NANJING UNIVERSITY OF SCIENCE AND TECHNOLOGY.

2022.12.03.

Language, Cognition, and Neuroscience

BRAIN + *LANGUAGE* = MIND

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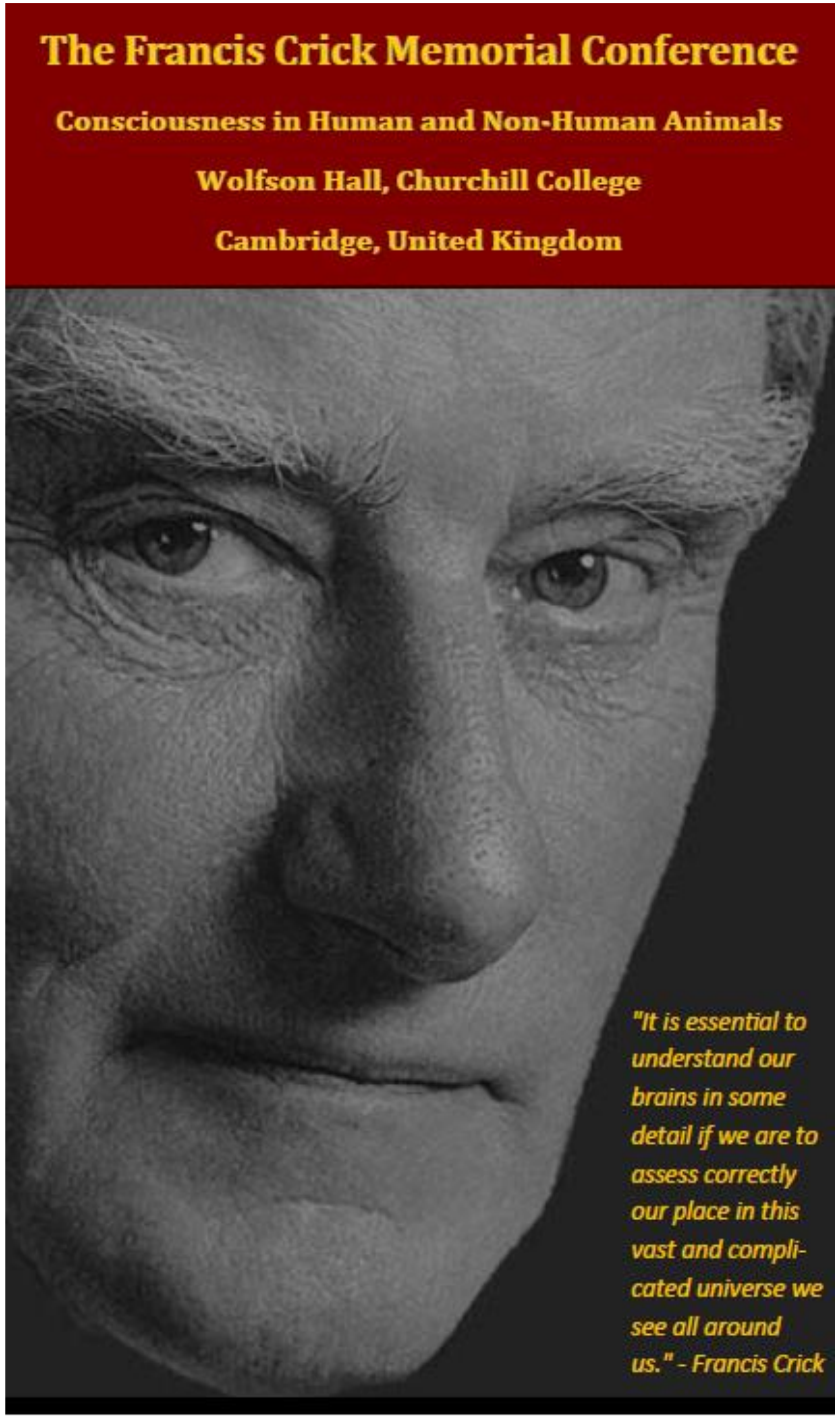
The concepts ***brain***, ***language***, ***mind***, listed in my title, are traditionally studied in the disciplines of neuroscience, linguistics & psychology; they are obviously related to each other in intricate & subtle ways. With the progress in multidisciplinary research in the life sciences made over the past century, including the advent of brain imaging, these concepts are merging into a single coherent area of scientific inquiry, which includes many other complex concepts as well, such as ***consciousness***, ***cognition***, ***memory***, ***intelligence*** & ***affect***. My effort today will be to examine the relationships among some of these concepts in human behavior, centering on language and language disorders, from an ***evolutionary*** perspective.

Life began on Earth some 3 billion years ago, in the form of simple cells with no nucleus. As biological evolution proceeded, some of these cells eventually acquired a **nucleus**, and joined together to form ever more complex **multicellular** organisms. Over this long time span countless species have emerged, especially around half a billion years ago around the Cambrian period when most of Earth's major phyla appeared. As cells differentiated in their structures and functions, it was also around this period that the first **nervous systems** can be detected in the fossils.



We declare the following: *"The absence of a neocortex does not appear to preclude an organism from experiencing affective states. Convergent evidence indicates that non-human animals have the neuroanatomical, neurochemical, and neurophysiological substrates of conscious states along with the capacity to exhibit intentional behaviors. Consequently, the weight of evidence indicates that humans are not unique in possessing the neurological substrates that generate consciousness. Nonhuman animals, including all mammals and birds, and many other creatures, including octopuses, also possess these neurological substrates."*

Cambridge Declaration on Consciousness: July 7, 2012:

We trace our ancestry to the class of mammals, so named because of the way neonates are nursed. Closer in time, we belong to the order of **primates** 灵长目, which emerged some 70 mya, distinguished by our stereoscopic vision, dexterous hands, among many other traits. Among the hundreds of species of primates, our closest living relatives are the chimpanzees, of which there are 2 species. Our lineage separated from theirs some 6 mya.

What makes us unique is our super powerful brain, that enabled us to move out of Africa in many successive waves, and colonized the entire planet. The history of these movements is still being written as new fossils are discovered. A recent example is the well preserved skull being analyzed in Yunyang 郧阳, China, of ***Homo erectus*** 直立人 a million years old.

Lewis, Dyani.

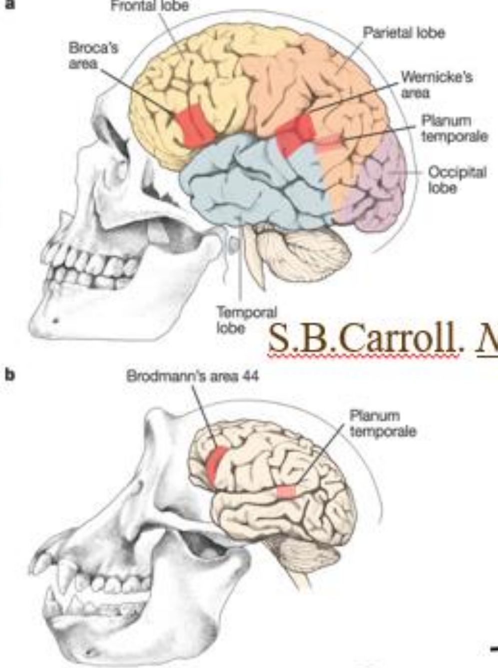
Nature, Nov 29. 2022

Ancient skull uncovered in China could be million-year-old *Homo erectus*.

湖北，郧阳区

doi: 10.1038/d41586-022-04142-0.

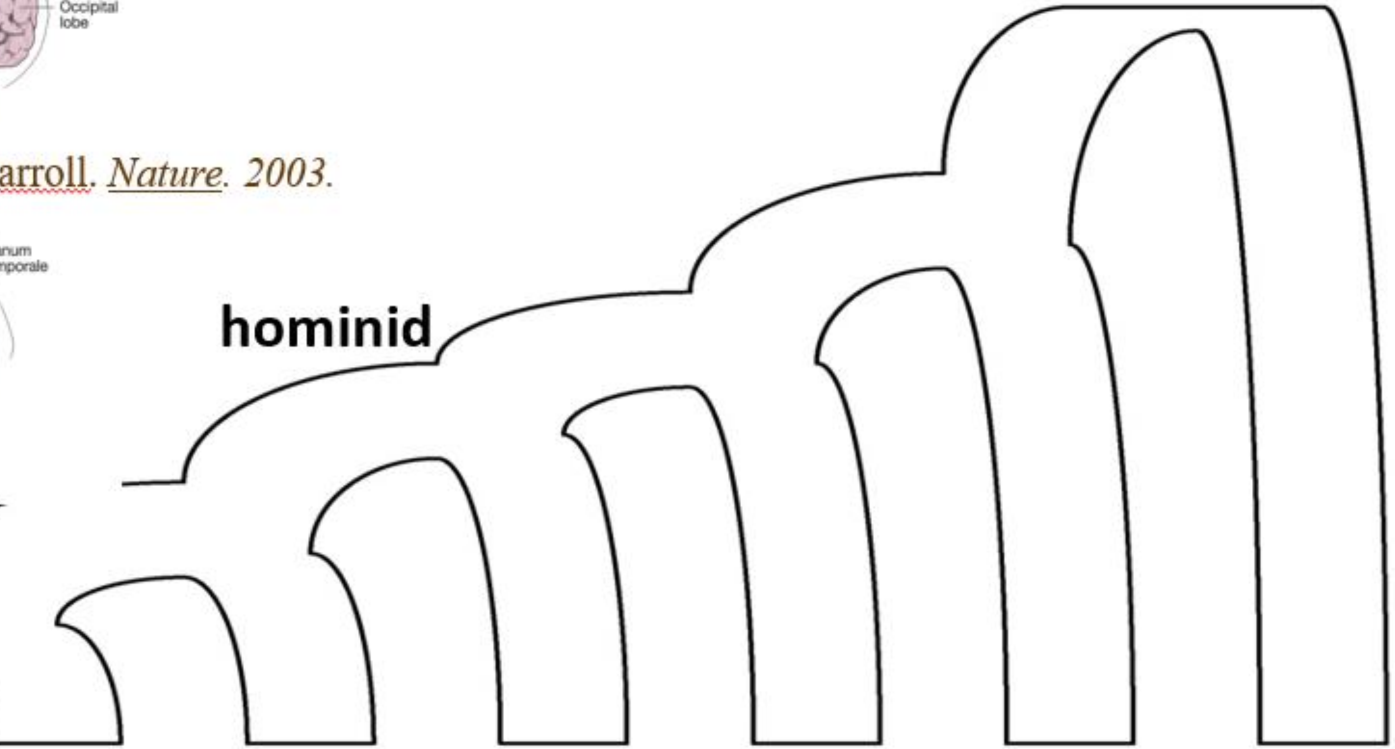
Genetic basis of human brain evolution. 2008. Vallender, Eric, et al. *Trends in Neuroscience*.



S.B.Carroll. *Nature. 2003.*

hominin

南方古猿 Australopithecus
巧人 Homo habilis
直立人 Homo erectus
智人 Homo sapiens

	Human	Chimpanzee 黑猩猩	Gorilla 大猩猩	Orangutan 红毛猩猩	Gibbon 長臂猿	Old World monkeys	New World monkeys
Millions of years since last common ancestor with human	---	5–7	7–9	~14	~18	~25	35–40
Genetic difference from human	---	~1.2%	~1.6%	~3.1%	~4.0%	~6.5%	~11.5%
Brain volume in cm^3	1129–1685	230–415	400–565	300–400	70–152	33–205	4–123

TRENDS in Neurosciences

Azevedo, F. et al. 2009. Equal numbers of neuronal and nonneuronal cells make the human brain an isometrically scaled-up primate brain. <u>*Journal of Comparative Neurology*</u> 513.532-41.

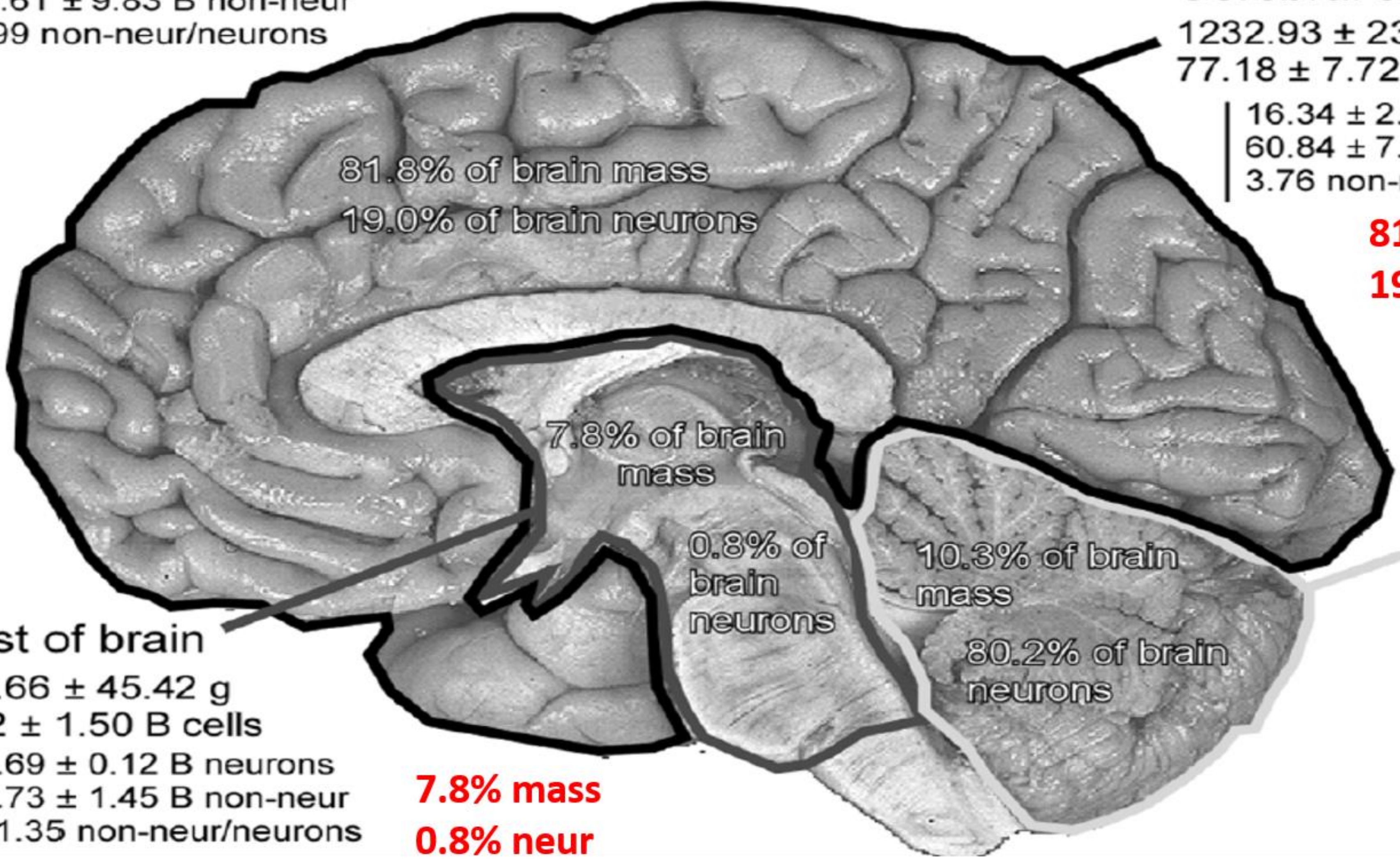
Whole brain
1508.91 ± 299.14 g
170.68 ± 13.86 B cells

- 86.06 ± 8.12 B neurons
- 84.61 ± 9.83 B non-neur
- 0.99 non-neur/neurons

Cerebral cortex (GM+WM)
1232.93 ± 233.68 g
77.18 ± 7.72 B cells

- 16.34 ± 2.17 B neurons
- 60.84 ± 7.02 B non-neur
- 3.76 non-neur/neurons

81.8% mass
19.0% neur



Cerebellum
154.02 ± 19.29 g
85.08 ± 6.92 B cells

- 69.03 ± 6.65 B neurons
- 16.04 ± 2.17 B non-neur
- 0.23 non-neur/neurons

10.3% mass; 80.2% neur

Rest of brain
117.66 ± 45.42 g
8.42 ± 1.50 B cells

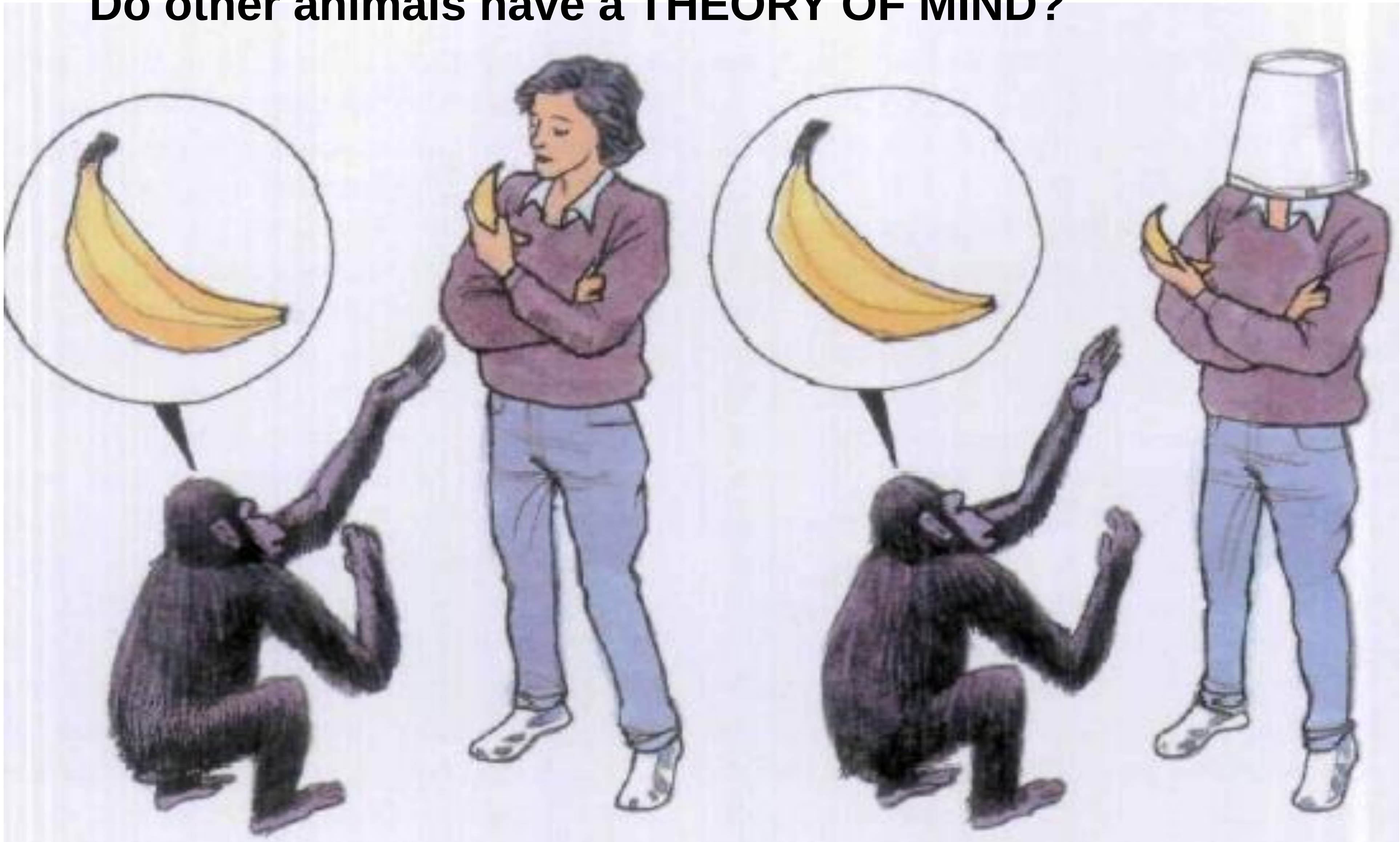
- 0.69 ± 0.12 B neurons
- 7.73 ± 1.45 B non-neur
- 11.35 non-neur/neurons

7.8% mass
0.8% neur

Chimpanzees have been studied for over a century by field observation, laboratory experiments, and home raising. They demonstrate many impressive abilities, including self awareness in front of a mirror, cooperation to achieve shared goals such as group hunting, teaching skills to the young, medication of self and others with insects, etc.

They can be taught numerical skills in interacting with a computer, and even lexicons of several hundred words, together with rudimentary syntax. However, they have not achieved various skills associated with a **Theory of Mind**, which typically show up in children 5 or 6 years old.

Corballis, M.C. 2007. *American Scientist* 95.240-48.
The Uniqueness of Human Recursive Thinking.
Do other animals have a THEORY OF MIND?



Following the Cambridge Declaration, many animals with large brains have minds, such as the chimpanzee; nonetheless, it is also clear that the human mind is unique. The major landmarks that separated us from other animals are:

[1] erect posture and freeing the hands for creative activities,
[2] making of tools, thus launching cultural evolution,
[3] mastering symbolization, leading to the invention of language.

These developments brought about **cultural evolution**, enabling humans to modify the environment at a much faster pace than biological evolution alone, which is limited to genetic transmission.

Language emerged as a **mosaic** to interface many basic skills, including the formation of various types of memories to store and retrieve experiences, the sequencing and grouping of thoughts to predict future or imaginary events, the development of sensory and motor skills for processing information within one's own mind as well as exchanging information with others. Various aspects of language were invented at different ancestral sites at different times over a million years or more, e.g., **polygenesis**.

Wang, W. S.-Y. (1982). Explorations in Language Evolution. Hyderabad, India, Osmania University Press.
Freedman, D. A. and W. S.-Y. Wang (1996). "Language polygenesis: a probabilistic model." Anthropological Science **104.2: 131-138.**
Chinese translation: 2000. 石鋒譯. 語言的多源性: 一個概率論模型.

There were innumerable episodes of populations coming into contact, mixing their languages whenever the contacts were intense or long lasting. Modern languages are the products of these long term developments of hybridization, though very early influences can no longer be detected. Family tree diagrams are of limited utility in these respects.

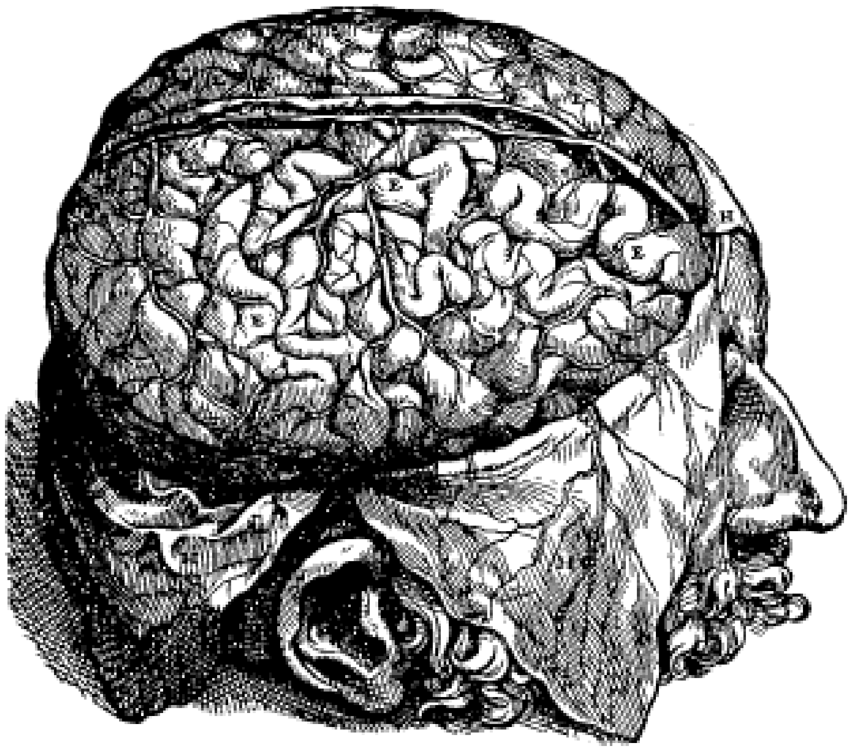
Ontogenetically, languages are acquired together with many other aspects of the ambient culture as the brain grows from a few cells in the fetus to the billions of neurons in the adult. The brain has different sensitive periods in acquiring different aspects of language, determined by the biological requirements of the task.

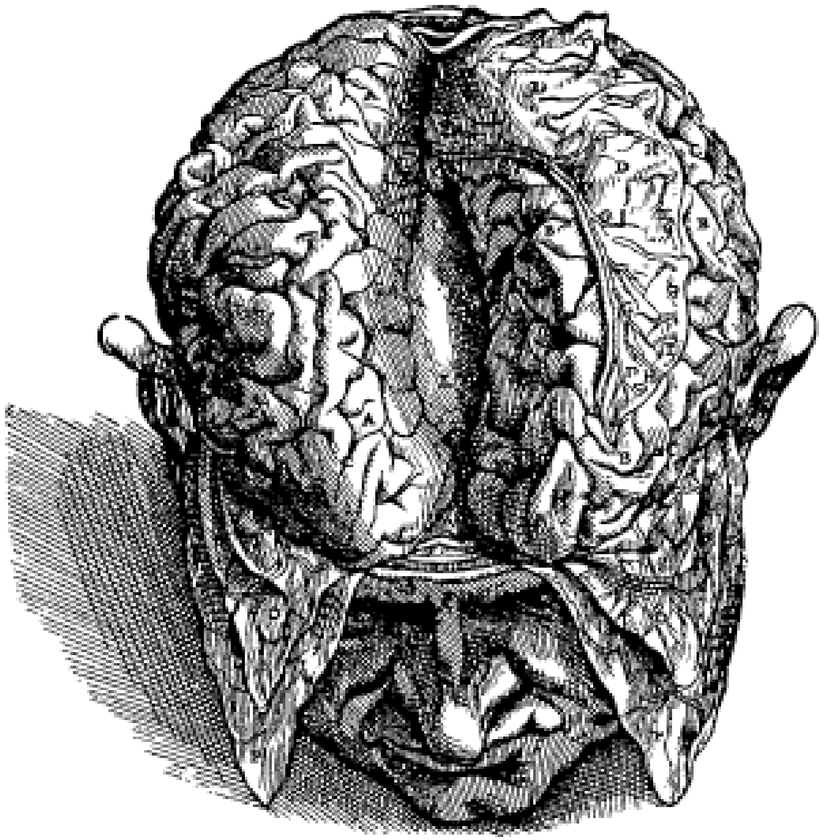
1543 was a very special year in science. Copernicus has just published his monumental volume suggesting that the sun is at the center of our galaxy. It was the beginning of Astronomy, ushering in modern science.

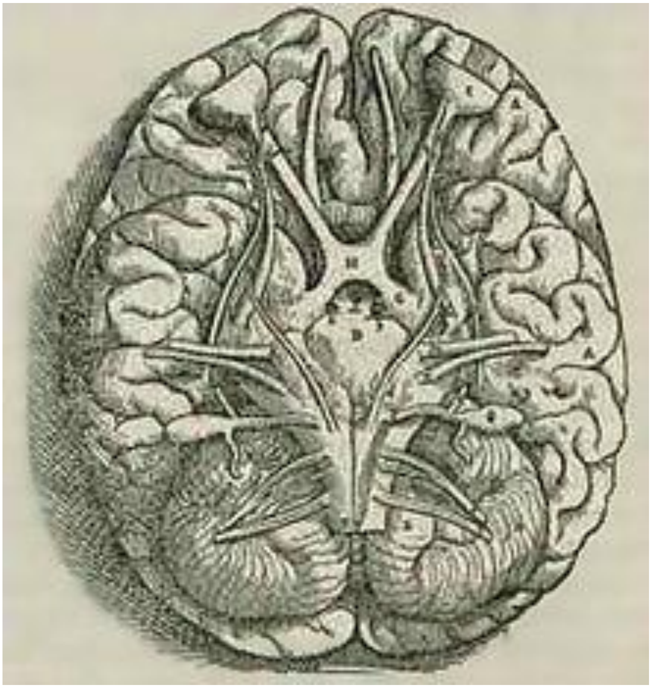
In the same year, Vesalius published his remarkably precise drawings of the human brain, a work of lasting value that is still used in medical schools today. It was the beginning of Neuroscience, or at least of Neuroanatomy.

‘This is from perhaps the most important book in the history of medicine, the "***Fabric of the Human Body***", published in 1543 by Andreas Vesalius.’

Fundamental Neuroscience, 2 ed. 2003:40.







Connecting the brain to language, however, had to wait some 300 years, and began with **Broca**'s famous article of 1861 on two patients who lost their ability to speak, but understanding speech remained intact. Upon autopsy, he identified a region on the left frontal lobe responsible for this loss that came to be known as Broca's Area. This pioneering work was quickly followed by other pioneers of neurolinguistics, notably **Wernicke** for speech comprehension, and **Dejerine** for written language.

These achievements of the early pioneers were brought together with later research into a masterful synthesis in the writings of Geschwind. The synthetic model that **Geschwind** put together has remained the **classic model** in neurolinguistics for many decades.

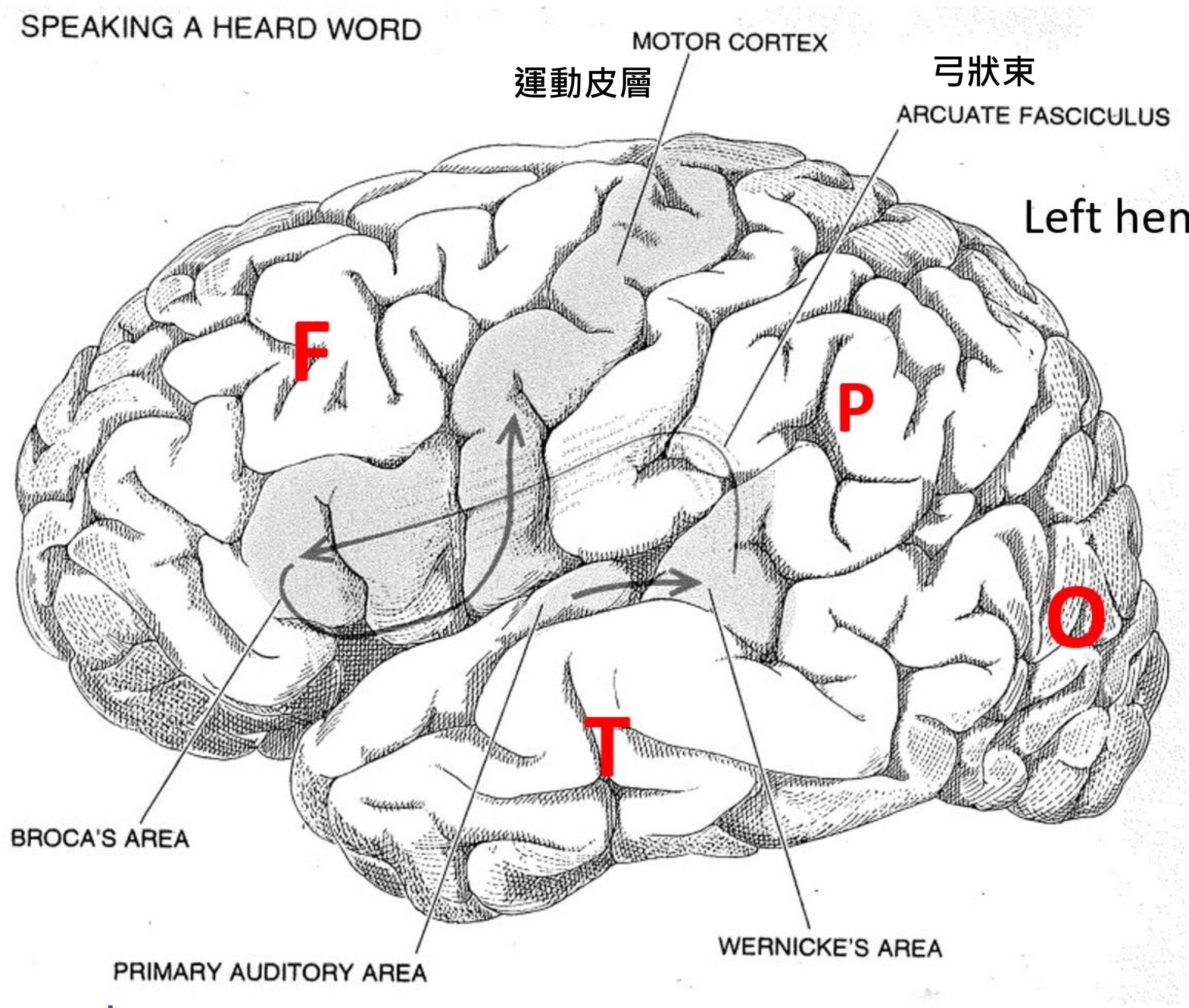
Three pioneers in studies of Language Disorders & Brain.

研究語言障礙的三位先驅。

Paul Pierre Broca
(1824-1880)

Carl Wernicke
(1848-1904)

Jules Dejerine
(1849-1917)



Reprinted in 王士元 2008.
語言湧現: 發展與演化.
中央研究院 語言學研究所.

Left hemisphere & its four lobes:

Frontal, 額葉
Parietal, 頂葉
Temporal, 顳葉
Occipital. 枕葉

Geschwind, Norman. 1979.

Specializations of the human brain.

Scientific American 241.158-68.

Broca was mindful of how little was known of the brain at his time, and with remarkable foresight, stored the two brains away for the future. That foresight paid off rich dividends when brain imaging became available.

Dronkers went back to those brains and analyzed them in great detail with the methods of Magnetic Resonance Imaging. Rather than the small localized region on the surface of the cortex that Broca identified, Dronkers found that the neural damage in both cases were much more extensive, going deeply into the interior of the brain. It is therefore grossly inaccurate to associate the language pathology with just that one region.

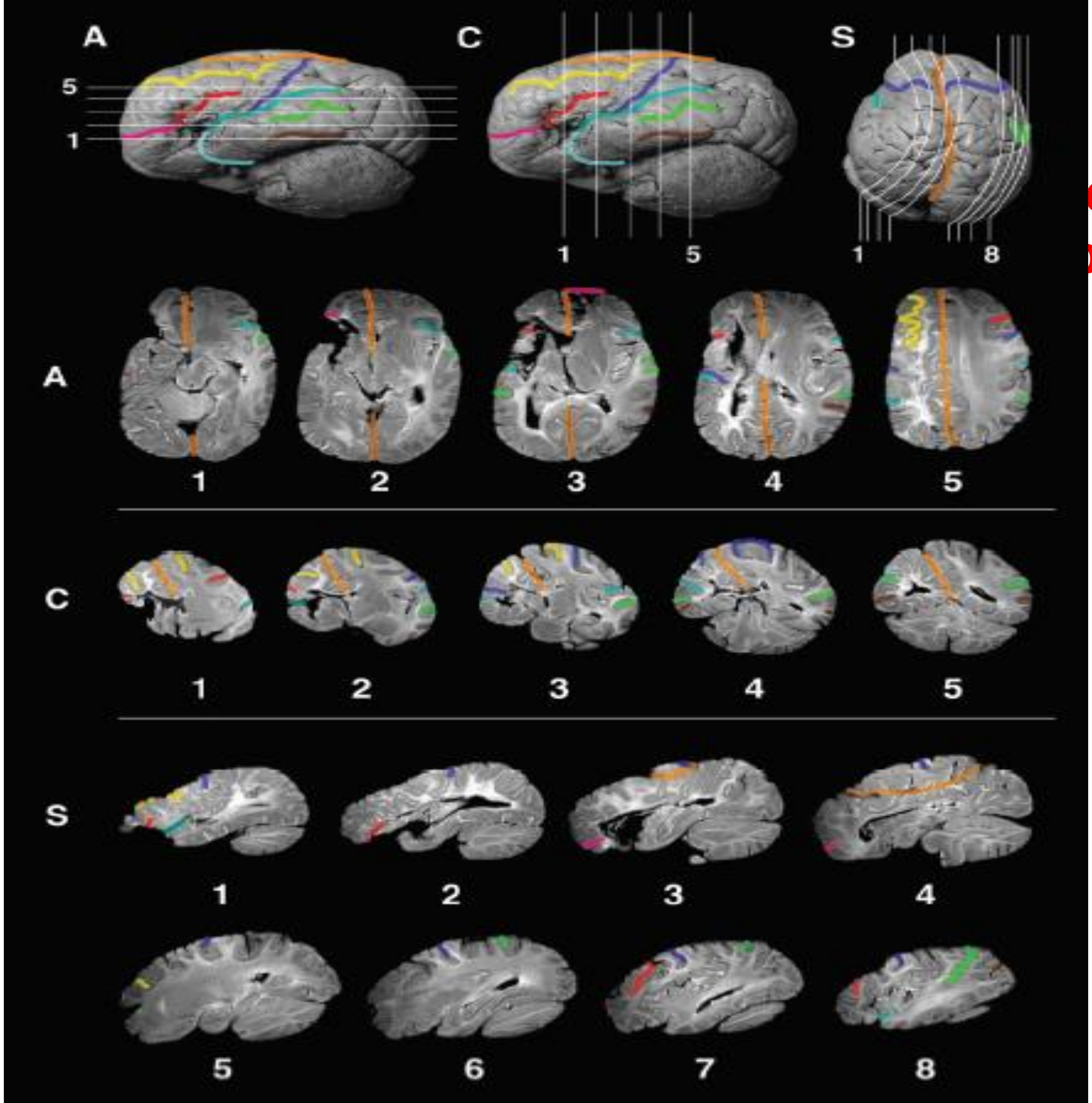
Dronkers, N. F., O. Plaisant, M. T. Iba-Zizen & E. A.Cabanis. 2007. Paul Broca's historic cases: high resolution MR imaging of the brains of Leborgne and Lelong. ***Brain*** **130.1432-41.**

A

B

Dronkers, N. et al. 2007.

Paul Broca’s historic cases: high esolution MR imaging of the rains of Leborgne & Lelong.



Brain **130.1432-41. Fig.4.**

“Sagittal, axial and coronal slices through the brain reveal lesions in the left inferior frontal gyrus, deep inferior parietal lobe and anterior superior temporal lobe. In addition, there is extensive subcortical involvement including the claustrum, putamen, globus pallidus, head of the caudate nucleus and internal and external capsules. The insula is completely destroyed. The entire length of the superior longitudinal fasciculus is also obliterated, along with other frontal-parietal periventricular white matter. The medial subcallosal fasciculus is also affected.” p.1436

Findings such as those by Dronkers have moved the field much past the classic model presented by Geschwind. This is announced aggressively in the title of a paper published in 2016 in Brain & Language, which is "***Broca and Wernicke are dead***, *or moving past the classic model of language neurobiology*." Indeed, with an abundance of new data, methods, and technology to help, the neurobiology of language has been making progress in great strides.

Tremblay, P. and A. S. Dick (2016). "Broca and Wernicke are dead, or moving past the classic model of language neurobiology." Brain & Language **162: 60-71.**

Aphasias of various sorts are typically caused by some local trauma, whether introduced from outside, such as concussions, or internally generated, as with cerebral vascular accidents. Aside from these, there are forms of language disorders, usually accompanied by other syndromes, whose causes are much more elusive, that elderly people are especially at risk for. Most prominent among these disorders is Alzheimer's Disease, first reported by Alzheimer in 1911.

With the numerous advances in the medical sciences, from personal hygiene to public health, people are living longer across the world, with dramatic advances in longevity over the past century and half.

The increase of people over 65 has been dramatic, especially in China. To take some numbers from the Chinese National Bureau of Statistics, the total population of China in 2005 changed from 1,307 million in 2005 to 1,412 million in 2021, an increase of 8%.

Of this population, the people aged **65 or greater** increased from 101 million to 201 million, essentially **doubling in number over just 16 years**. This large change in demographic distribution poses immense challenges for society at every level.

香港 政府統計處 人口估計 2022 年 8 月 11 日

Age	All	0 – 14	15 – 59	≧60		60 - 64	≧65
# (%)	7292 K @ 2022	773 K (10.60%)	4376 K (60.02%)	2142 K (29.38%)		622.5 K (8.54%)	**1520 K (20.85%)**
10-yr Diff. (%)	7150 K @ 2012 **+1.98%**	**-0.77%**	**-8.91%**	**+9.69%**			

第七次 全國人口普查 國家統計局局長 甯吉喆 2021 年 5 月11 日

# (%)	1.41 B @ 2021	253 M (17.95%)	894 M (63.35%)	264 M (18.70%)		73 M (5.20%)	**191 M (13.50%)**
10-yr Diff. (%)	1.34 B @ 2011 **+5.22%**	**+1.35%**	**-6.79%**	**+5.44%**			

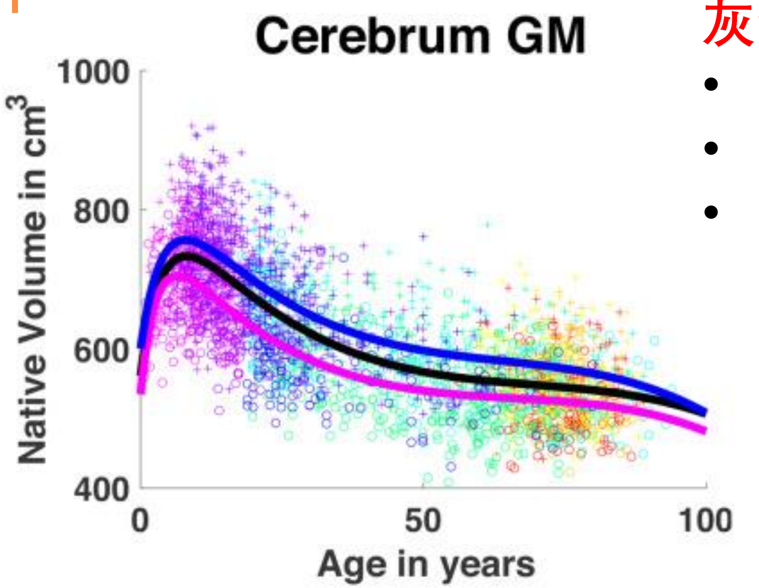
It is easy to see the process from the outside as people get old: loss of hair and teeth, wrinkled skin, reduced muscle mass, changed gait and postures. In audition, they have increasing difficulty in hearing the high frequencies or the rapid transitions of consonant sounds. The eyes require more time to focus and get tired easily. Overall, they slow down across the board: in eating, talking, thinking, and walking.

Less noticeable but much more insidious, many changes take place in the brain as well. As always, genetics plays a role in these changes in addition to the environment. The gene ***APOE-4*** has been long known to be a high risk factor for Alzheimer's Disease. Just two weeks ago, a paper published in *Nature* by Tsai's (蔡立慧) group at MIT zeroed in on its role in dysregulating **myelin** production in certain glia cells, reducing connectivity among neurons.

For the cerebrum in general, gray matter volume consisting of the bodies of neurons reduces as neurons die off; it decreases linearly with age, declining about 9 to 10% between the ages of 30 and 70, and about 11 to 12 % by age 80. In contrast, white matter volume consisting of axons and dendrites of the neurons, coated by sheaths of myelin increases until the mid-50s, after which it declines at an accelerated rate. **At 70, white matter volume was only 5–6 % less than at 30, but by 80 the decrease could be as much as 25 %.**

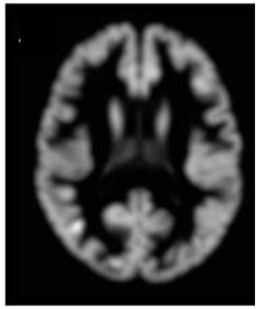
Allen, J.S., et al. 2005. Normal neuroanatomical variation due to age: The major lobes and a parcellation of the temporal region. Neurobiology of Aging 26: 1245–1260

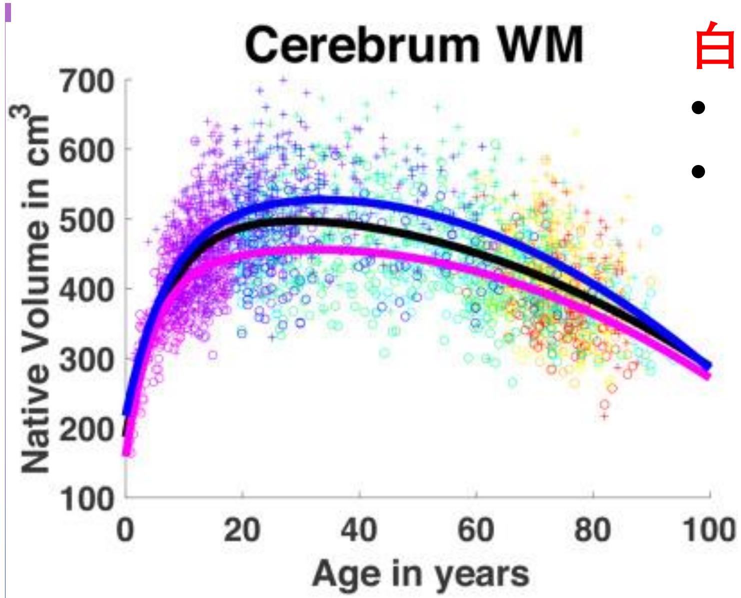
腦部及認知能力的變化. Brain and cognitive ageing.



灰質 Grey matter

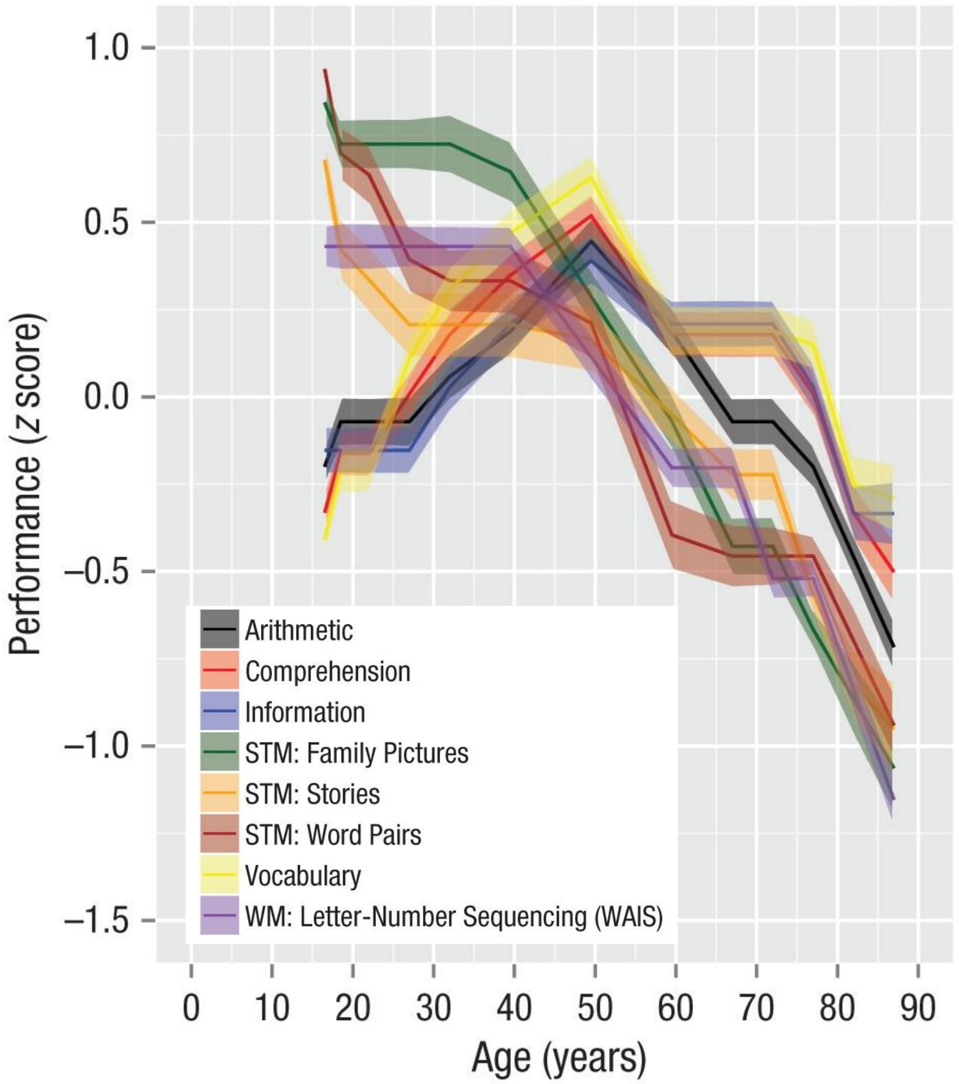
- 神經元的細胞體
- 於 11 歲左右到頂峰
- 突觸修剪 (synaptic pruning)





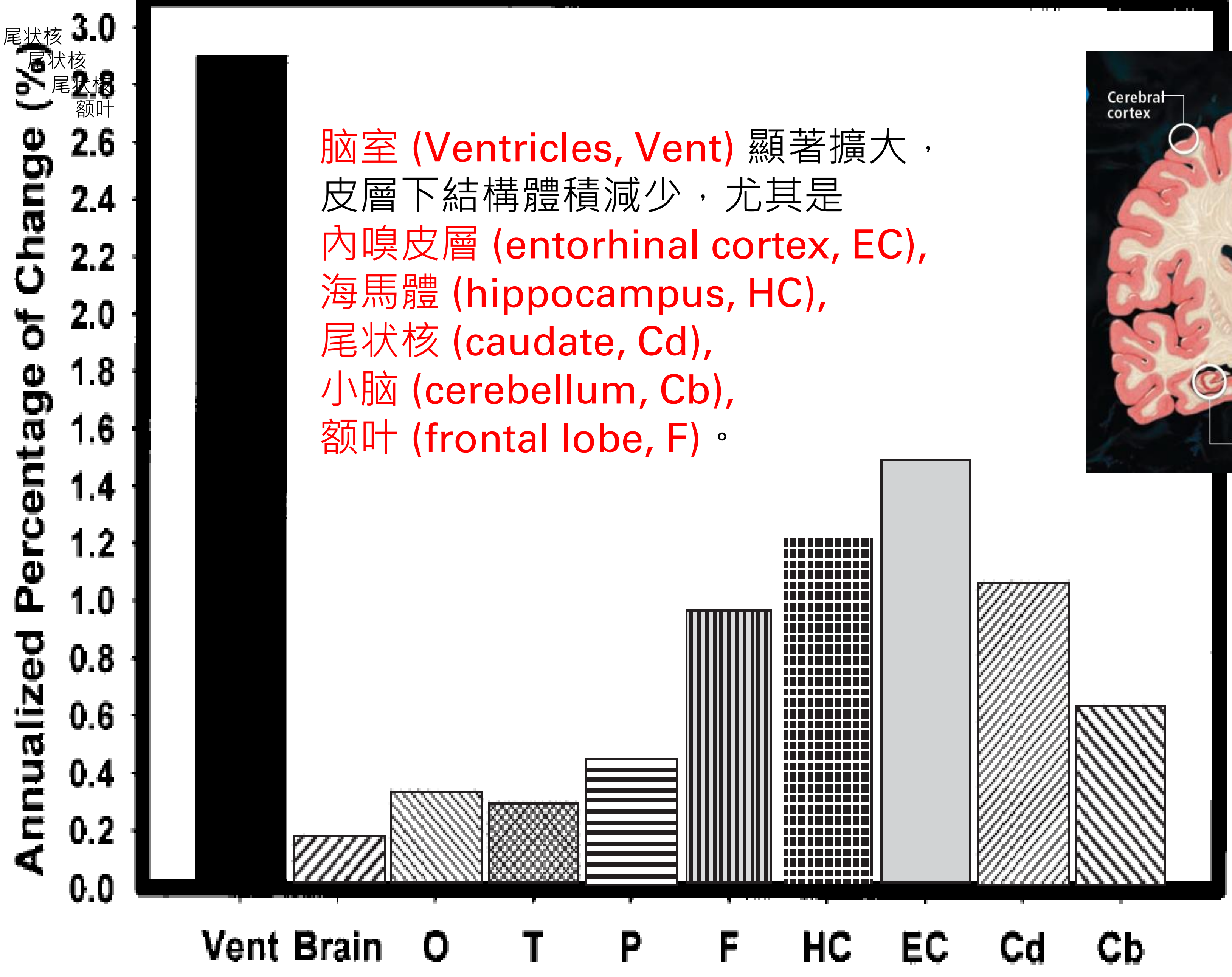
白質 White matter

- 神經元的神經纖維
- 於 30 歲左右才到頂峰

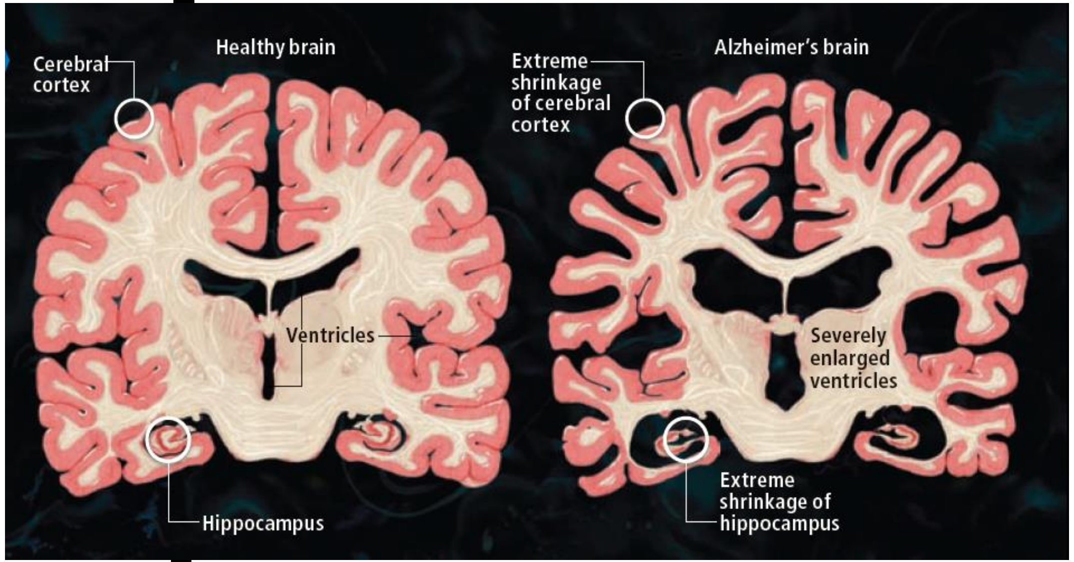


Hartshorne, J. K., & Germine, L. T. (2015). *Psychological science, 26*(4), 433-443.

Using brain imaging, Raz has reported some figures on regions of the brain as cognition declines. The volume of several subcortical structures reduce significantly, especially the entorhinal cortex and the hippocampus. The frontal lobe, the last lobe to mature fully in early adulthood is also the first to atrophy. As the volumes of these structures reduce, the space is taken up by expanding ventricles, often to several times their original sizes.



脑室 (Ventricles, Vent) 顯著擴大，皮層下結構體積減少，尤其是
內嗅皮層 (entorhinal cortex, EC),
海馬體 (hippocampus, HC),
尾狀核 (caudate, Cd),
小脑 (cerebellum, Cb),
額叶 (frontal lobe, F)。



Raz, N. 2005:41.
In Cabeza, R.et al. eds. *Cognitive Neuroscience of Aging: Linking Cognitive and Cerebral Aging*: Oxford University Press.

Stix, G. 2010. Alzheimer's: Forestalling the darkness. *Scientific American* 50-7.

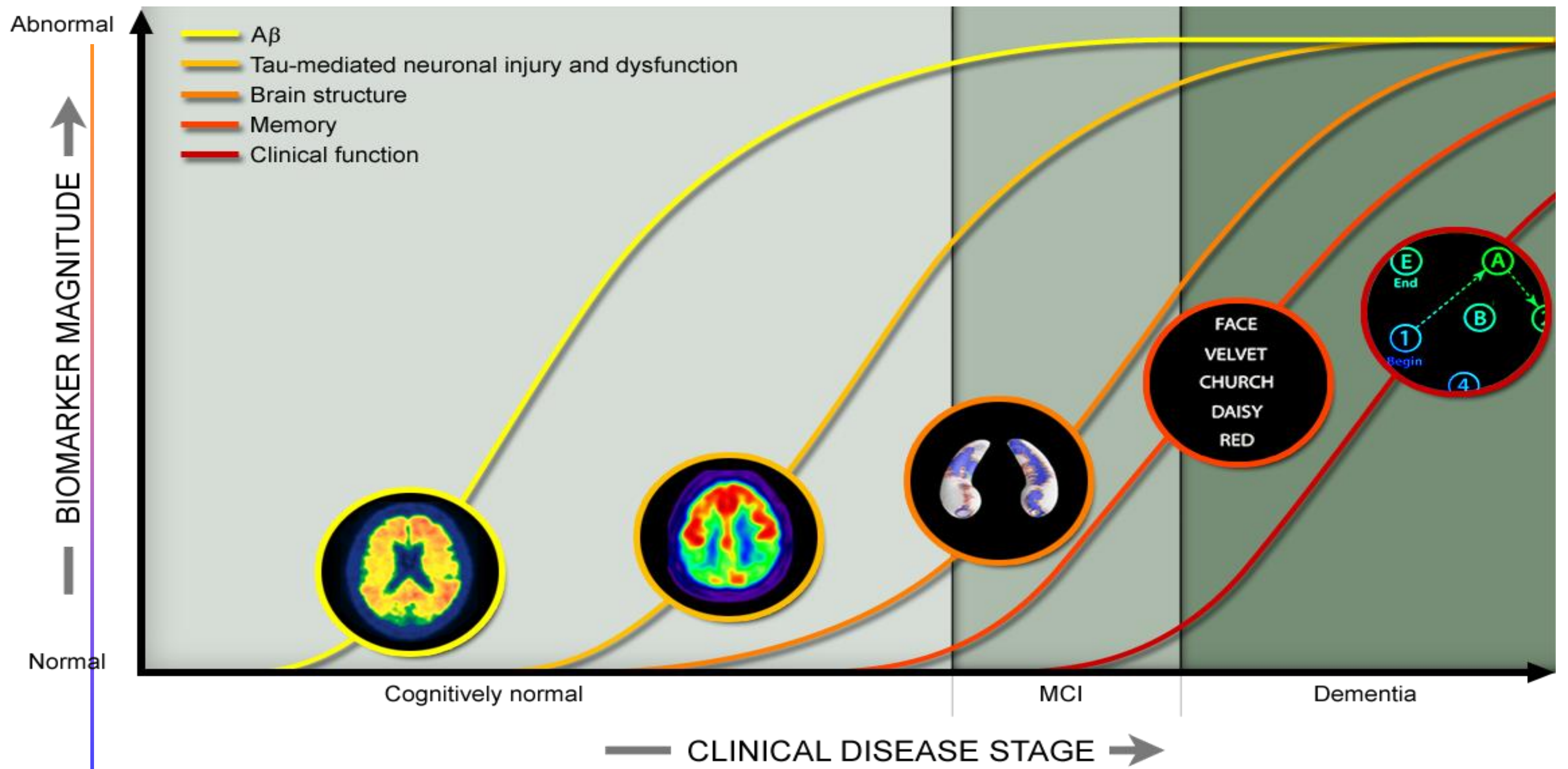
The brain orchestrates every aspect of our behavior, sensory, motoric, memorial, emotional, etc. The effects of these losses of its cells may be subtle as first, though detectable by means of various experiments. But when such losses in neurons are exacerbated by other factors, such as beta amyloid, tau, or dysfunctional mitochondria within or malignant glia cells in the environment, severe pathologies will surely follow.

Without a functioning brain, there is little mind left. Long lifespan must be accompanied by long health span.

In 2010, C.R.Jack et al proposed a hypothetical model of what they called the “Alzheimer’s pathological cascade”. Beta amyloid and tau may start invading the brain decades before the patient confirms the disorder, and get diagnosed clinically as Mild Cognitive Impairment, MCI.

By that time, the damage to his brain can be readily seen via brain imaging. His performance on the various cognitive tests, such as MMSE (Mini-Mental State Examination) or MoCA (Montreal Cognitive Assessment) gets increasingly poorer until severe dementia sets in, when he becomes completely incapable to take care of himself.

Unfortunately, at present there is no cure for Alzheimer’s Disease, only feeble methods to delay the tragic end.



http://adni.loni.usc.edu/studydesign/background-rationale/ Based on Jack, C.R., et al. (2010). Hypothetical model of dynamic biomarkers of the Alzheimer's pathological cascade. *Lancet Neurol. 9*(1), 119-128.

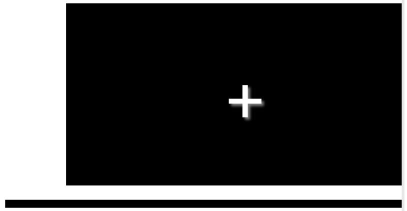
Given this long incubation time, the hope is that the disease can be detected as early as possible so that intervention can be planned. The critical issue here for us is whether the patient's **language and cognitive behavior** can give us some clues on the nature of disorder, in addition to the physician's biomarkers.

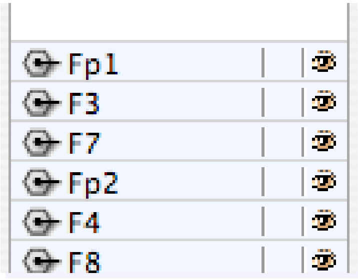
Over the past many decades, numerous studies have been made on children's language and aphasic speech. But the language and speech that accompany neurodegeneration has not been given much attention.

Furthermore, the relatively few studies that have been reported in this direction are almost exclusively done in a so-called **WEIRD** context, so their results may not be generalizable to Asian populations.

But the situation appears to be getting better. With the high visibility and high finance of the China Brain Project, 2016-2030, launched by the government, more and more teams have joined the effort to meet the challenges that large scale ageing has brought. This is no doubt due in part to the conviction that knowledge about the brain will not only help us cure neurodegenerative diseases one day, but will also provide a source of insights for computer sciences.

See the views of the neuroscientist **蒲慕明** on this dual perspective: *Poo, Muming, et al. (2016).* ***China Brain Project****: Basic Neuroscience, Brain Diseases, and Brain-Inspired Computing. Neuron 92(3): 591-596.*




Fp1
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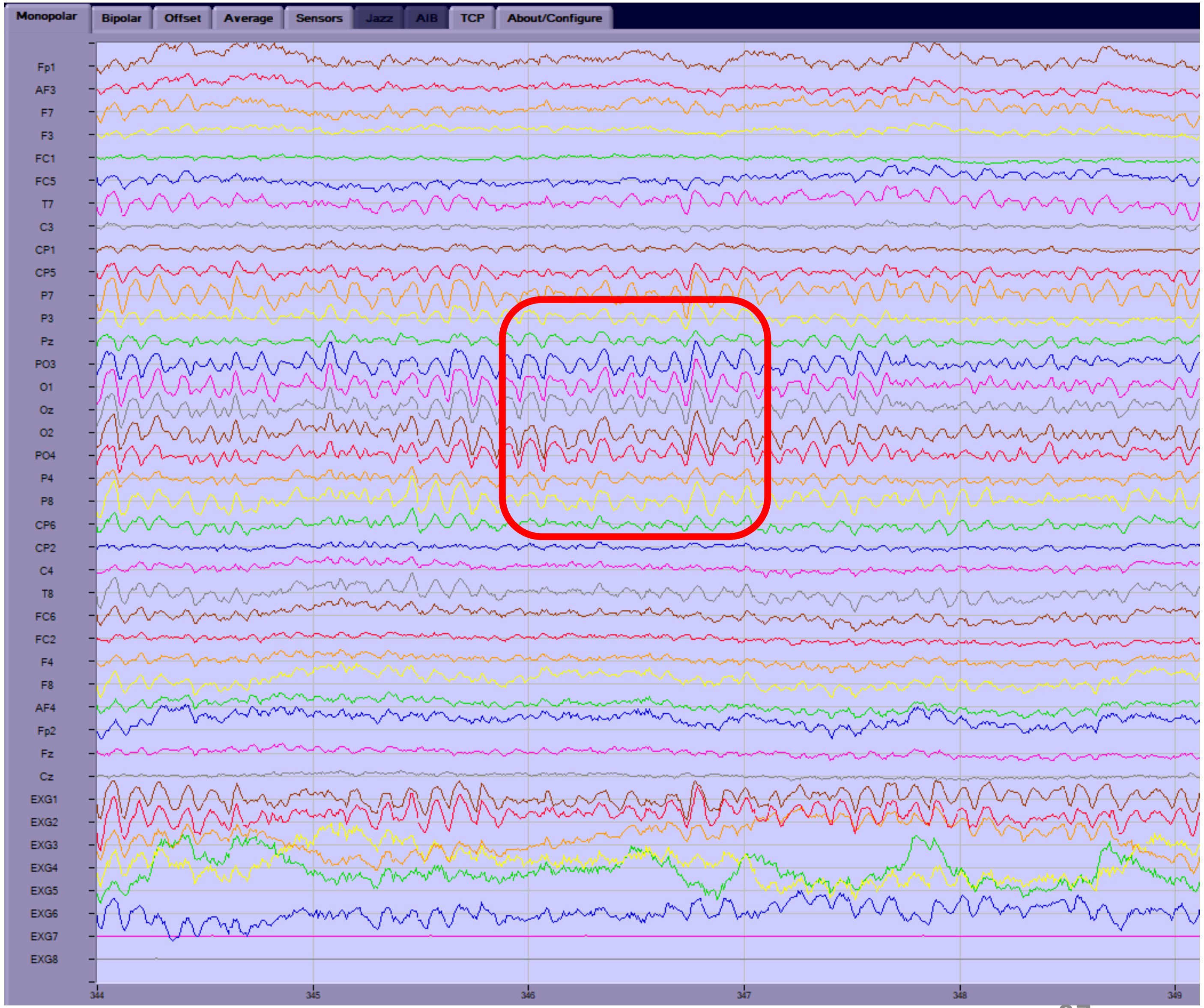
Electroencephalography 腦電圖

BioSemi 32 channel. 20160414 @ GH146 HKPolyU



T1 MP-RAGE

TE = 2.29 ms TR = 2000 ms

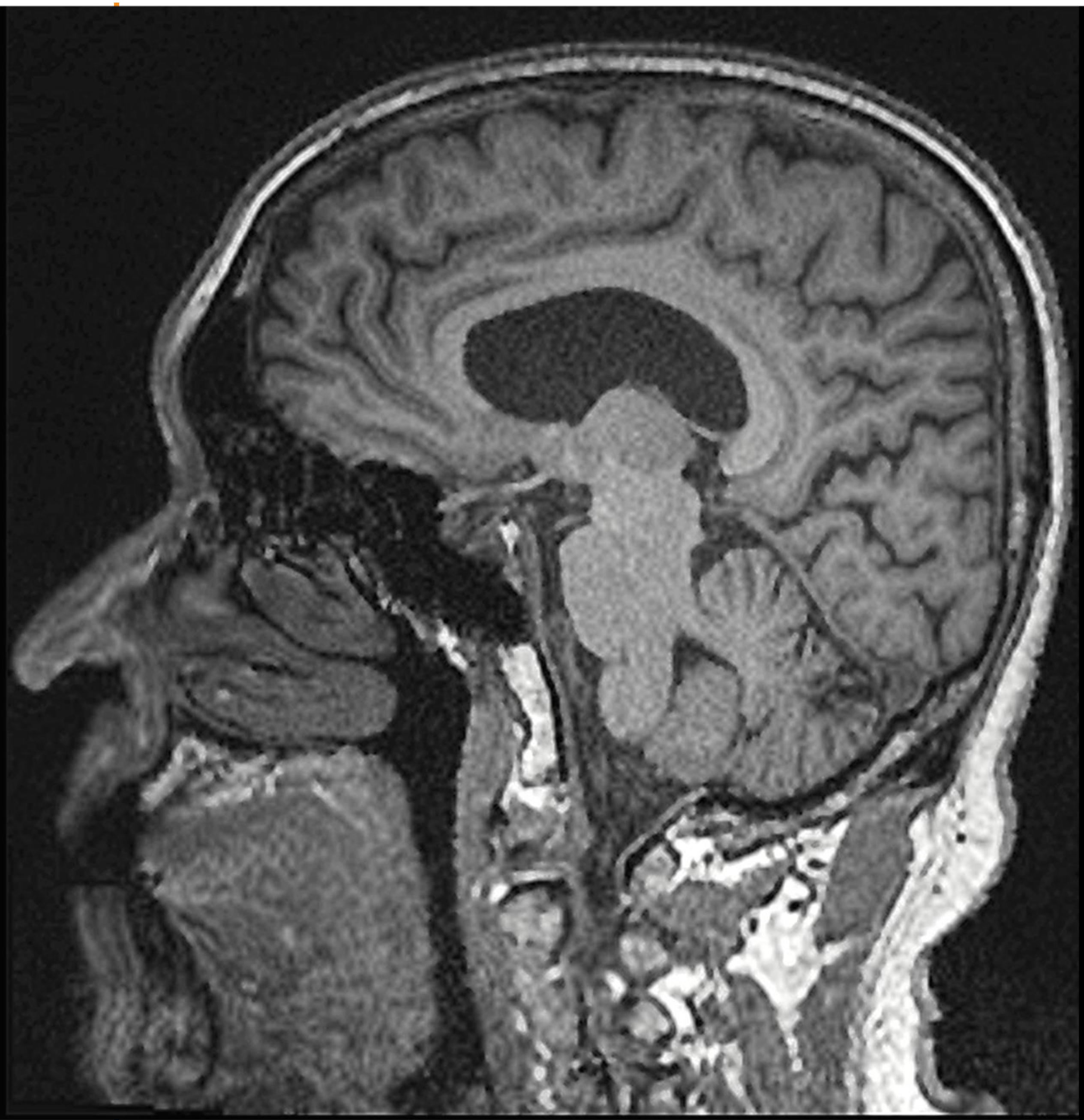
TI = 900 ms

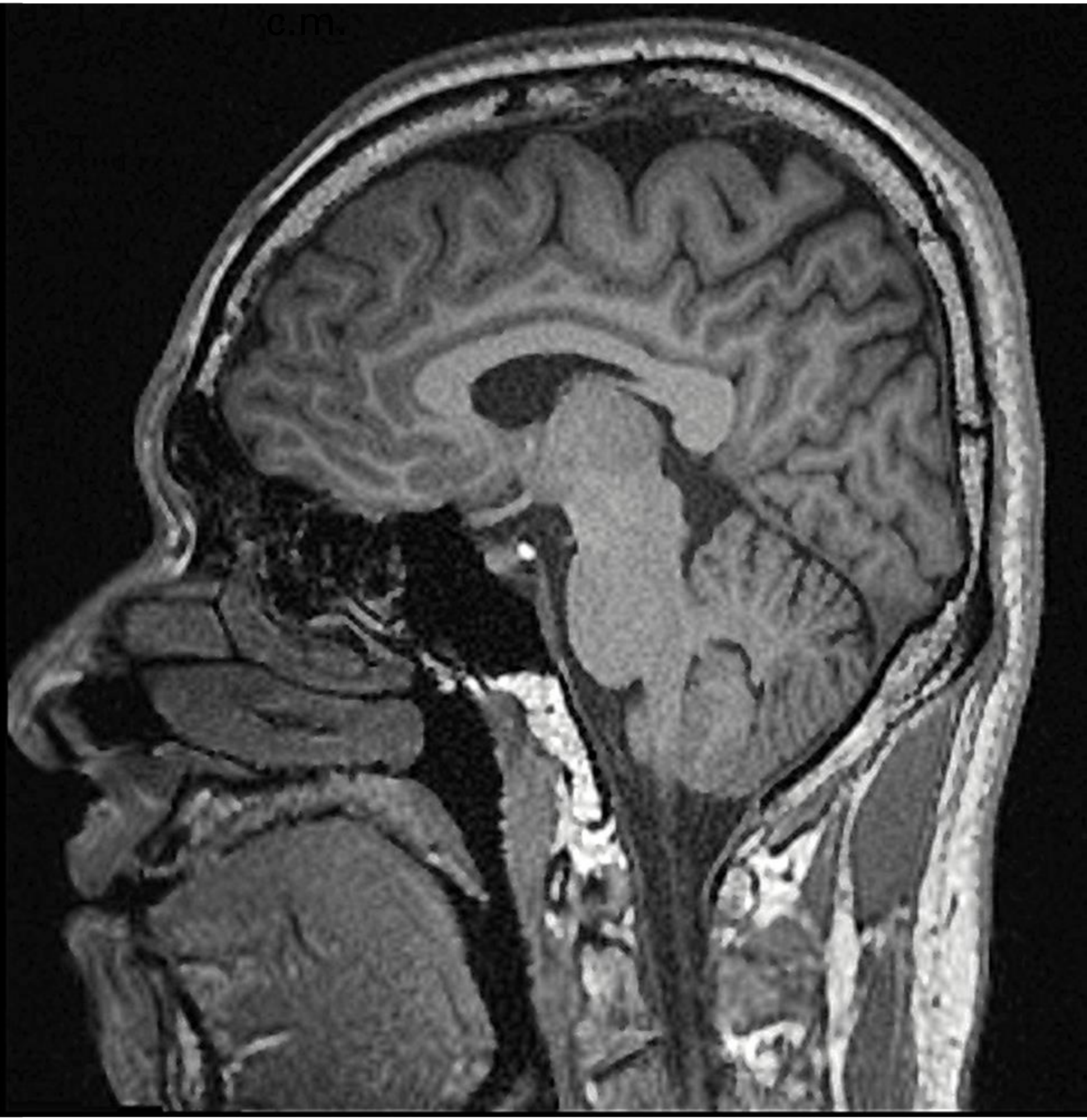
Video produced by Manson Fong, 2017.

Young

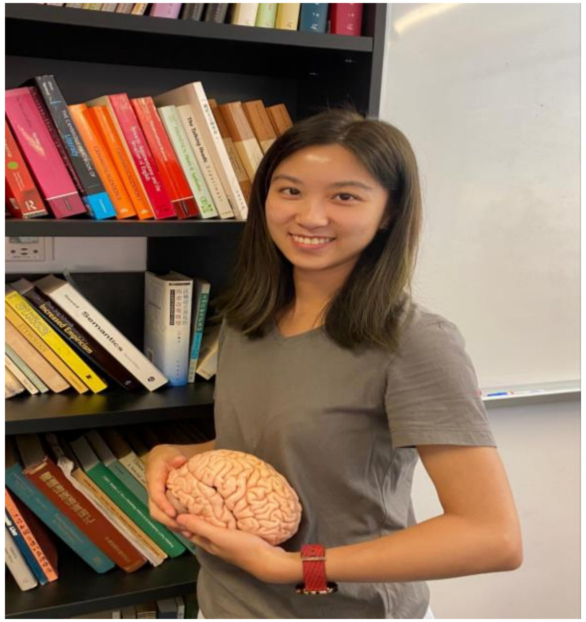
Old

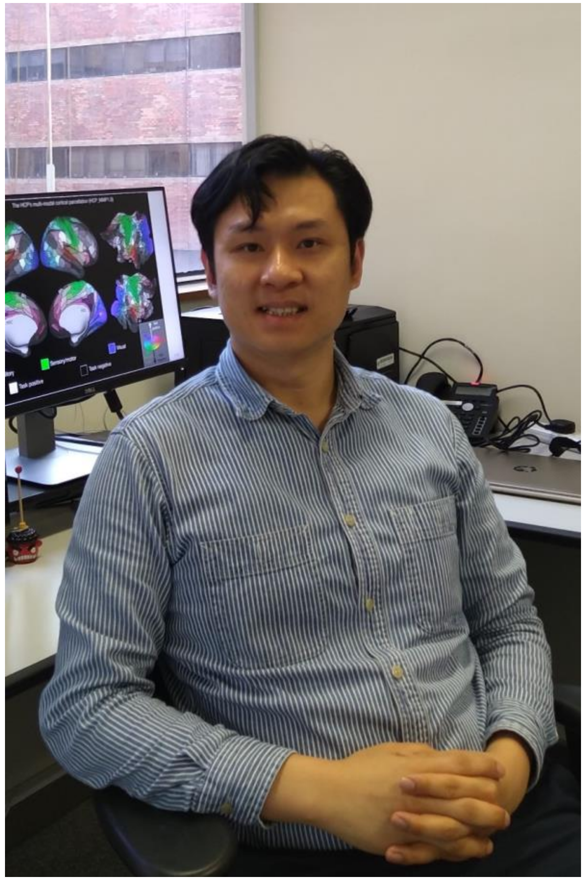
LEFT VENTRICLE: Frame number = 87 35,254 c.m. Frame number = 91 5,256 c.m.





Feng, Yun, et al. (2022). Electrophysiological evidence for aging effects on automatic semantic processing in semantic priming. *BrainConnects*, Aug. 8-15, Japan.



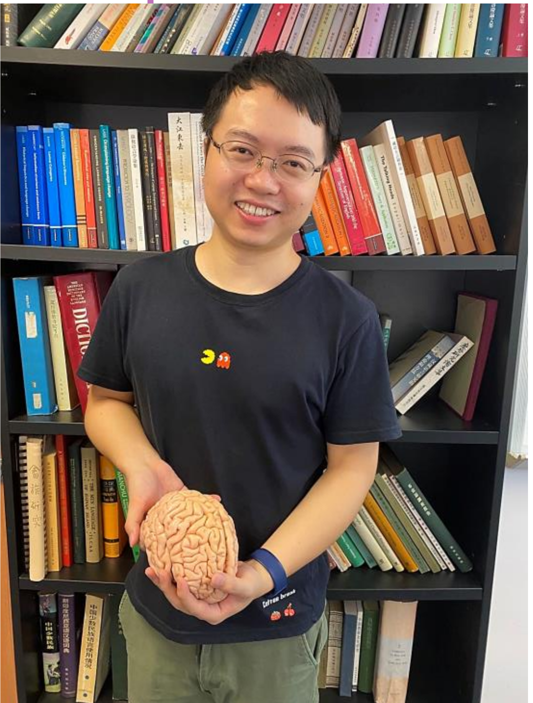


Fong, M. C.-M., et al. (2021). "Can inhibition deficit hypothesis account for age-related differences in semantic fluency? Converging evidence from Stroop color and word test and an ERP flanker task." *Brain and Language* 218: 104952.

Fong, M. C.-M., et al. (2022). "Foreign Language Learning in Older Adults: Anatomical and Cognitive Markers of Vocabulary Learning Success." *Frontiers in Human Neuroscience* 16.

Hui, N-Y., et al. (2022). Successful older language learners show changes in cognitive abilities towards the pattern of lifelong bilinguals, Bilingualism Matters Research Symposium, Edinburgh.

Ma, M. K.-H., et al. (2021). Regularity and randomness in ageing: Differences in resting-state EEG complexity measured by largest Lyapunov exponent. *Neuroimage: Reports*, *1*(4), 100054.



Xie, C. (2022). An experimental investigation into older adults of production /comprehension asymmetries and declarative/procedural memory contributions: a Chinese context. PhD dissertation. HK Polytechnic University.

Thank you !!

谢谢!!!

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