was a surgeon, a neurologist and an anthropologist, a major figure in the development of both medicine and anthropology in the mid-nineteenth century. He performed distinguished work on cancer pathology and the treatment of aneurisms, and made a landmark contribution to understanding the origins of aphasia – an impairment of the ability to articulate ideas. Broca was a brilliant and compassionate man. He was concerned with medical care for the poor. Under cover of darkness, at the risk of his own life, he successfully smuggled out of Paris in a horse-drawn cart 73 million francs, stuffed into carpetbags and hidden

under potatoes, the treasury of the Assistance Publique which – he believed, at any rate – he was saying from pillage. He was the founder of modern brain surgery. He studied infant mortality. Towards the end of his career he was created a senator.

He loved, as one biographer said, mainly serenity and tolerance. In 1848 he founded a society of 'freethinkers'. Almost alone among French savants of the time, he was sympathetic to Charles Darwin's idea of evolution by natural selection. T. H. Huxley, 'Darwin's Bulldog', remarked that the mere mention of Broca's name filled him with a sense of gratitude, and Broca was quoted as saying, 'I would rather be a transformed ape than a degenerate son of Adam.' For these and other views he was publicly denounced for 'materialism' and, like Socrates, for corrupting the young. But he was made a senator nevertheless.

Earlier, Broca had encountered great difficulty in establishing a society of anthropology in France. The Minister of Public Instruction and the Prefect of Police believed that anthropology must, as the free pursuit of knowledge about human beings, be innately subversive to the state. When permission was at last and reluctantly granted for Broca to talk about science with eighteen colleagues, the Prefect of Police held Broca responsible personally for all that might be said in such meetings 'against society, religion, or the government'. Even so, the study of human beings was considered so dangerous that a police spy in plain clothes was assigned to attend all meetings, with the understanding that authorization to meet would be withdrawn immediately if the spy was offended by anything that was said. In these circumstances the Society of Anthropology of Paris gathered for the first time on May 19, 1859, the year of the publication of *The Origin of Species*. In subsequent meetings an enormous range of subjects was discussed – archaeology, mythology, physiology, anatomy, medicine, psychology, linguistics, and history – and it is easy to imagine the police spy nodding off in the corner on many an occasion. Once, Broca related, the spy wished to take a small unauthorized walk and asked if he might leave without anything threatening to the state being said in his absence. 'No, no, my friend,' Broca responded. 'You must not go for a walk: sit down and earn your pay.' Not only the police but also the clergy opposed the development of anthropology in France, and in 1876 the Roman Catholic political party organized a major campaign against the teaching of the subject in the Anthropological Institute of Paris founded by Broca.

Paul Broca died in 1880, perhaps of the very sort of aneurism that he had studied so brilliantly. At the moment of his death he was working on a comprehensive study of brain anatomy. He had established the first professional societies, schools of research, and scientific journals of modern anthropology in France. His laboratory specimens became incorporated into what for many years was called the Musée, Broca. Later it merged to become a part of the Musée de l'Homme.

It was Broca himself, whose brain I was cradling, who had established the macabre collection I had been contemplating. He had studied embryos and apes, and people of all races, measuring like mad in an effort to understand the nature of a human being. And despite the present appearance of the collection and my suspicions, he was not, at least by the standards of his time, more of a jingoist or a racist than most, and certainly not that standby of fiction and, more rarely, of fact: the cold, uncaring, dispassionate scientist, heedless of the human consequences of what he does. Broca very much cared.

In the *Revue d'Anthropologie* of 1880 there is a complete bibliography of Broca's writings. From the titles I could later glimpse something of the origins of the collection I had viewed: 'On the Cranium and Brain of the Assassin Lemaire', 'Presentation of the Brain of a Male Adult Gorilla', 'On the Brain of the Assassin Prévost', 'On the Supposed Heredity of Accidental Characteristics', 'The Intelligence of Animals and the Rule of Humans', 'The Order of the Primates: Anatomical Parallels between Men and Apes', 'The Origin of the Art of Making Fire', 'On Double Monsters', 'Discussion on Microcephalics', 'Prehistoric Trepanning', 'On Two Cases of a Supernumerary Digit Developing at an Adult Age', 'The Heads of Two New Caledonians' and 'On the Skull of Dante Alighieri'. I did not know the present resting place of the cranium of the author of *The Divine Comedy*, but the collection of brains and skulls and heads that surrounded me clearly began in the work of Paul Broca.

BROCA was a superb brain anatomist and made important investigations of the limbic region, earlier called the rhinencephalon (the 'smell brain'), which we now know to be profoundly involved in human emotion. But Broca is today perhaps best known for his discovery of a small region in the third convolution of the left frontal lobe of the cerebral cortex, a region now known as Broca's area. Articulate speech, it turns out, as Broca inferred on only fragmentary evidence, is to an important extent localized in and controlled by Broca's area. It was one of the first discoveries of a separation of function between the left and right hemispheres of the brain. But most important, it was one of the first indications that specific brain functions exist in particular locales in the brain, that there is a connection between the anatomy of the brain and what the brain does, an activity sometimes described as 'mind'.

Ralph Holloway is a physical anthropologist at Columbia University whose laboratory I imagine must bear some resemblance to Broca's. Holloway makes rubber-latex casts of the insides of skulls of human and related beings, past and present, to attempt a reconstruction, from slight impressions on the interior of the cranium, of what the brain must have been like. Holloway believes that he can tell from a creature's cranium whether Broca's area is present, and he has

found evidence of an emerging Broca's area in the brain of *Homo habilis* some two million years ago — just the time of the first constructions and the first tools. To this limited extent there is something to the phrenological vision. It is very plausible that human thought and industry went hand in hand with the development of articulate speech, and Broca's area may in a very real sense be one of the seats of our humanity, as well as a means for tracing our relationships with our ancestors on their way towards humanity.

And here was Broca's brain floating, in formalin and in fragments, before me. I could make out the limbic region which Broca had studied in others. I could see the convolutions on the neocortex. I could even make out the grey-white left frontal lobe in which Broca's own Broca's area resided, decaying and unnoticed, in a musty corner of a collection that Broca had himself begun.

It was difficult to hold Broca's brain without wondering whether in some sense Broca was still *in* there — his wit, his sceptical mien, his abrupt gesticulations when he talked, his quiet and sentimental moments. Might there be preserved in the configuration of neurons before me a recollection of the triumphant moment when he argued before the combined medical faculties (and his father, overflowing with pride) on the origins of aphasia? A dinner with his friend Victor Hugo? A stroll on a moonlit autumn evening, his wife holding a pretty parasol, along the Quai Voltaire and the Pont Royal? Where do we go when we die? Is Paul Broca still there in his formalin-filled bottle? Perhaps the memory traces have decayed, although there is good evidence from modern brain investigations that a given memory is redundantly stored in many different places in the brain. Might it be possible at some future time, when neurophysiology has advanced substantially, to reconstruct the memories or insights of someone long dead? And would that be a good thing? It would be the ultimate breach of privacy. But it would also be a kind of practical immortality, because, especially for a man like Broca, our minds are clearly a major aspect of who we are.

From the character of this neglected storeroom in the Musée de l'Homme I had been ready to attribute to those who had assembled the collection — I had not known it was Broca at the time — a palpable sexism and racism and jingoism, a profound resistance to the idea of the relatedness of human beings and the other primates. And in part it was true. Broca was a humanist of the nineteenth century, but unable to shake the consuming prejudices, the human social diseases, of his time. He thought men superior to women, and whites superior to blacks. Even his conclusion that German brains were not significantly different from French ones was in rebuttal to a Teutonic claim of Gallic inferiority. But he concluded that there were deep connections in brain physiology between gorillas and men. Broca, the founder of a society of freethinkers in his youth, believed in the importance of untrammelled inquiry and had lived his life in pursuit of that aim.

His falling short of these ideals shows that someone as unstinting in the free pursuit of knowledge as Broca could still be deflected by endemic and respectable bigotry. Society corrupts the best of us. It is a little unfair, I think, to criticize a person for not sharing the enlightenment of a later epoch, but it is also profoundly saddening that such prejudices were so extremely pervasive. The question raises nagging uncertainties about which of the conventional truths of our own age will be considered unforgivable bigotry by the next. One way to repay Paul Broca for this lesson which he has inadvertently provided us is to challenge, deeply and seriously, our own most strongly held beliefs.

These forgotten jars and their grisly contents had been collected, at least partly, in a humanistic spirit; and perhaps, in some era of future advance in brain studies, they would prove useful once again. I would be interested in knowing a little more about the red-mustachioed man who had been, in part, returned to France from New Caledonia.

But the surroundings, the sense of a chamber of horrors, evoked unbidden other unsettling thoughts. At the very least, we feel in such a place a pang of sympathy for those — especially those who died young or in pain — who are in so unseemly a way thus memorialized. Cannibals in northwestern New Guinea employ stacked skulls for doorposts, and sometimes for lintels. Perhaps these are the most convenient building materials available, but the architects cannot be entirely unaware of the terror that their constructions evoke in unsuspecting passers-by. Skulls have been used by Hitler's SS, Hell's Angels, shamans, pirates, and even those who label bottles of iodine, in a conscious effort to elicit terror. And it makes perfectly good sense. If I find myself in a room filled with skulls, it is likely that there is someone nearby, perhaps a pack of hyenas, perhaps some gaunt and dedicated decapitator, whose occupation or hobby it is to collect skulls. Such fellows are almost certainly to be avoided, or, if possible, killed. The prickle of the hairs on the back of my neck, the increased heartbeat and pulse rate, that strange, clammy feeling are designed by evolution to make me fight or flee. Those who avoid decapitation leave more offspring. Experiencing such fears bestows an evolutionary advantage. Finding yourself in a room full of brains is still more horrifying, as if some unspeakable moral monster, armed with ghastly blades and scooping tools, were shuffling and drooling somewhere in the attics of the Musée de l'Homme.

But all depends, I think, on the purpose of the collection. If its objective is to find out, if it has acquired human parts *post mortem* — especially with the prior consent of those to whom the parts once belonged — then little harm has been done, and perhaps in the long run some significant human good. But I am not sure the scientists are entirely free of the motives of those New Guinea cannibals; are they not at least saying, 'I live with these heads every day. They

don't bother me. Why should *you* be so squeamish?'

LEONARDO AND VESALIUS were reduced to bribery and stealth in order to perform the first systematic dissections of human beings in Europe, although there had been a flourishing and competent school of anatomy in ancient Greece. The first person to locate, on the basis of neuroanatomy, human intelligence in the head was Herophilus of Chalcedon, who flourished around 300 B.C. He was also the first to distinguish the motor from the sensory nerves, and performed the most thorough study of brain anatomy attempted until the Renaissance. Undoubtedly there were those who objected to his gruesome experimental predilections. There is a lurking fear, made explicit in the Faust legend, that some things are not 'meant' to be known, that some inquiries are too dangerous for human beings to make. And in our own age, the development of nuclear weapons may, if we are unlucky or unwise, turn out to be a case of precisely this sort. But in the case of experiments on the brain, our fears are less intellectual. They run deeper into our evolutionary past. They call up images of the wild boars and highwaymen who would terrorize travellers and rural populations in ancient Greece, by Procrustean mutilation or other savagery, until some hero — Theseus or Hercules — would effortlessly dispatch them. These fears have served an adaptive and useful function in the past. But I believe they are mostly emotional baggage in the present. I was interested, as a scientist who has written about the brain, to find such revulsions hiding in me, to be revealed for my inspection in Broca's collection. These fears are worth fighting.

All inquiries carry with them some element of risk. There is no guarantee that the universe will conform to our predispositions. But I do not see how we can deal with the universe — both the outside and the inside universe — without studying it. The best way to avoid abuses is for the populace in general to be scientifically literate, to understand the implications of such investigations. In exchange for freedom of inquiry, scientists are obliged to explain their work. If science is considered a closed priesthood, too difficult and arcane for the average person to understand, the dangers of abuse are greater. But if science is a topic of general interest and concern — if both its delights and its social consequences are discussed regularly and competently in the schools, the press, and at the dinner table — we have greatly improved our prospects for learning how the world really is and for improving both it and us. That is an idea, I sometimes fancy, that may be sitting there still, sluggish with formalin, in Broca's brain.