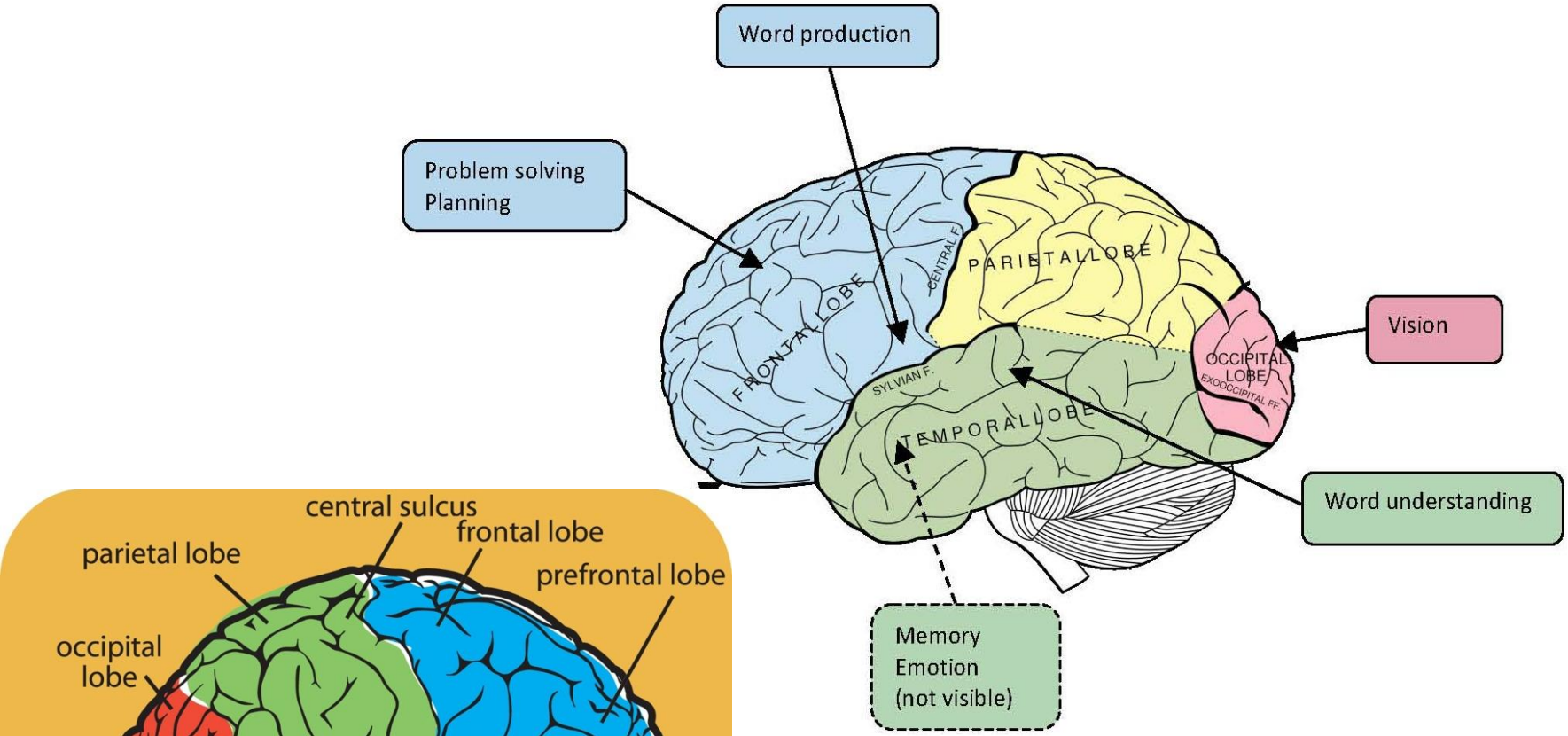
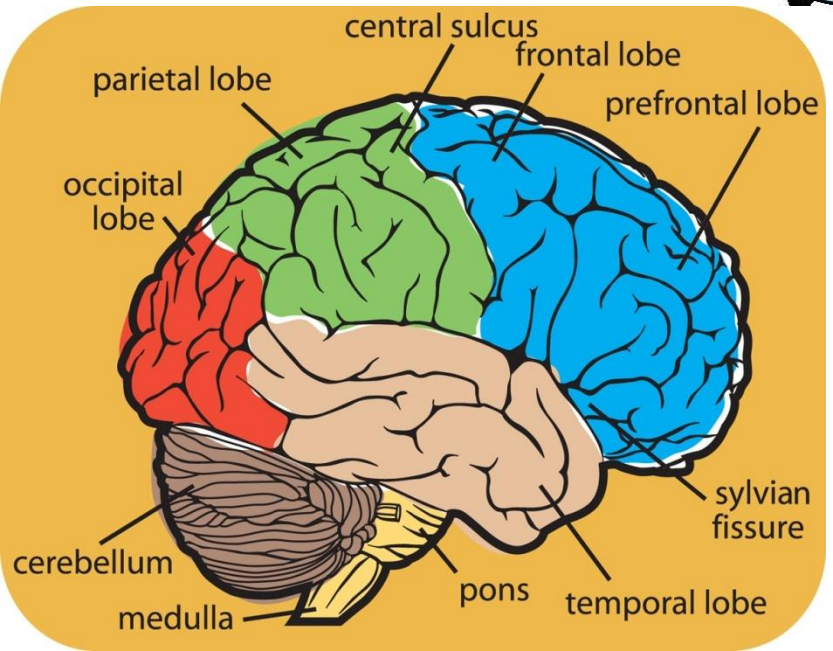
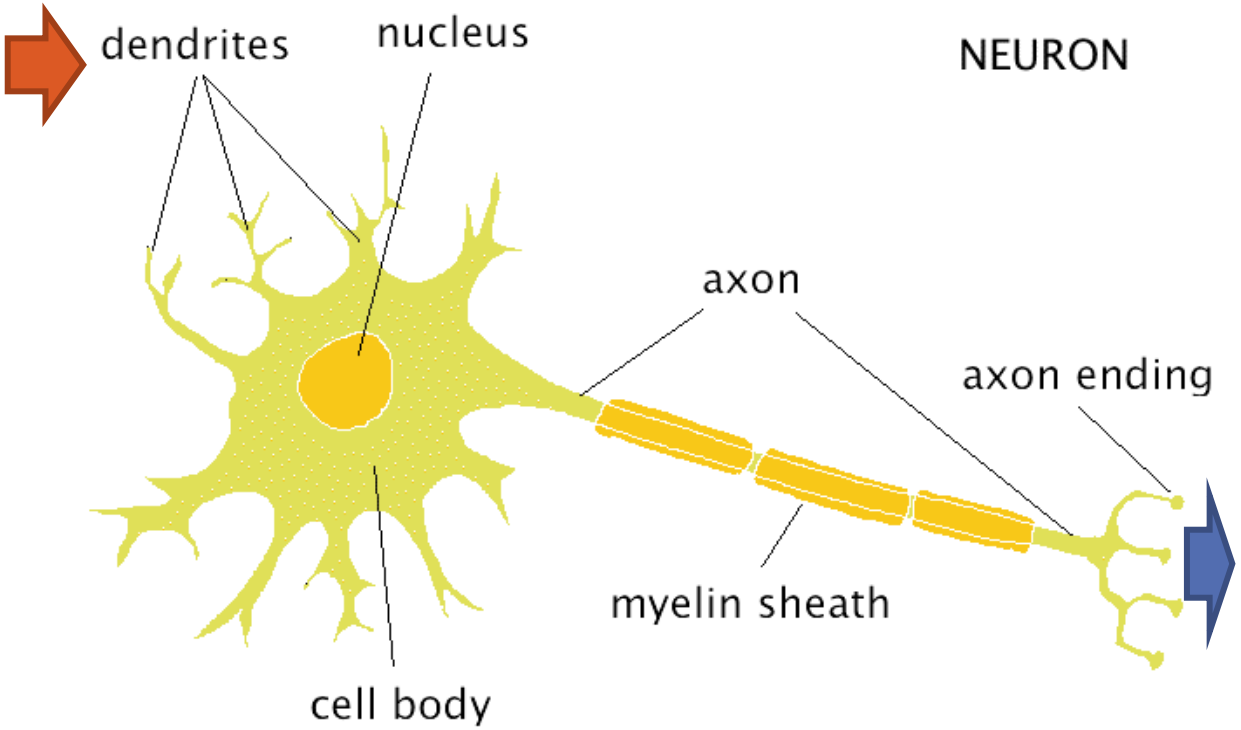
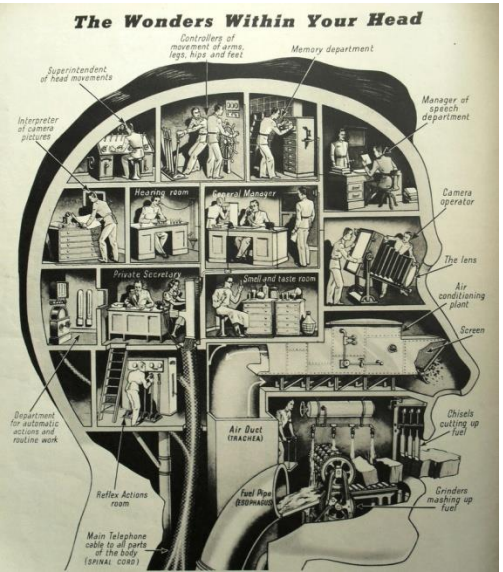

Word production
Problem solving
Planning
Vision
Word understanding
Memory
Emotion
(not visible)
FRONTAL LOBE
CENTRAL F.
PARIETAL LOBE
SYLVIAN F.
TEMPORAL LOBE
OCCIPITAL LOBE
EXOOCCIPITAL FF.


central sulcus
frontal lobe
parietal lobe
prefrontal lobe
occipital lobe
sylvian fissure
cerebellum
pons
temporal lobe
medulla

NEURON:



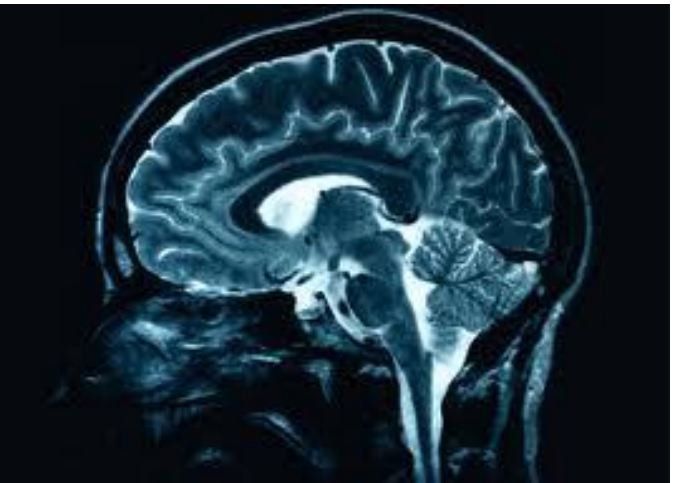


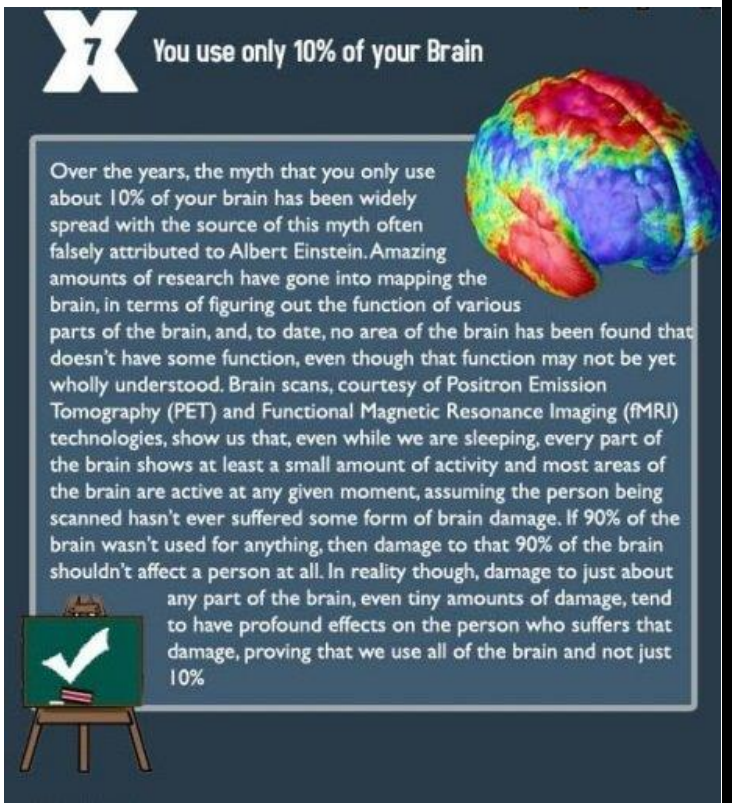
Glial cells are nerve cells that don't carry nerve impulses.
Include: Immune system, support, nutrients..

5 BRAIN MYTHS: #1 YOU ONLY USE 10 % OF YOUR BRAIN.

NO! Evidence

1. : fMRI. PET scans.
2. Effects of Damage.
3. Evolution.(Wasted space)





5 BRAIN MYTHS:

MYTH #2: BIGGER = BETTER BRAIN

The bigger = better relationship collapses, when comparing **species across orders .**

Humans	**1.5kg**
Elephants	5.6kg
Whales	7.8 kg

•Cows have larger brains than just about any species of monkey..

•Capybara & Capuchin monkey..

MYTH #3: HUMAN BRAINS ARE THE RELATIVELY LARGEST

1. Brain/body mass ratio
2. **Encephalization** quotient

Species	Name	Weight (kg)	Brain (grams)	EQ
Human	*Homo sapiens*	75.00	1400.00	6.56
Whale dolphin	*Lissodelphis borealis*	73.00	1162.00	5.55
Bottlenose dolphin	*Tursiops truncatus*	119.96	1535.00	5.26
Commerson's dolphin	*Cephalorhynchus commersonii*	43.00	732.00	4.97
Macaque	*Macaca nemestrina*	4.89	108.87	3.15
Baboon	*Papio hamadryas*	9.88	155.44	2.81
Chimpanzee	*Pan troglodytes*	45.00	398.60	2.63
Capuchin	*Cebus capucinus*	3.10	66.94	2.63
Gorilla	*Gorilla gorilla*	120.50	512.92	1.75
Coyote	*Canis latrans*	8.51	84.24	1.69
African gray parrot	*Psittacus erithacus*	0.33	5.70	1.00
Lion	*Felis leo*	142.82	240.60	0.73
Tiger	*Felis tigris*	184.50	263.50	0.68
Hippopotamus	*Hippopotamus amphibius*	1351.00	732.00	0.50
Blue whale	*Balaenoptera musculus*	58059.00	6800.00	0.38

MYTH #4: BIGGER BRAIN = MORE NEURONS THAN A SMALLER BRAIN

neuronal *density* = # neurons relative to mass of brain

MYTH #5: 100 BILLION NEURONS

Neurons are the fundamental building blocks of any nervous system. These cells, tree-like branches which reach out with their neighbors, forming vast electrical and chemical network that is our brain. It's our neurons that allow our brains to do all of these things more rapidly and efficiently than any machine.

DEAR (FUTURE) SCIENTISTS, WHO CAN TELL ME:

- How Many **Cells** in the brain?
- **% Neurons**? 10%? 25%?
- **% Glia**? 90%? 1%?

I. Comparative Brains: Isotropic Fractionation +Findings

II. Is the Human Brain *Neuroanatomically* Unique?

"There was, to our knowledge, no actual, direct estimate of numbers of cells or of neurons in the entire human brain to be cited until 2009".

"It is commonly assumed that glia outnumber neurons in the brain and specifically in humans by a factor of 10 or 50 despite the lack of data for these assumptions = {Kandel, 2000} .

Azevedo, Herculano-Houzel, Lent et al. (2009). Equal numbers of neuronal and nonneuronal cells make the human brain an isometrically scaled-up primate brain. *The Journal of comparative neurology*, *513*(5), 532-41.

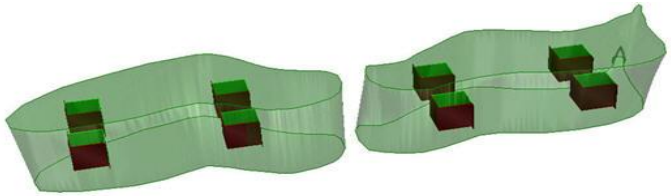
איך סופרים?

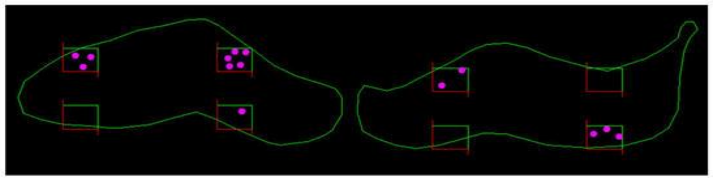
Optical Fractionation:

Count average cell **density**, **multiply** by **volume** of investigated "slice".

Problems:

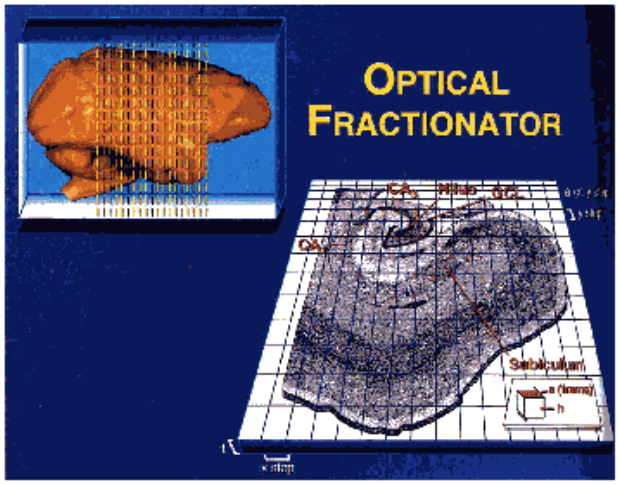
- "***Estimate*** cell count" **(Looks at regions, not whole)**
- Different regions -**different densities**
- **# Reached by {cell} Density X Volume. This is not an independent variable and cannot be used in statistical comparisons against volume**





Stereology.Info, MBF Bioscience; West 1999

Modern Methods to count Neurons



Zigmond et al., Fig. 51-9

THE ISOTROPIC FRACTIONATOR

1. Method

I. Theoretical basis.

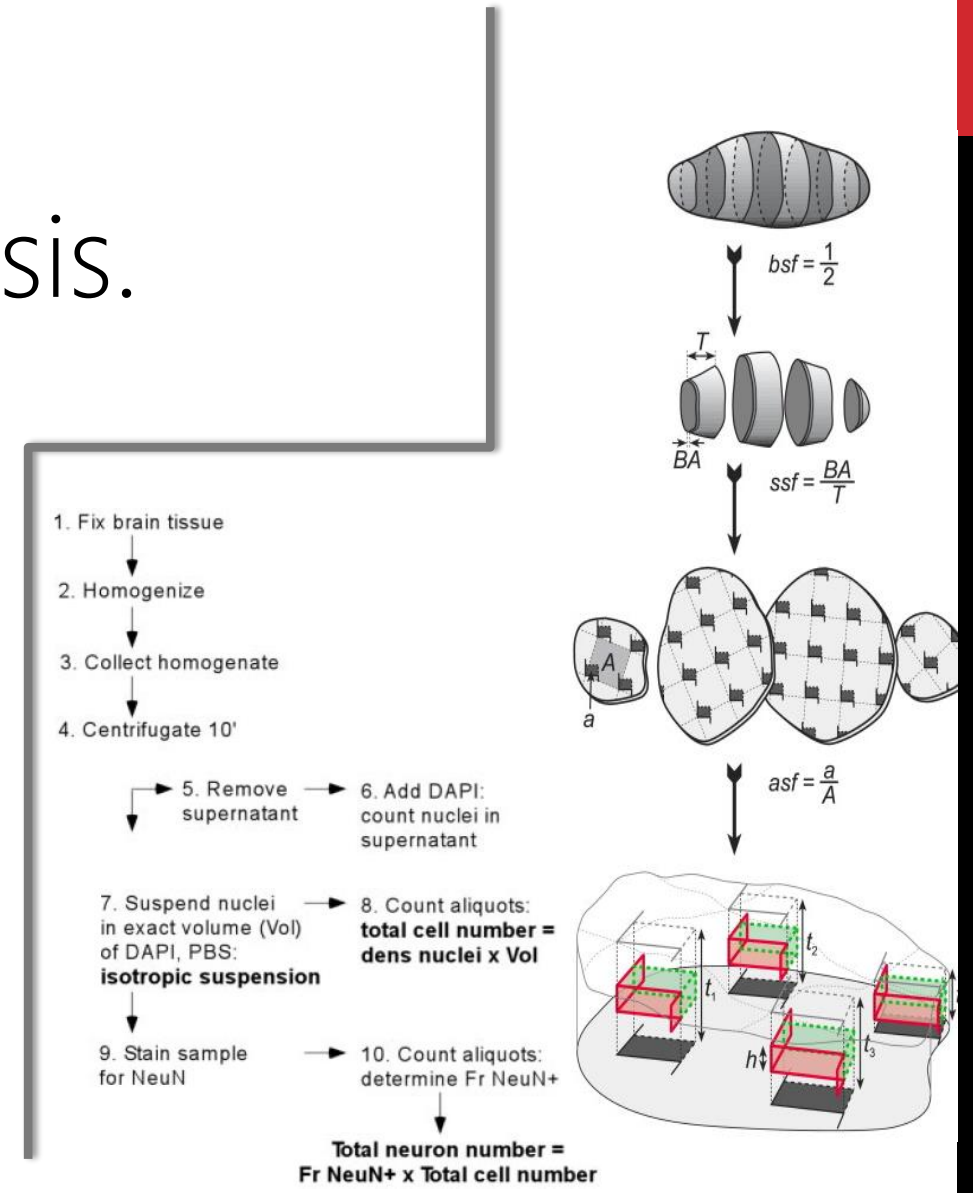
II. How it works.

2. Benefits

3. Findings:

a. Rats & Glia

b. Humans.

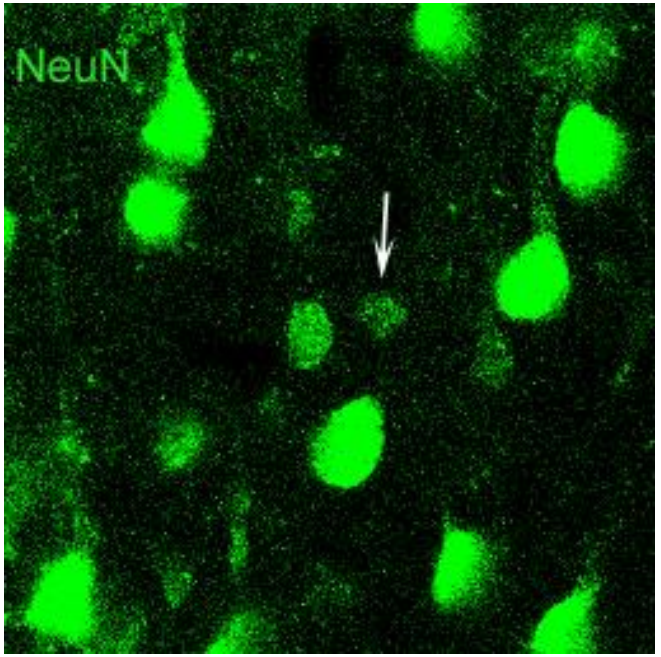


ISOTROPIC FRACTIONATION

THEORETICAL BASIS: 2 AXIOMS

1. 1 Cell = 1 Nucleus

2. NeuN - **neu**ronal **n**uclei specific protein



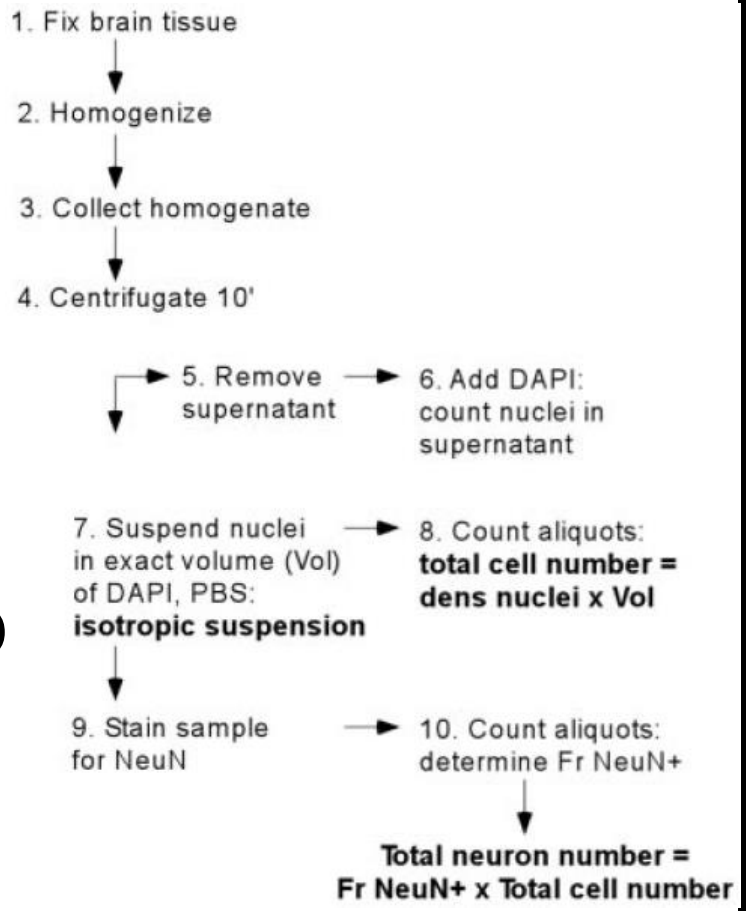
Iso = Equal

Mullen, et al. (1992). "NeuN, a neuronal specific nuclear protein in vertebrates". *Development* **116;**

ISOTROPIC FRACTIONATION

HOW IT WORKS (I):

A. "Slice" Preserved Brain (Or structures)
B. "Stir" (Homogenize + Centrifugate)
C. DAPI (DNA dye) Stain.
D. "Pour" homogenate+DAPI into Vat(s) in a **isotropic** suspension



ISOTROPIC FRACTIONATION

HOW IT WORKS (II):

E. Extract (8+) aliquots (דגימות)

F. Count with hemocytometer (= microscope counting).

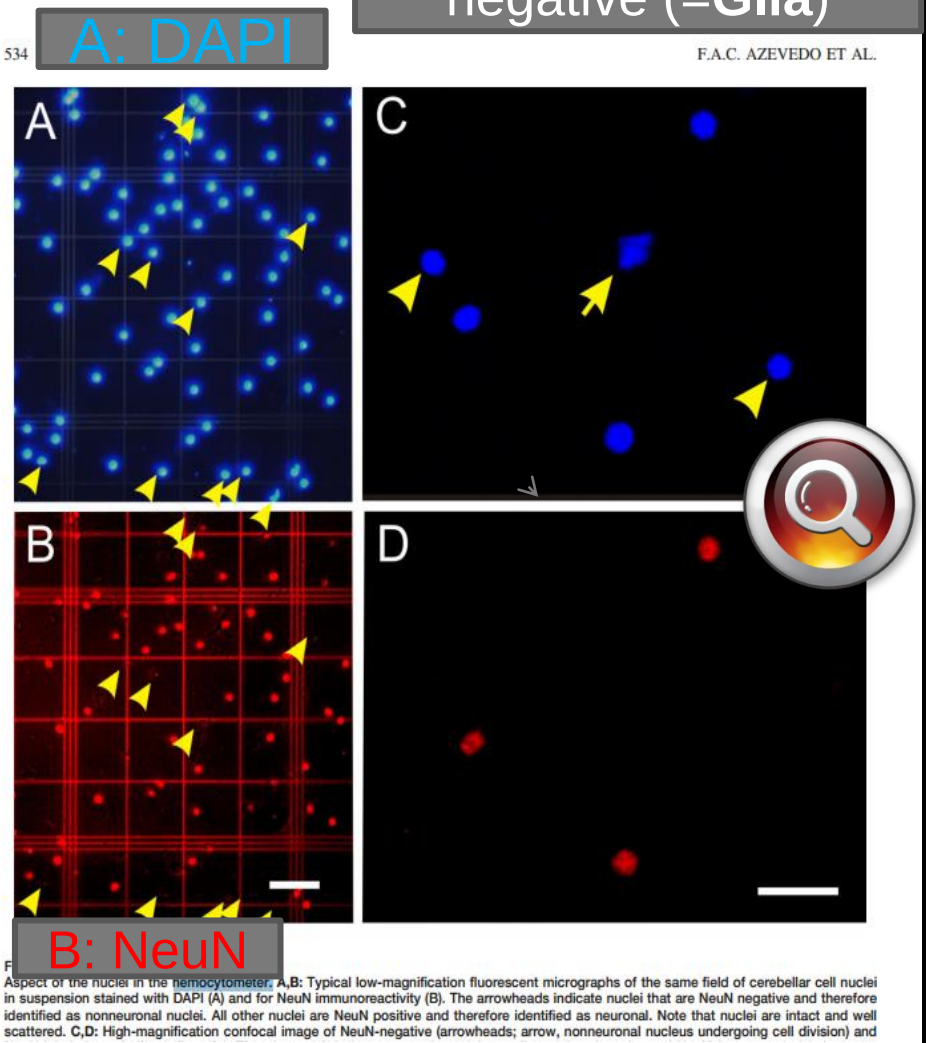
Total Cell # = Nuclei Density X Volume

G. Add NeuN specific Antigen (Mark Neurons).

H. Count "Neurons" ($NeuN^+$)

Glia Cell# = Total Cell# - #NeuN+

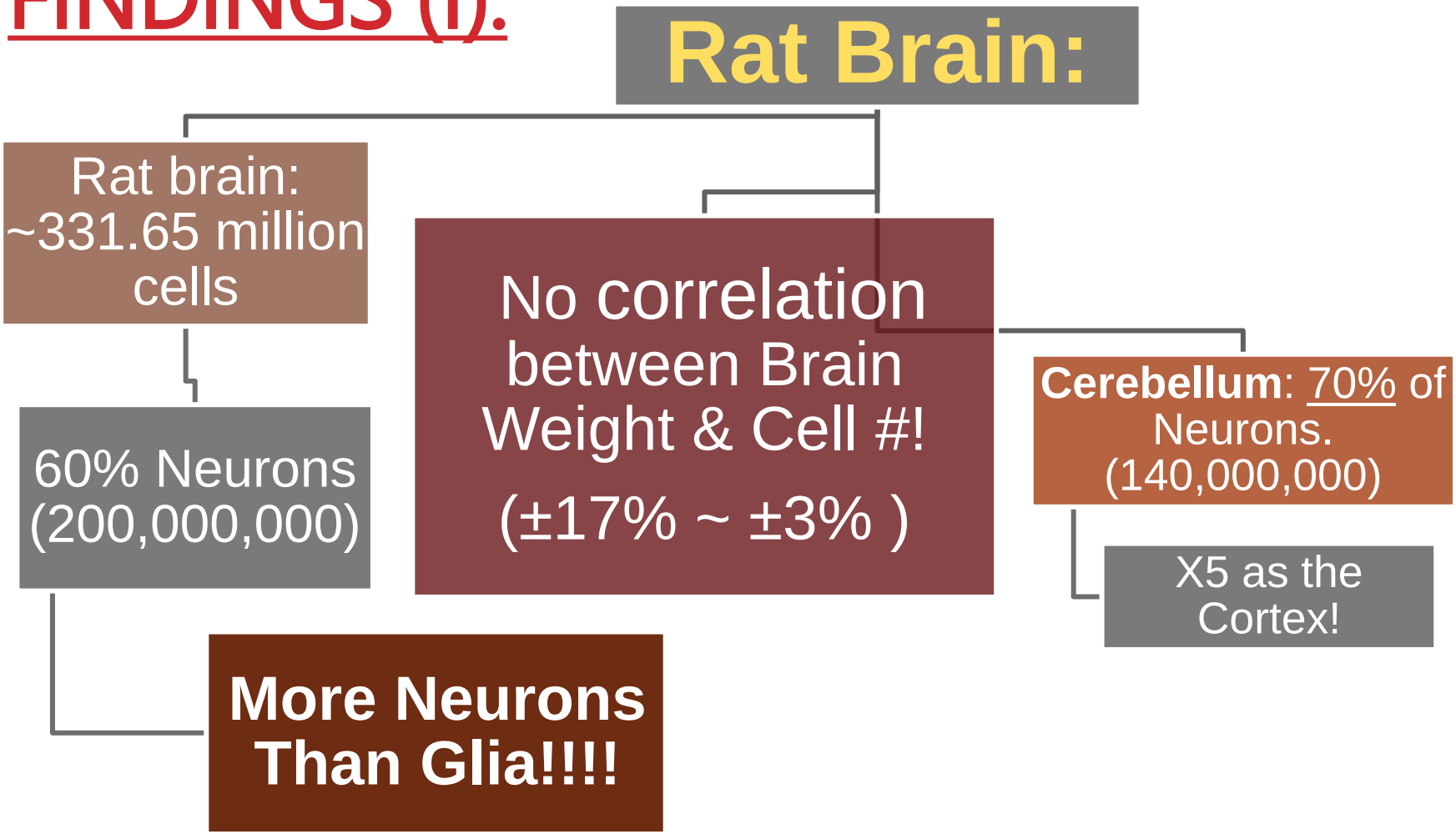
Arrowheads = NeuN negative (=**Glia**)



ISOTROPIC FRACTIONATION BENEFITS:

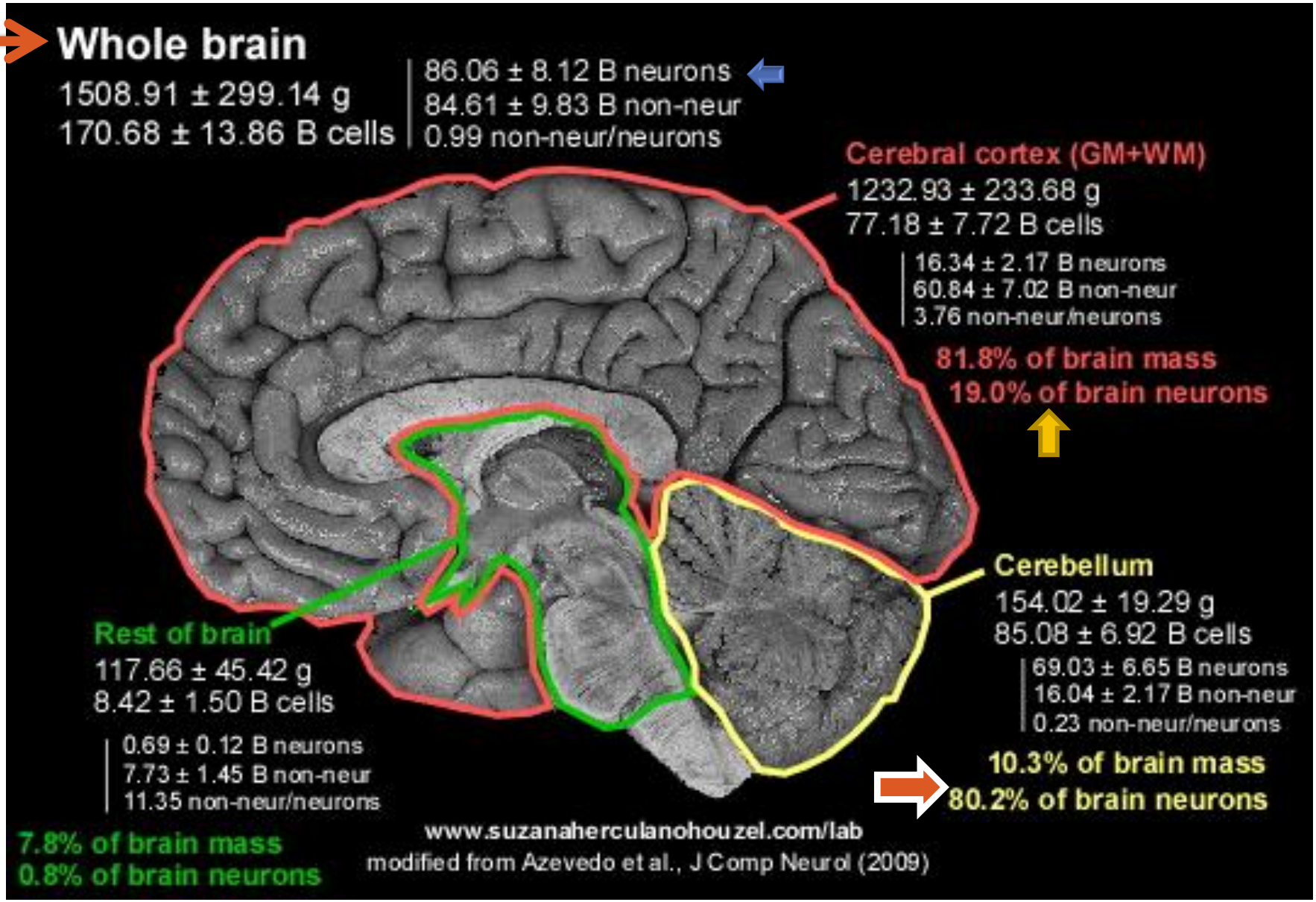
Absolute, accurate quantitative count of Neurons, Glia	**Less room for human error.** **Can Analyze whole brain, not just slices or regions.** **Yields absolute Cell Count independent of Brain Volume/Mass.**

ISOTROPIC FRACTIONATION FINDINGS (I):



Herculano-Houzel and Lent; Isotropic Fractionator: A Simple, Rapid Method for the Quantification of Total Cell and Neuron Numbers in the Brain; *Journal of Neuroscience, 2005*

FINDINGS (II): - HUMANS:



FINDINGS (III): - HUMANS:

Our brain has 86 ± 8 billion NeuN+ ("neurons") and ~84.6 billion "Glia".

NOT 100 Billion!

- *More* Neurons than Glia!
  Nonneuronal/Neuronal ratio = 0.99 for whole human brain.
- Cerebral Cortex: contains just 19% of neurons despite size and mass (*82%*)!
- Cerebellum: Just 10% of brain mass, But ~69 billion neurons - 80%!

Equal Numbers of Neuronal and Nonneuronal Cells Make the Human Brain an Isometrically Scaled-Up Primate Brain; HERCULANO-HOUZEL et al., J. of Comparative Neurology, 2009

IS THE HUMAN BRAIN UNIQUE?

"we have brains that are bigger than expected for an ape, we have a neocortex that is three times bigger than predicted for our body size, we have … areas of the neocortex and cerebellum that are larger than expected.." (Gazzaniga, 2008).

"The only brain that studies brains"

CORTEX SIZE

"Oversized Neo-cortex" - 82% of the Brain's mass.

The cortex contains only 19% of neurons!

Cerebellar cortex & Cerebellum Size = Same relative size as Apes

***BUT*! Mass =!>Neuron**

"No Correlation of Variance between Brain Weight & # neurons!"

(Semendeferi, 2001)

CLAIMS OF HUMAN UNIQUENESS: **CORTICAL FOLDING?**

No!

The *folding ratio* increases along with overall brain volume

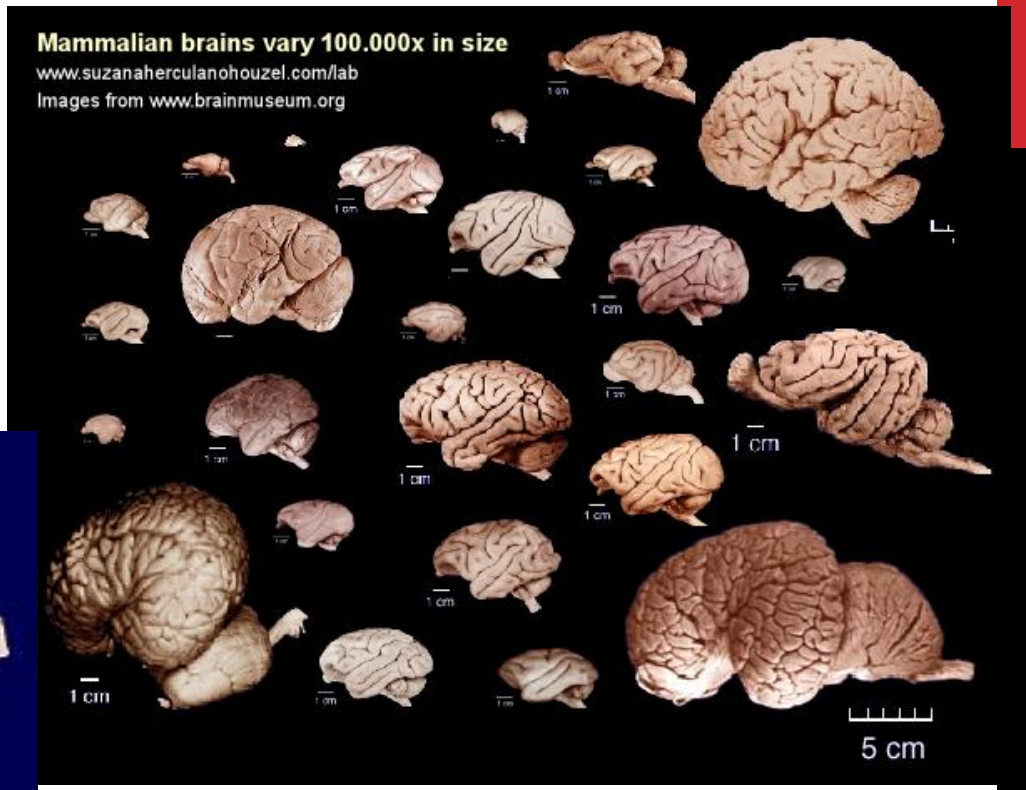
Humans: 2.86;

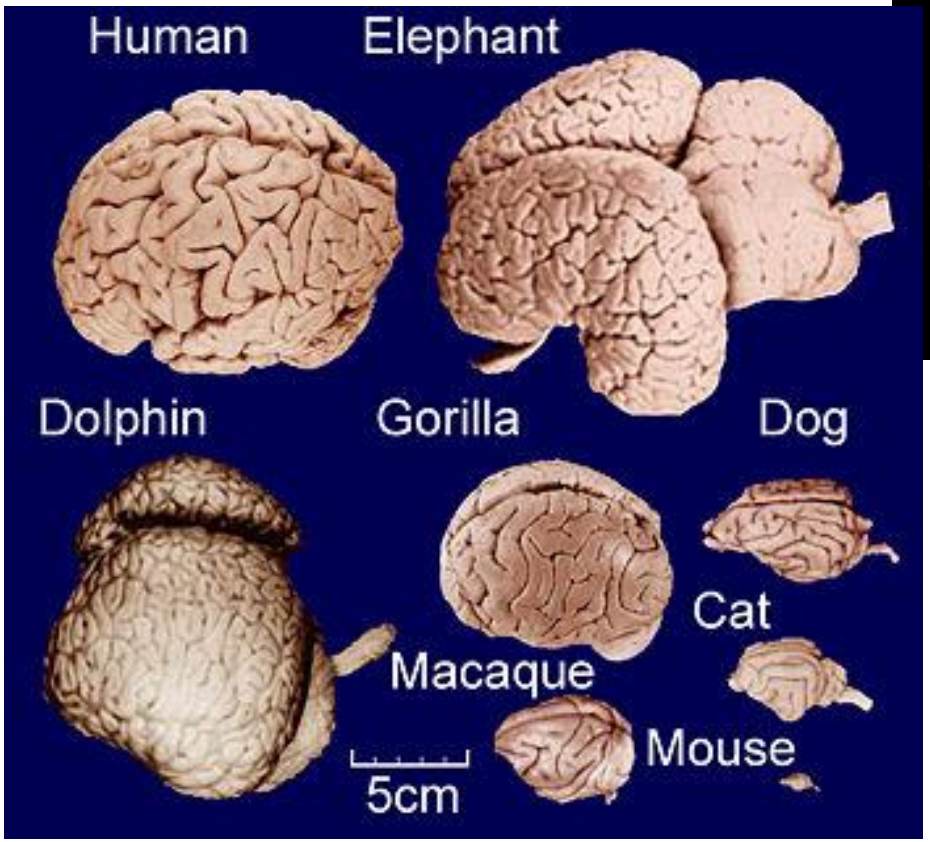
Dolphins and whales- 4.0 - 8.55..

Von Bonin (1941); (Macphail, 247)

CLAIMS OF HUMAN UNIQUENESS: BRAIN SIZE

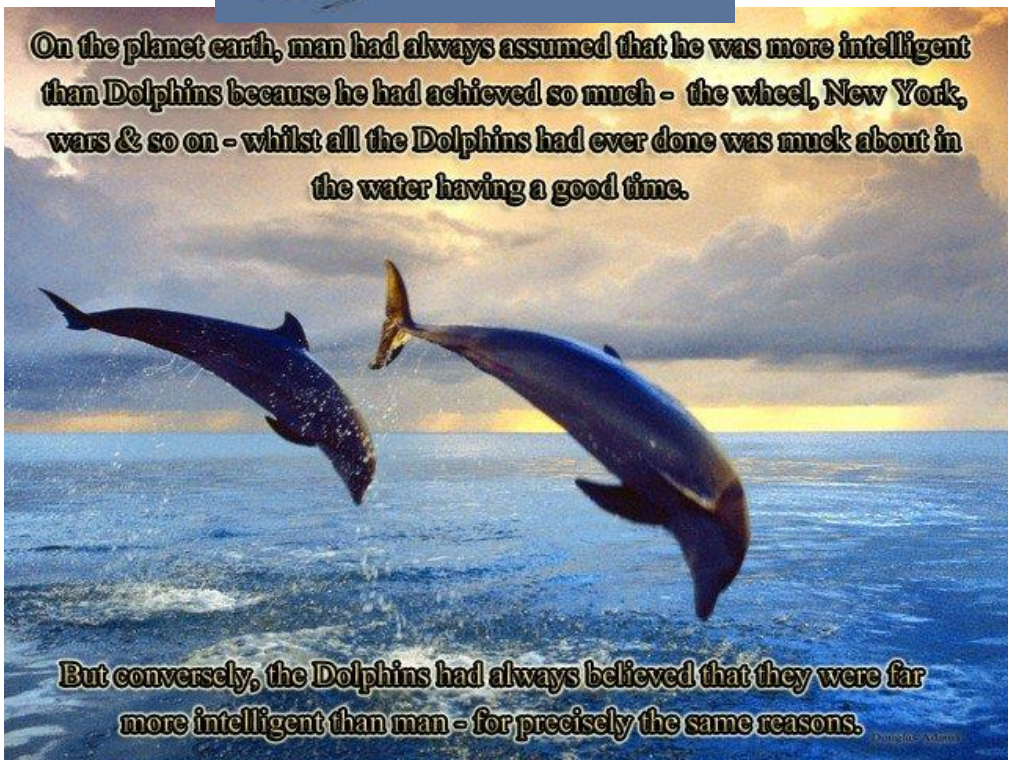
Absolute Size?





CLAIMS OF HUMAN UNIQUENESS:
BRAIN/BODY MASS RATIO

Humming bird: 1/25
Squirrel monkeys: 1/20
Mice: 1/40
Humans: 1/49
Dolphins: ~1/80
Cats: 1/100
Dogs: 1/125
Lions: 1/500
Elephants: 1/560
Horses: 1/600
Sharks: 1/2500



Kuhlenbeck (1973)

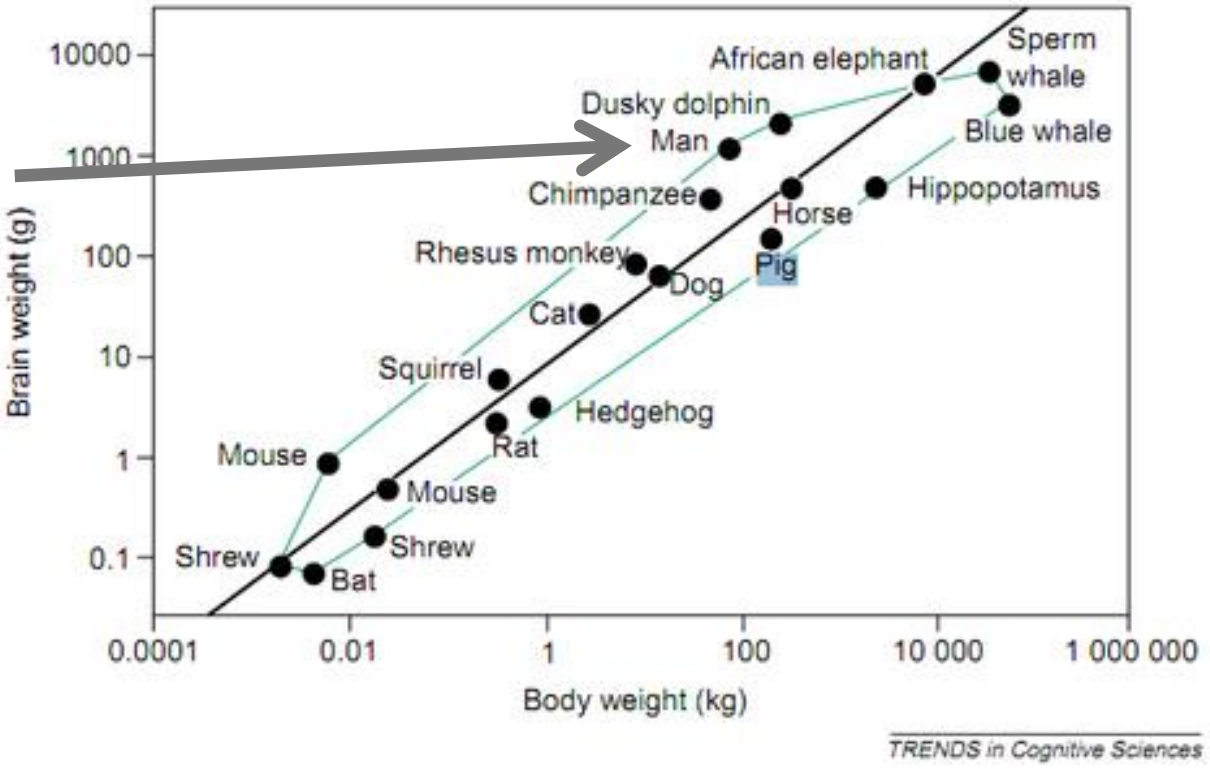
CLAIMS OF HUMAN UNIQUENESS:
ENCEPHALIZATION

Encephalization Quotient : האם המוח גדול מהמצופה עבור חיה עם גודל גוף כזה?

E.Q>1 : bigger brain than expected.

Human E.Q ~ 7

Jerison (1973)



CLAIMS OF HUMAN UNIQUENESS: **ENCEPHALIZATION**

"A brain 7 times too large for a mammal of its size…"

(Marino, 1998)

Species	*EQ*	*Species*	*EQ*
Man	7.44	**Cat**	1.00
Dolphin	5.31	**Horse**	0.86
Chimpanzee	2.49	**Sheep**	0.81
Rhesus Monkey	2.09	**Mouse**	0.50
Elephant	1.87	**Rat**	0.40
Whale	1.76	**Rabbit**	0.40
Dog	1.17	(Macphail, 243)	

(Jerison, 1973).
(Macphail, 243)

CLAIMS OF HUMAN UNIQUENESS: **ENCEPHALIZATION**

No!

- **The expected body–brain ratio depends on the Species compared!**
- **Compared to Primates: E.Q of 3**
- **Compared to small monkeys: E.Q 1.1!**

"gorillas and orangutans, rather than humans, are outlier species in terms of body size" {Brain: 1% vs 2% of body mass}

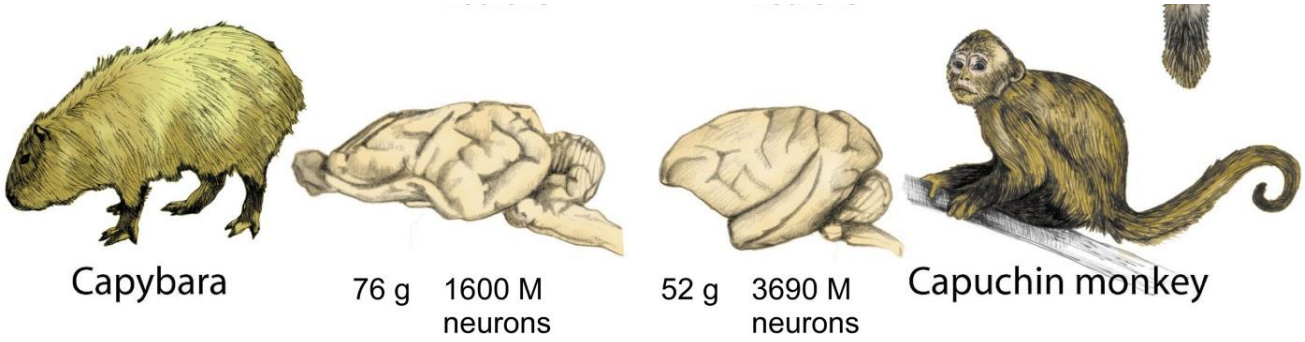
(Semendeferi and Damasio, 2000)

(Barton, 2006; Herculano-Houzel et al.,2007).
The human brain in numbers: a linearly scaled-up primate brain; Herculano-Houzel, 2009

WHAT MATTERS:
RELATIVE OR ABSOLUTE BRAIN SIZE ?

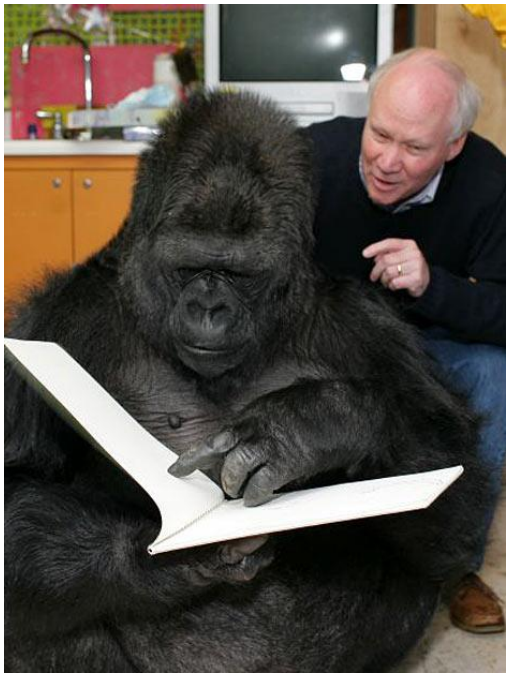
Absolute?

Capybara vs Capuchin Monkey:



Relative?

Gorilla Vs Capuchin



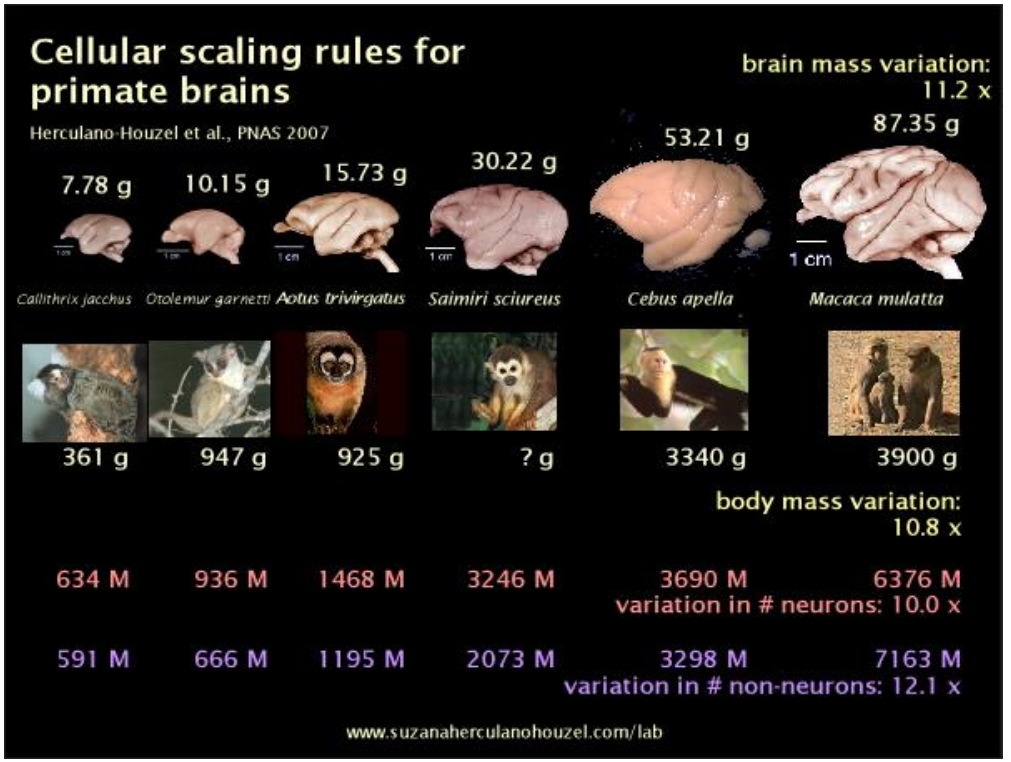
(Roth and Dicke, 2005)

WHAT MAKES US *SPECIAL*?

1. **Absolute** Number of Neurons.

Why?

2. We Have the Largest **PRIMATE** Brain!



Different Specie Orders' Brains SCALE Differently!

*Primates Vs Rodentia Vs Insectivores…

WHAT MAKES US *SPECIAL*: BIGGEST PRIMATE BRAIN

3. **(Efficient) Isometric Primate Brain *Scaling*.**

"**Primate** brain size increases ***isometrically*** as a function of **neuron** number".

Rodents – ***Hypermetric*** Increase.

- *"average neuronal size increases together with neuronal number, but not in primates"*

X10 neurons in **Primates** → X11 larger brain.

X10 neurons in rodents →X35 larger brain.

Linear, economical **cellular scaling rules** apply to primate brains. Herculano-Houzel et al, Natl Acad Sci USA (2007).; Equal Numbers of Neuronal and Nonneuronal Cells Make the Human Brain an Isometrically Scaled-Up Primate Brain. Herculano-Houzel et al. Journal of Comparative Neurology 513:532–541 (2009)

POTENTIAL SOURCES OF HUMAN SPECIALNESS:

- **Neuroanatomical regions (Area 10 Prefrontal, specific layers of cortex..)**
- **Lengthy infant Development (Increased Learning Plasticity/development).**
- **Connectivity (Dendritic connection density..)**
- **Genes.**
- **Special Cellular traits**
- **Absolute # Neurons**
- **…**