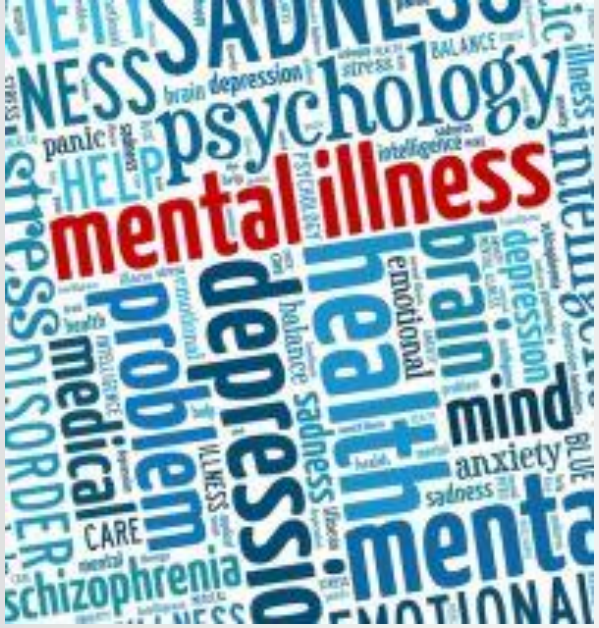
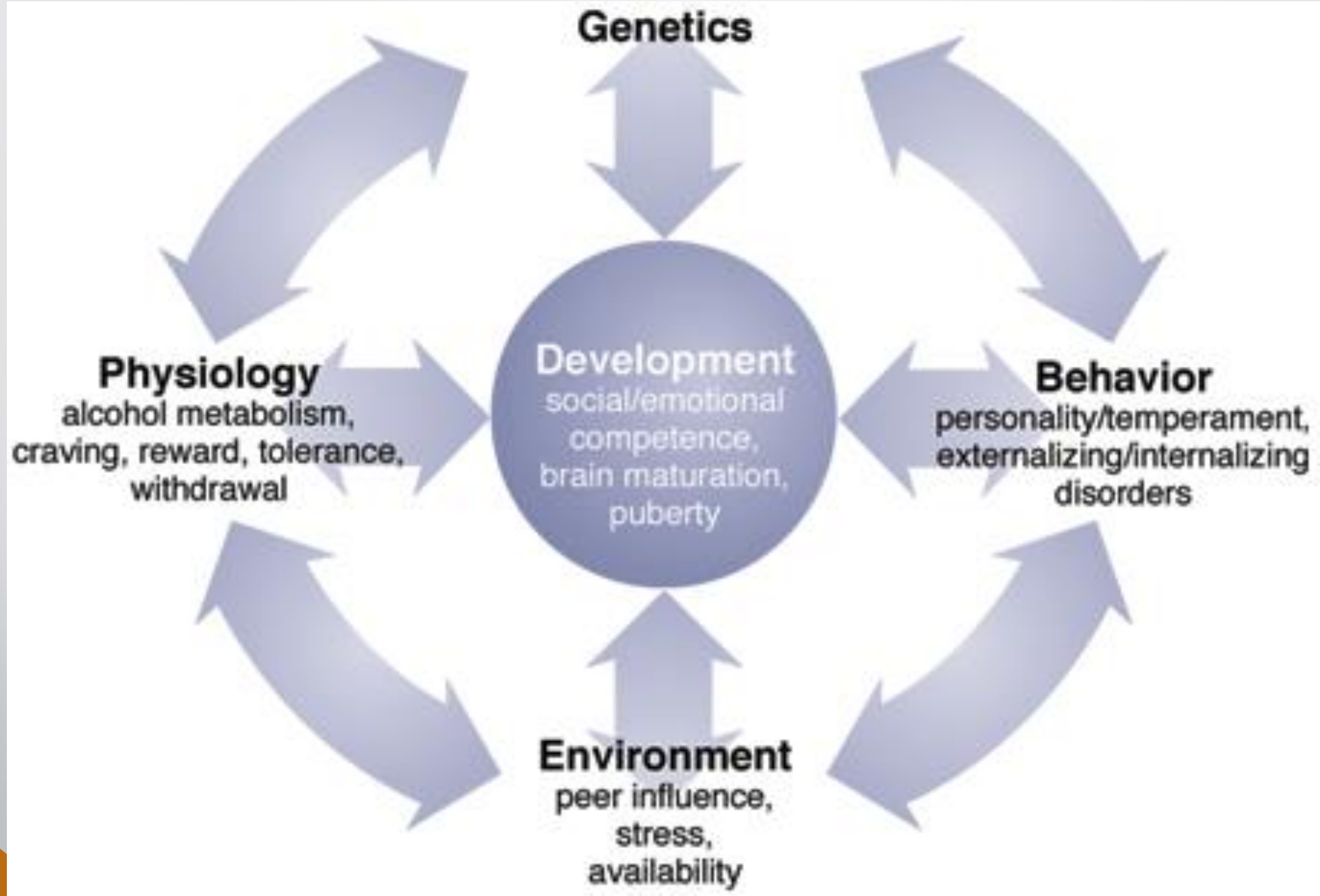


Neuroscience of Mental Health Disorders

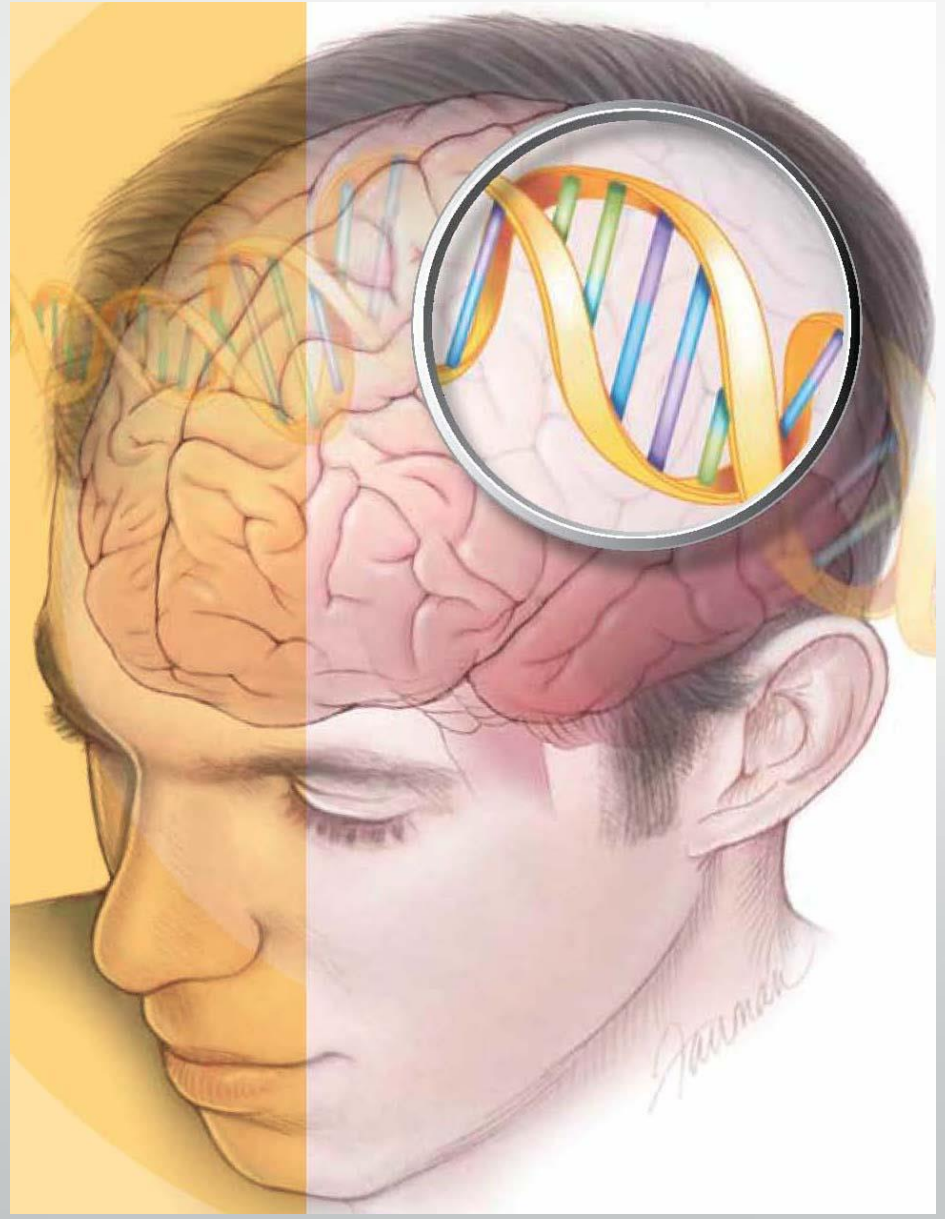
Prepared by:

Jim Messina, Ph.D., CCMHC, NCC, DCMHS

Assistant Professor, Troy University Tampa Bay S1te


Genetics
Physiology
alcohol metabolism, craving, reward, tolerance, withdrawal
Development
social/emotional competence, brain maturation, puberty
Behavior
personality/temperament, externalizing/internalizing disorders
Environment
peer influence, stress, availability

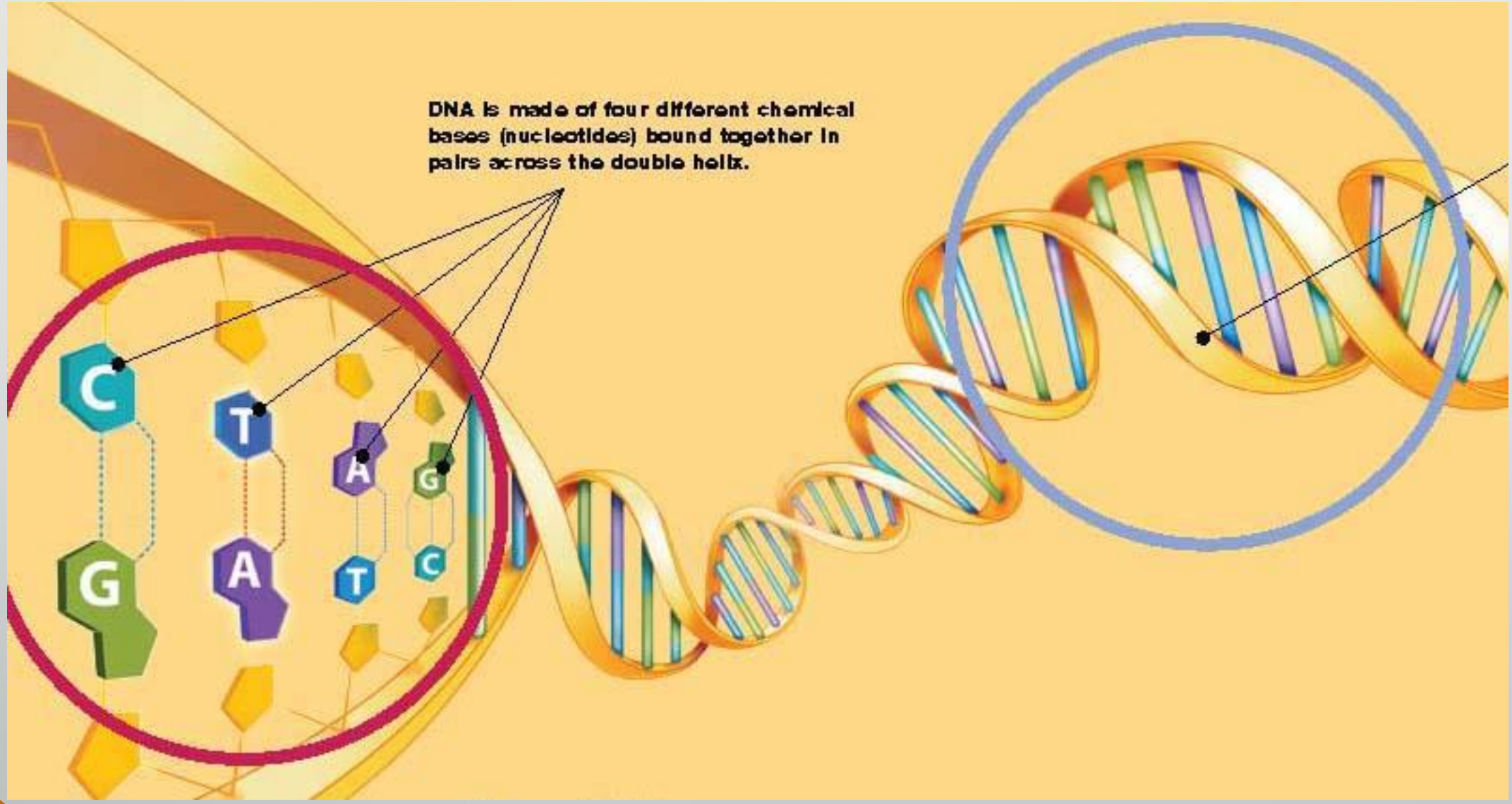
The Role of Genes in the Brain



Role of Genes in the Brain

- Genes do more than just determine the color of eyes or whether people are tall or short.
- Genes are at the center of everything that makes people human.
- Genes are responsible for producing the proteins that run everything in the body.
- Some proteins are visible, such as the ones that compose hair and skin. Others work out of sight, coordinating basic biological functions.
- For the most part, every cell in the body contains exactly the same genes, but inside individual cells some genes are active while others are not.
- When genes are active, they are capable of producing proteins. This process is called gene expression.
- When genes are inactive, they are silent or inaccessible for protein production.
- At least a third of the approximately 20,000 different genes that make up the human genome are active (expressed) primarily in the brain.
- This is the highest proportion of genes expressed in any part of the body.
- These genes influence the development and function of the brain, and ultimately control how people move, think, feel, and behave. Combined with the effects of the environment, changes in these genes can also determine whether people are at risk for a particular disease and if they are, the course it might follow.

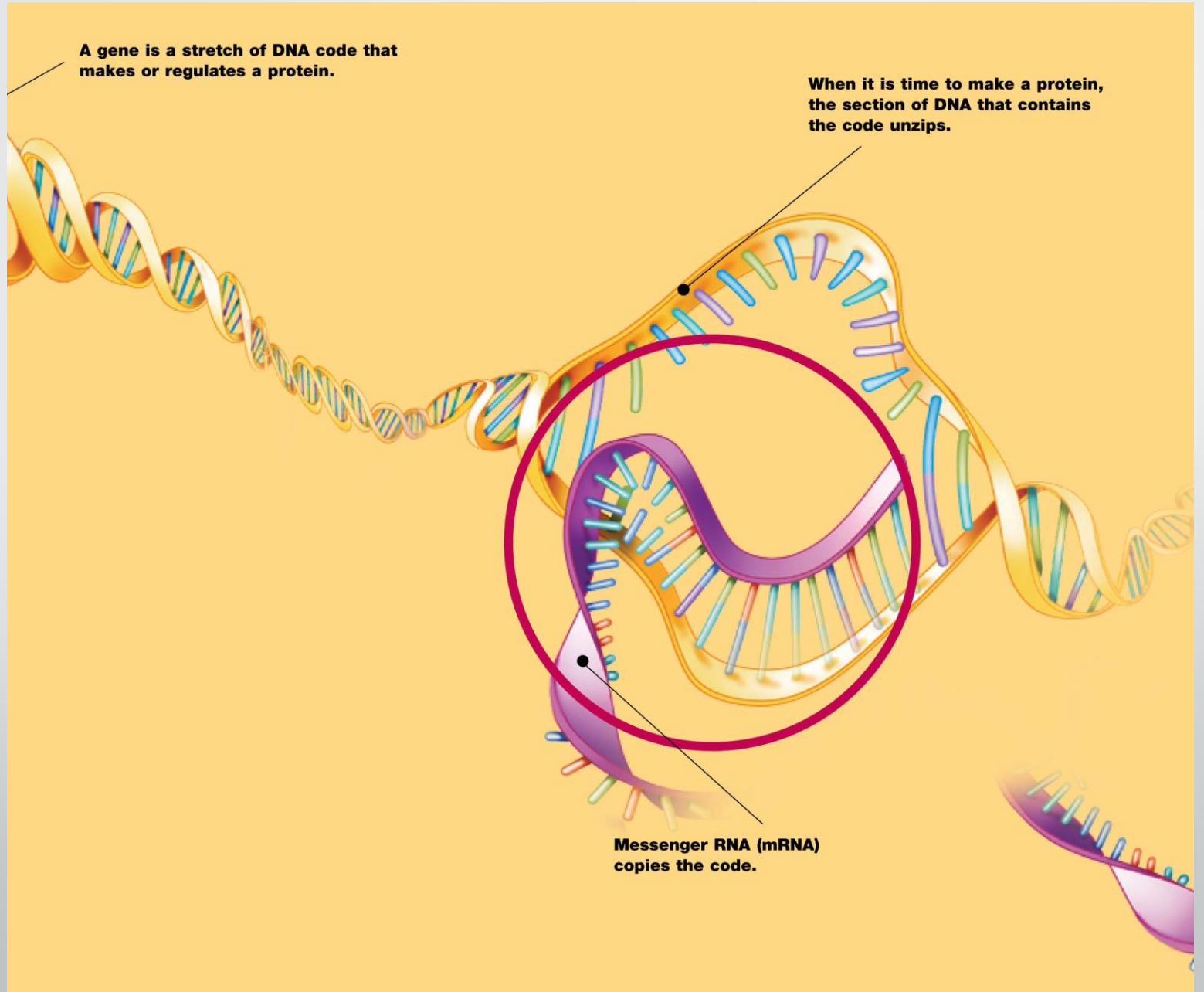
DNA


DNA is made of four different chemical bases (nucleotides) bound together in pairs across the double helix.
C
T
A
G
G
A
T
C

What is DNA?

- In order to understand how genes work in the brain, one has to understand how genes make proteins. This begins with DNA (deoxyribonucleic acid).
- DNA is a long molecule packaged into structures called chromosomes. Humans have 23 pairs of chromosomes, including a single pair of sex chromosomes (XX in females and XY in males). Within each pair, one chromosome comes from an individual's mother and the other comes from the father. In other words, people inherit half of their DNA from each of their parents.
- DNA consists of two strands wound together to form a double helix. Within each strand, chemicals called nucleotides are used as a code for making proteins.
- DNA contains only four nucleotides – adenine (A), thymine (T), cytosine (C), and guanine (G) – but this simple genetic alphabet is the starting point for making all of the proteins in the human body, estimated to be as many as one million.

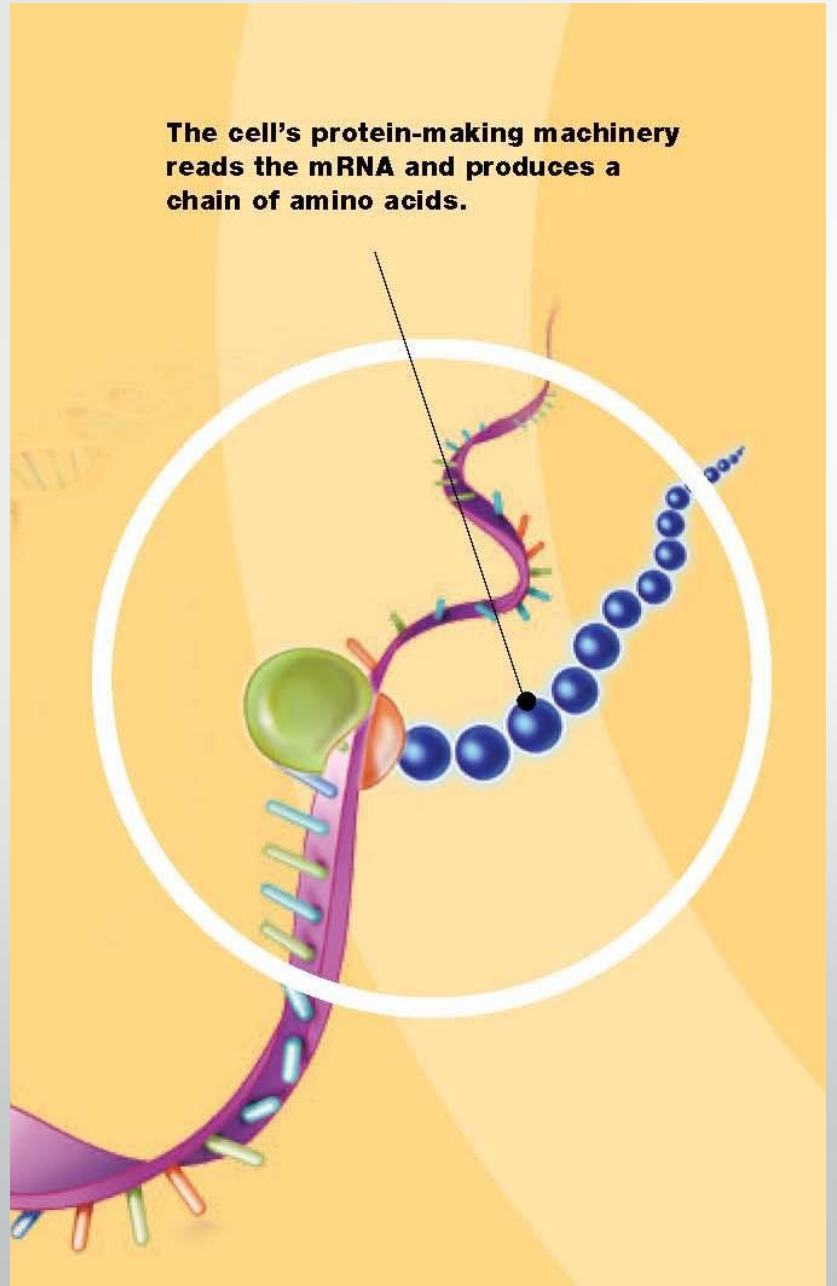
GENE

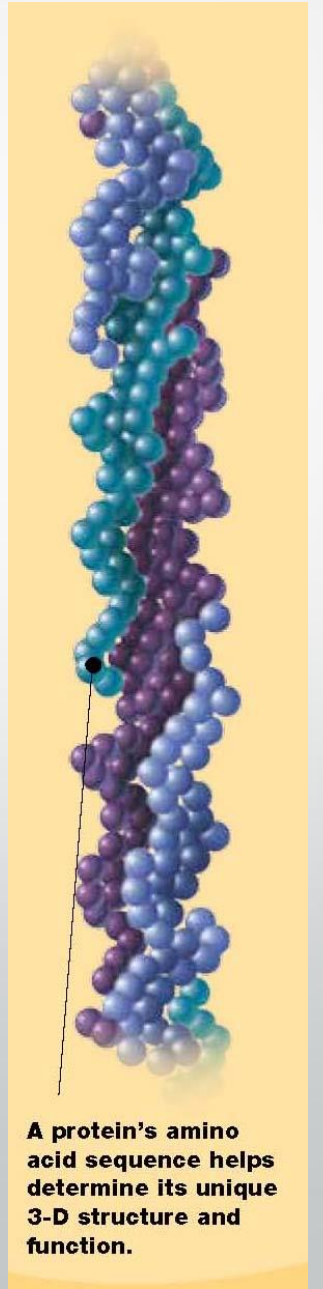

A gene is a stretch of DNA code that makes or regulates a protein.
When it is time to make a protein, the section of DNA that contains the code unzips.
Messenger RNA (mRNA) copies the code.

What is a Gene?

- A gene is a stretch of DNA that contains the instructions for making or regulating a specific protein.
- Genes that make proteins are called protein-coding genes. In order to make a protein, a molecule closely related to DNA called ribonucleic acid (RNA) first copies the code within DNA. Then, protein-manufacturing machinery within the cell scans the RNA, reading the nucleotides in groups of three. These triplets encode 20 distinct amino acids, which are the building blocks for proteins. The largest known human protein is a muscle protein called titin, which consists of about 27,000 amino acids.
- Some genes encode small bits of RNA that are not used to make proteins, but are instead used to tell proteins what to do and where to go. These are called non-coding or RNA genes. There are many more RNA genes than protein-coding genes.

What is Protein?





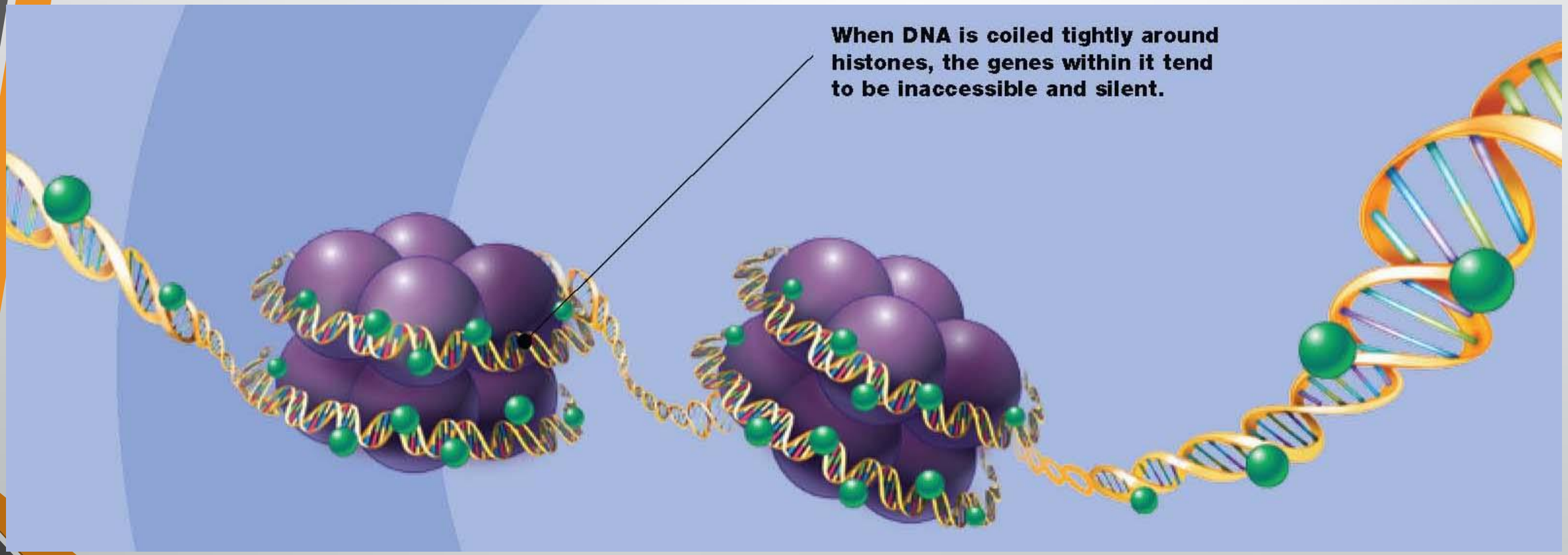
What are Proteins?

- Proteins form the internal machinery within brain cells and the connective tissue between brain cells. They also control the chemical reactions that allow brain cells to communicate with each other.
- Some genes make proteins that are important for the early development and growth of the infant brain. For example, the ASPM gene makes a protein that is needed for producing new nerve cells (or neurons) in the developing brain. Alterations in this gene can cause microcephaly, a condition in which the brain fails to grow to its normal size.
- Certain genes make proteins that in turn make neurotransmitters, which are chemicals that transmit information from one neuron to the next. Other proteins are important for establishing physical connections that link various neurons together in networks.
- Still other genes make proteins that act as housekeepers in the brain, keeping neurons and their networks in good working order.
- For example, the SOD1 gene makes a protein that fights DNA damage in neurons. Alterations in this gene are one cause of the disease amyotrophic lateral sclerosis (ALS), in which a progressive loss of muscle-controlling neurons leads to eventual paralysis and death. The SOD1 gene is believed to hold important clues about why neurons die in the common "sporadic" form of ALS, which has no known cause.

How is Gene Expression Regulated?

- One can know which protein a gene will make by looking at its code, also called its DNA sequence. What cannot be predicted is the amount of protein that will be made, when it will be made, or what cell will make it.
- Each cell turns on only a fraction of its genes, while it silences the rest. For example, genes that are expressed in brain cells may be silenced in liver cells or heart cells. Some genes are only turned on during the early months of human development and then are silenced later.
- What determines these unique patterns of gene expression? Like people, cells have a unique lineage, and they tend to inherit traits from their parents. So, a cell's origins influence the genes it turns on to make proteins. The cell's environment – its exposure to surrounding cells and to hormones and other signals – also helps determine which proteins the cell makes.
- These cues from a cell's past and from its environment act through many regulatory factors inside the cell

What Determines Gene Expression?



What Determines Gene Expression?

DNA Binding Proteins

- About 10 percent of the genes in the human genome encode DNA binding proteins. Some of these proteins recognize and attach to specific bits of DNA to activate gene expression. Another type of DNA binding protein, called a histone, acts as a spool that can keep DNA in tight coils and thus suppress gene expression.

sRNA

- Scattered throughout the genome are many types of small RNA (sRNA) that actively regulate gene expression. Because of their short length, they are able to target, match, and deactivate small bits of genetic code.

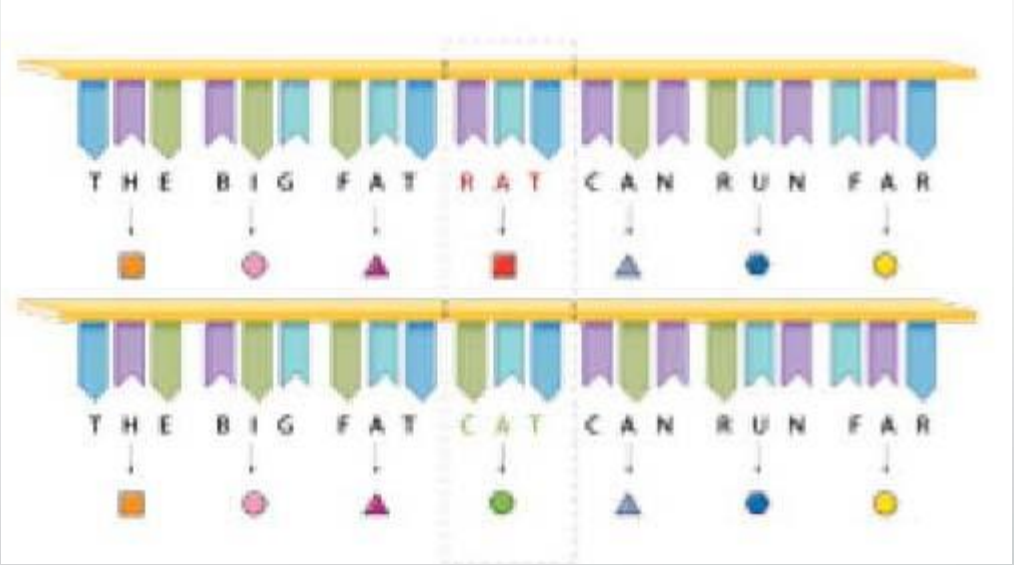
Epigenetic Factors

- The word epigenetics comes from the Greek word epi, meaning above or beside. In a broad sense, epigenetics refers to long-lasting changes in gene expression without any changes to the genetic code. Epigenetic factors include chemical marks or tags on DNA or on histones that can affect gene expression.

Variations in Genetic Codes

- A genetic variation is a permanent change in the DNA sequence that makes up a gene.
- Most variations are harmless or have no effect at all.
- However, other variations can have harmful effects leading to disease.
- Still others can be beneficial in the long run, helping a species adapt to change.

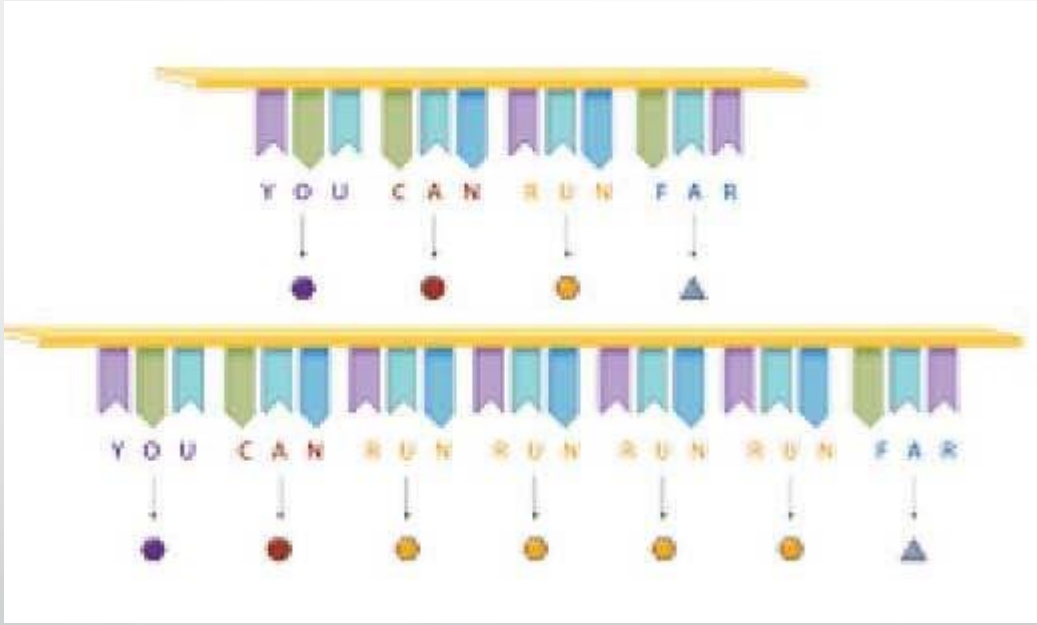
Single Nucleotide Polymorphism (SNP)



Single Nucleotide Polymorphism (SNP)

- SNPs are variations that involve a change in just one nucleotide.
- It is estimated that the human genome contains more than 10 million different SNPs.
- Because SNPs are such small changes within DNA, most of them have no effect upon gene expression.
- Some SNPs, however, are responsible for giving people unique traits, such as hair and eye color.
- Other SNPs may have subtle effects on people's risk of developing common diseases, such as heart disease, diabetes, or stroke.

Copy Number Variation (CNV)



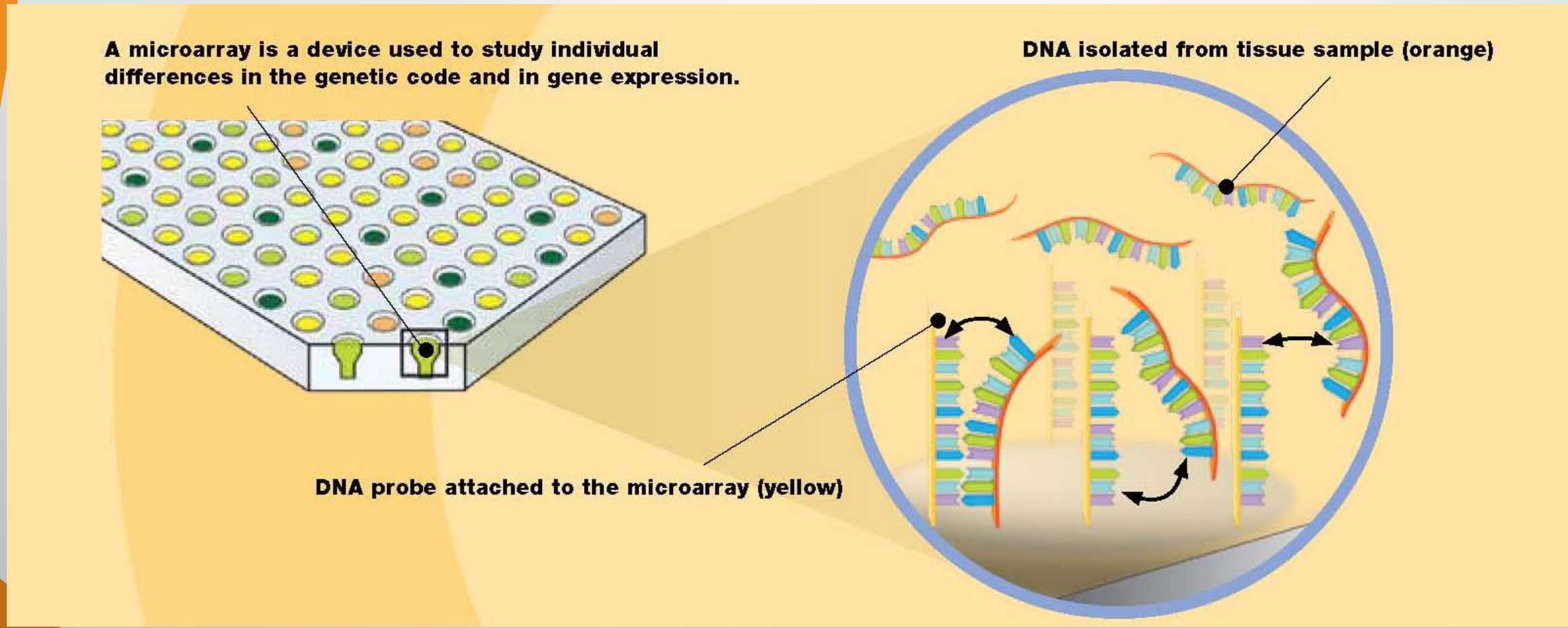
Copy Number Variation (CNV)

- At least 10 percent of the human genome is made up of CNVs, which are large chunks of DNA that are deleted, copied, flipped or otherwise rearranged in combinations that can be unique for each individual. These chunks of DNA often involve protein coding genes. This means that CNVs are likely to change how a gene makes its protein.
- Since genes usually occur in two copies, one inherited from each parent, a CNV that involves a single missing gene could lower the production of a protein below the amount needed.
- Having too many copies of a gene can be harmful, too. Although most cases of Parkinson's disease are sporadic (without a known cause), some cases have been linked to having two or more copies of the SNCA gene, which encodes a protein called alpha-synuclein. The excess alpha-synuclein accumulates in clumps inside brain cells, and appears to jam the cells' machinery. For reasons that are not clear, similar clumps are associated with sporadic Parkinson's disease.

Single Gene Mutation

- Some genetic variations are small and affect only a single gene. These single gene mutations can have large consequences, however, because they affect a gene's instructions for making a protein. Single gene mutations are responsible for many rare inherited neurological diseases.
- For example, Huntington's disease is the result of what is called an expanded "triplet repeat" in the huntingtin gene. Normal genes often have triplet repeats, in which the same triplet amino acid code occurs multiple times like a stutter. These repeats are usually harmless.
- In the huntingtin gene, triplet repeats of 20 to 30 times are normal. But in people with Huntington's disease, the number of repeats reaches 40 or more. The mutation creates an abnormally shaped protein that is toxic to neurons. As cells start to die, the symptoms of Huntington's disease appear uncontrollable writhing movements of the legs and arms, a loss of muscle coordination, and changes in personality and thinking.

The Role of Genes in Neurological Disease



The Role of Genes in Neurological Disease

- Most of the single gene mutations that cause rare neurological disorders such as Huntington’s disease have been identified.
- In contrast, there is still much to learn about the role of genetic variations in common neurological disorders and conditions, like Alzheimer's disease and stroke. A few things are clear:
- **First,** for most people, a complex interplay between genes and environment influences the risk of developing these diseases.
- **Second,** where specific gene variations such as SNPs are known to affect disease risk, the impact of any single variation is usually very small. In other words, most people affected by stroke or Alzheimer's disease have experienced an unfortunate combination of many "hits" in the genome and in the environment.
- **Finally,** beyond changes in the DNA sequence, changes in gene regulation - for example, by sRNAs and epigenetic factors - can play a key role in the disease.

What kinds of Studies Research Gene Disease Relatedness?

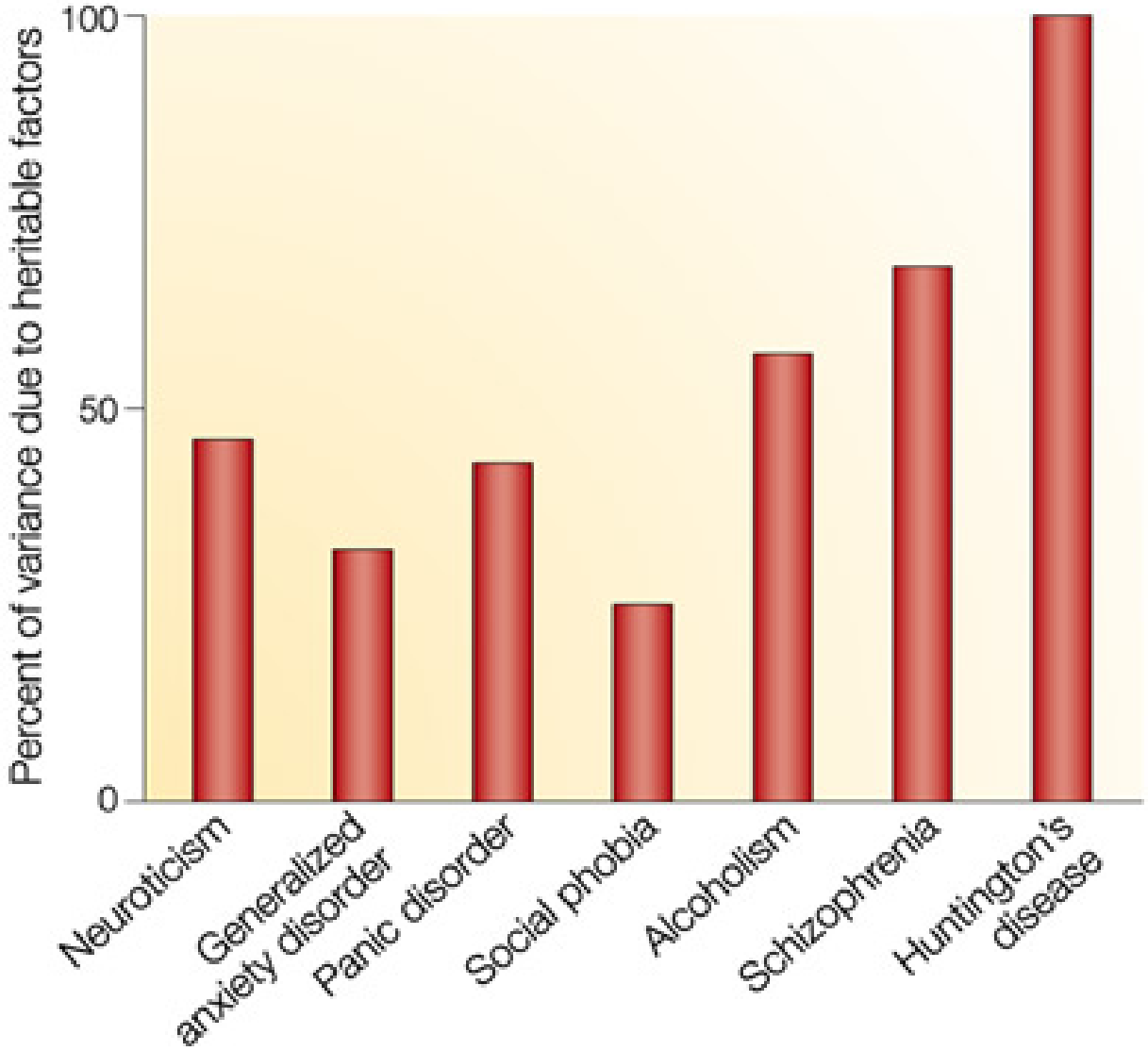
Scientists search for connections between genes and disease risk by performing two kinds of studies:

1. **Genome-wide association (GWA) study**, scientists search for SNPs or other changes in DNA sequence, comparing the genomes of the subjects (people, laboratory animals or cells) that have a disease and subjects that do not have the disease.
2. **Gene expression profiling**, scientists look for changes in gene expression and regulation that are associated with a disease.

- Both kinds of studies often use a device called a DNA microarray, which is a small chip, sometimes called a gene chip, coated with row upon row of DNA fragments. The fragments act as probes for DNA (in a GWA study) or RNA (in gene expression profiling) isolated from a sample of blood or tissue.
- Increasingly, scientists are conducting these studies by direct sequencing, which involves reading DNA or RNA sequences nucleotide by nucleotide. Sequencing was once a time-consuming and expensive procedure, but a new set of techniques called next-generation sequencing has emerged as an efficient, cost-effective way to get a detailed readout of the genome.

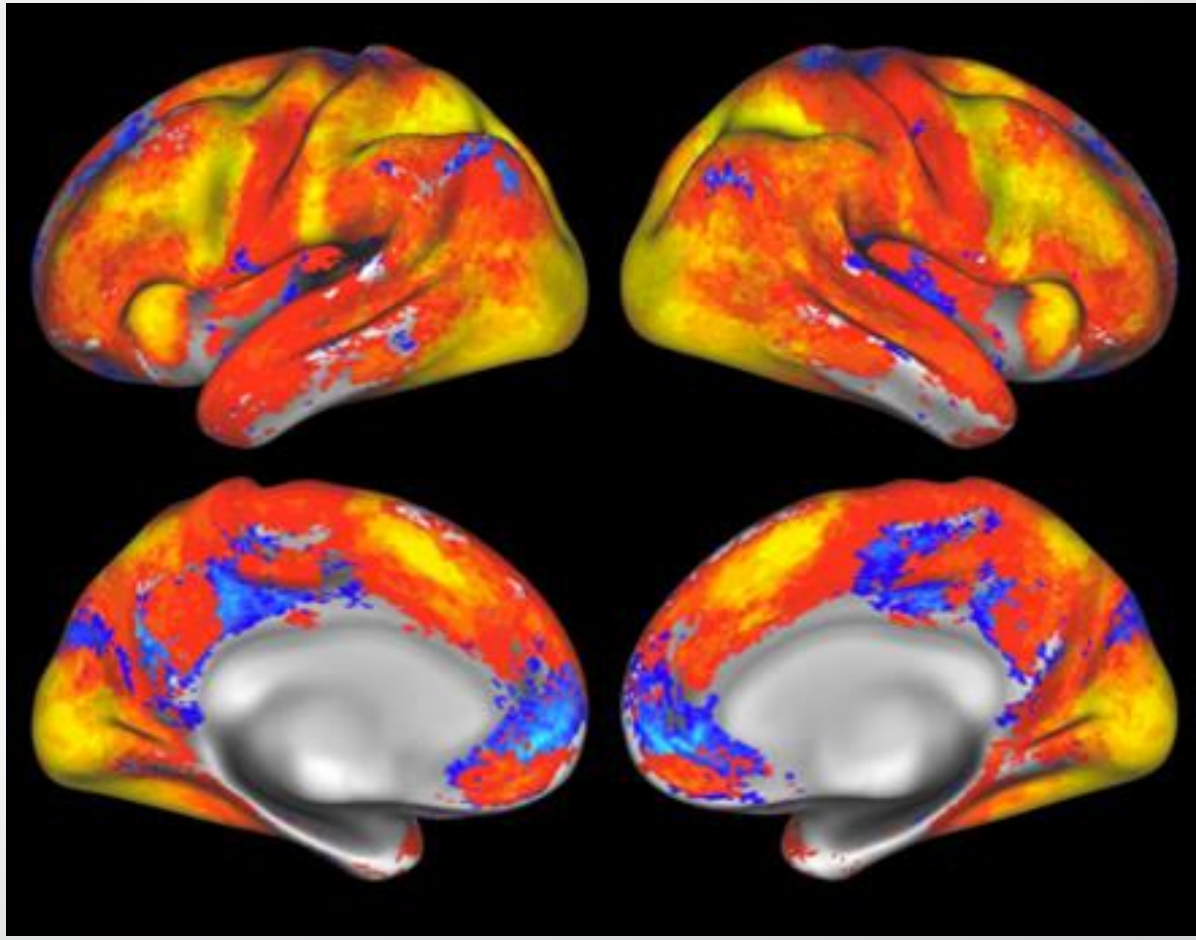
Genes at Work for Better Treatments & Cures

- Doctors can prescribe DNA-based tests to look for mutations that cause single gene mutation disorders such as Duchenne muscular dystrophy, neurofibromatosis type 1, and Huntington's disease. Genetic tests are often used to confirm the diagnosis of disease in people who already have symptoms, they can also be used to establish the presence of a mutation in individuals who are at risk for the disease but who have not yet developed any symptoms.
- In the laboratory, GWA studies and gene expression profiling studies are leading to insights into new possibilities for disease prevention, diagnosis and treatment. When scientists identify a gene or gene regulatory pathway associated with a disease, they uncover potential new targets for therapy. Understanding the relationships between genes and complex diseases also is expected to play an important part in personalized medicine. One day, microarray-based genome scanning could become a routine way to estimate a person’s genetic risk of developing diseases like stroke, Alzheimer’s disease, Parkinson’s disease and certain brain cancers. Researchers hope to develop customized drug “cocktails” that are matched to a person’s unique genetic profile. Researchers believe that these customized drugs will be much less likely than current medicines to cause side effects.


Percent of variance due to heritable factors
100
50
0
Neuroticism
Generalized anxiety disorder
Panic disorder
Social phobia
Alcoholism
Schizophrenia
Huntington's disease
Nature Reviews | Neuroscience

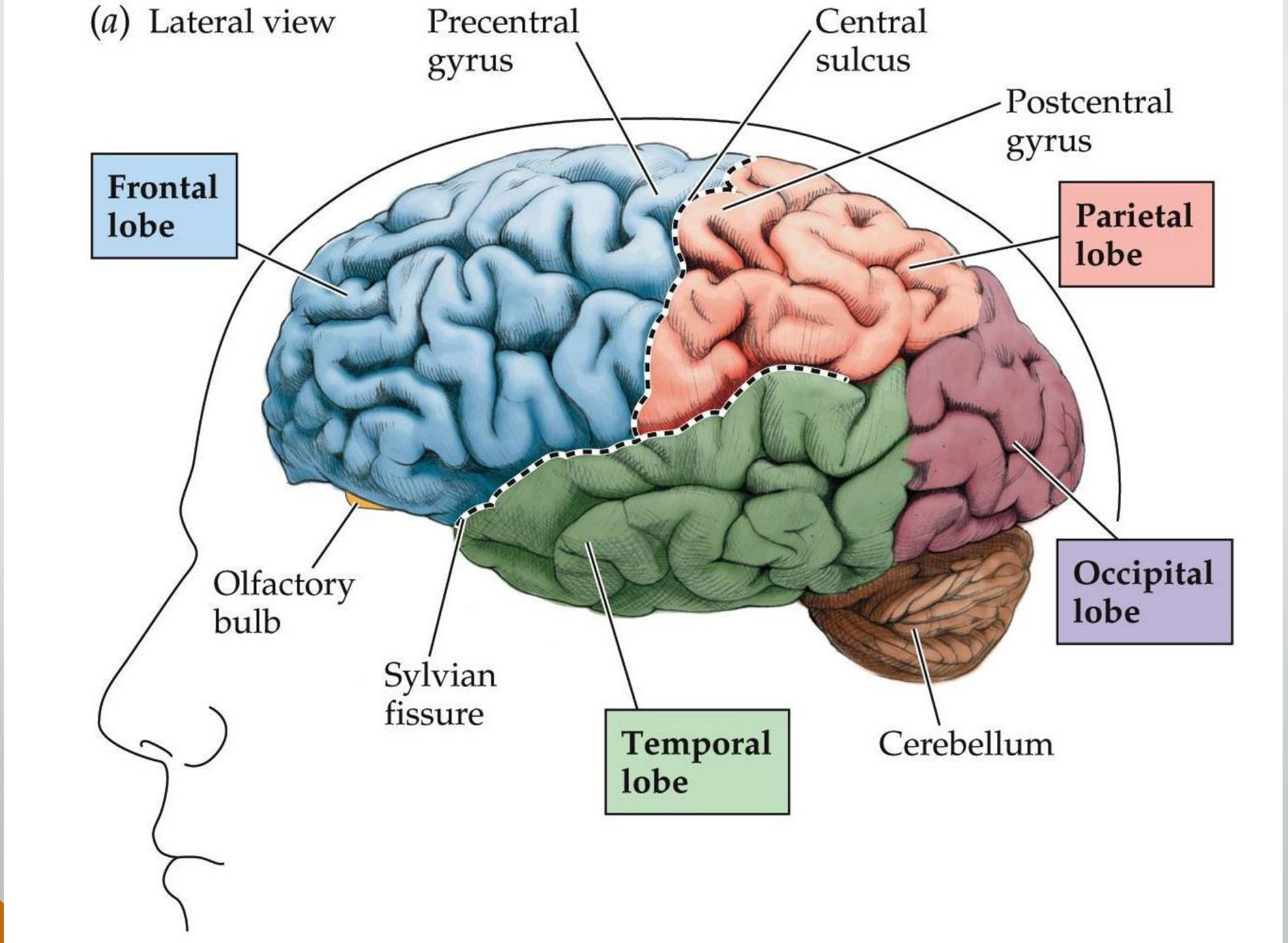
WHAT IS THE BRAIN INITIATIVE?

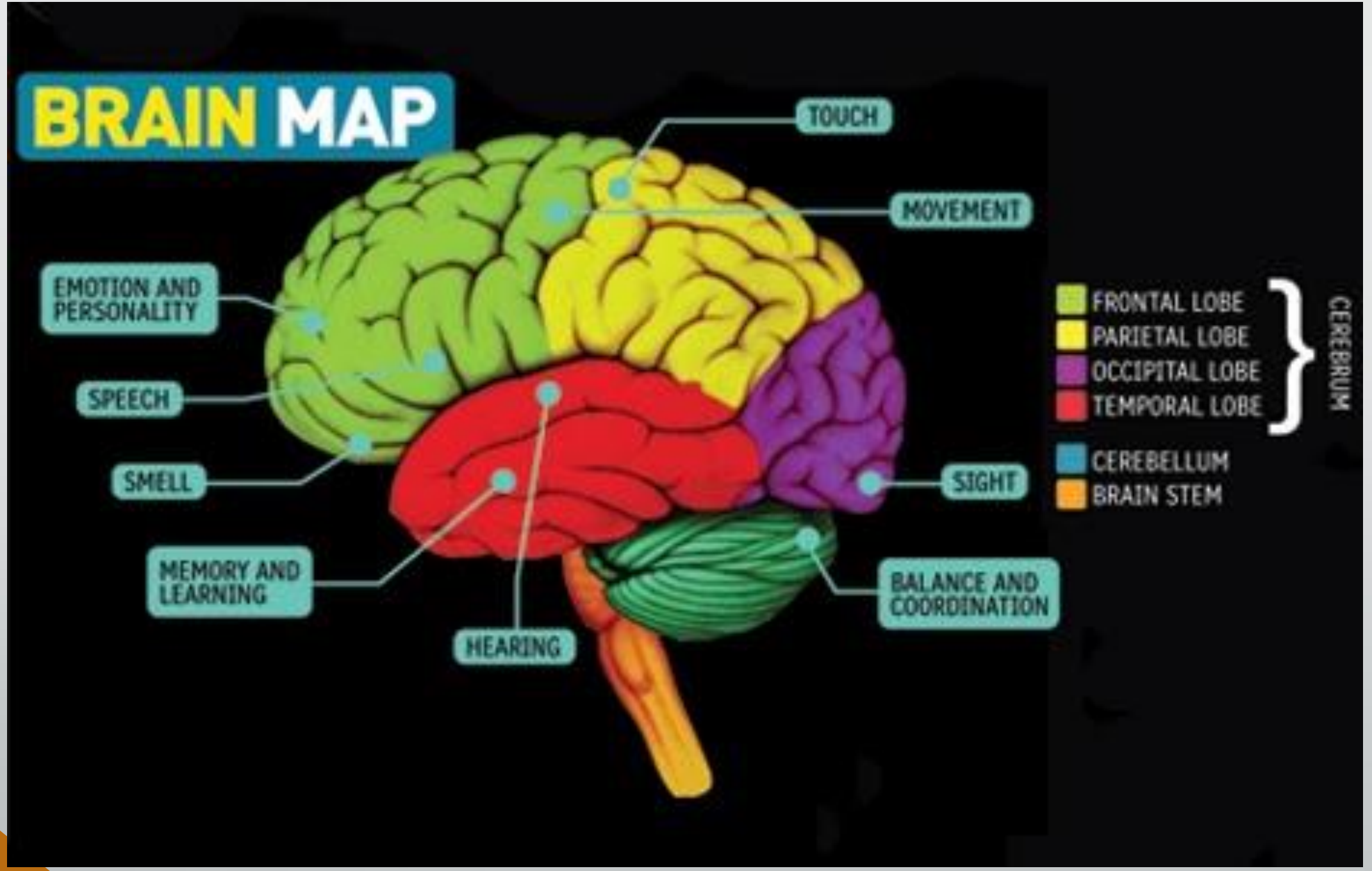
- The Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative is part of a new Presidential focus aimed at revolutionizing our understanding of the human brain.
- By accelerating the development and application of innovative technologies, researchers will be able to produce a revolutionary new dynamic picture of the brain that, for the first time, shows how individual cells and complex neural circuits interact in both time and space.
- Long desired by researchers seeking new ways to treat, cure, and even prevent brain disorders, this picture will fill major gaps in our current knowledge and provide unprecedented opportunities for exploring exactly how the brain enables the human body to record, process, utilize, store, and retrieve vast quantities of information, all at the speed of thought.

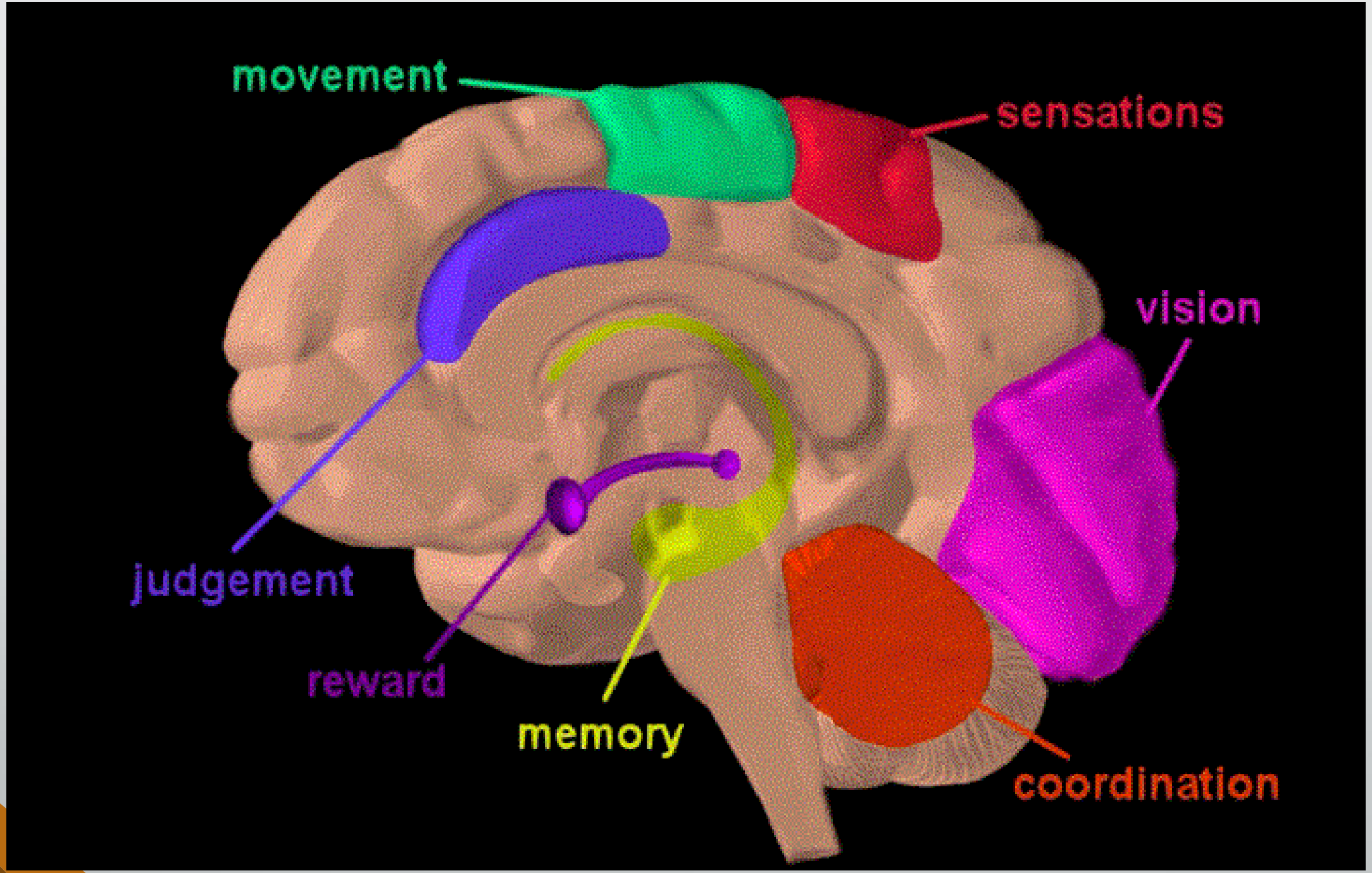


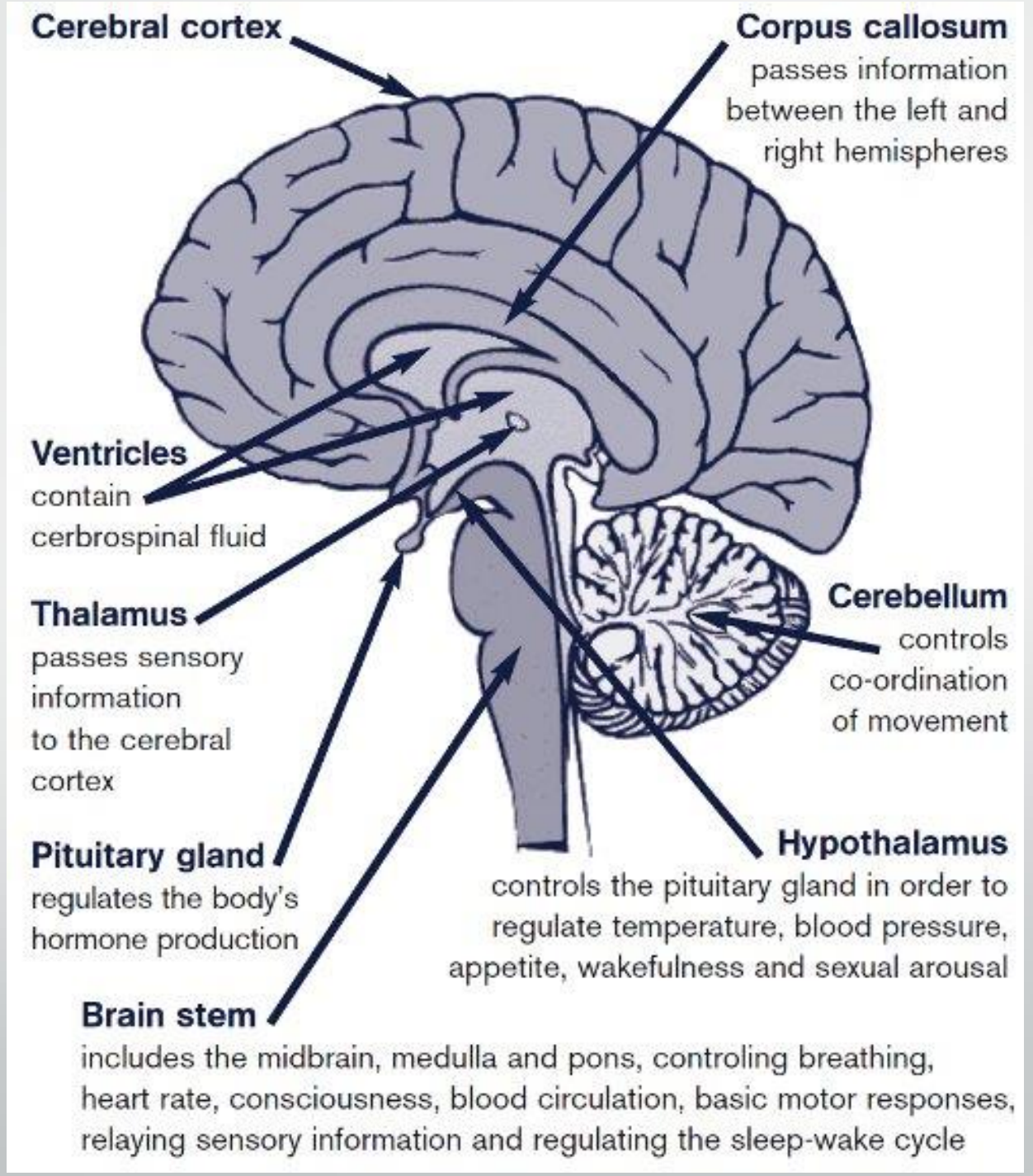
A map of overall task-fMRI brain coverage from the seven tasks used in the Human Connectome Project. Yellow and red represent regions that become more active in most participants during one or more tasks in the MR scanner; blue represents regions that become less active. Source: D.M. Barch for the WU-Minn HCP Consortium.

Review of Functions of Components of Brain

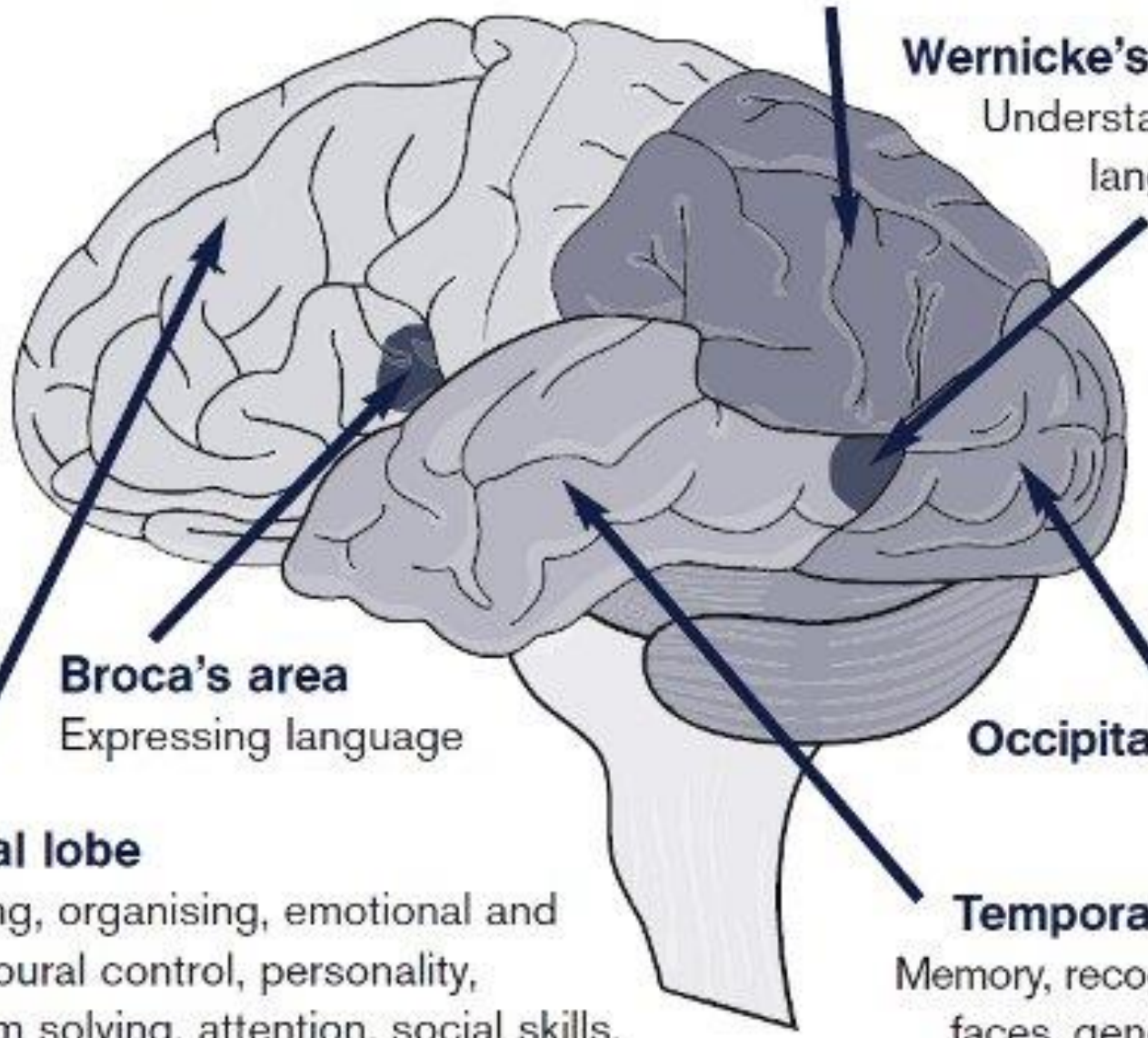

(a) Lateral view
Precentral gyrus
Central sulcus
Postcentral gyrus
Frontal lobe
Parietal lobe
Occipital lobe
Temporal lobe
Olfactory bulb
Sylvian fissure
Cerebellum


BRAIN MAP
TOUCH
MOVEMENT
EMOTION AND PERSONALITY
SPEECH
SMELL
MEMORY AND LEARNING
HEARING
SIGHT
BALANCE AND COORDINATION
FRONTAL LOBE
PARIETAL LOBE
OCCIPITAL LOBE
TEMPORAL LOBE
CEREBRUM
CEREBELLUM
BRAIN STEM


movement
sensations
vision
judgement
reward
memory
coordination


Cerebral cortex
Corpus callosum
passes information between the left and right hemispheres
Ventricles
contain cerbrospinal fluid
Thalamus
passes sensory information to the cerebral cortex
Cerebellum
controls co-ordination of movement
Pituitary gland
regulates the body's hormone production
Hypothalamus
controls the pituitary gland in order to regulate temperature, blood pressure, appetite, wakefulness and sexual arousal
Brain stem
includes the midbrain, medulla and pons, controling breathing, heart rate, consciousness, blood circulation, basic motor responses, relaying sensory information and regulating the sleep-wake cycle

The cerebral cortex



Parietal lobe
Perception, spatial awareness, manipulating objects, spelling

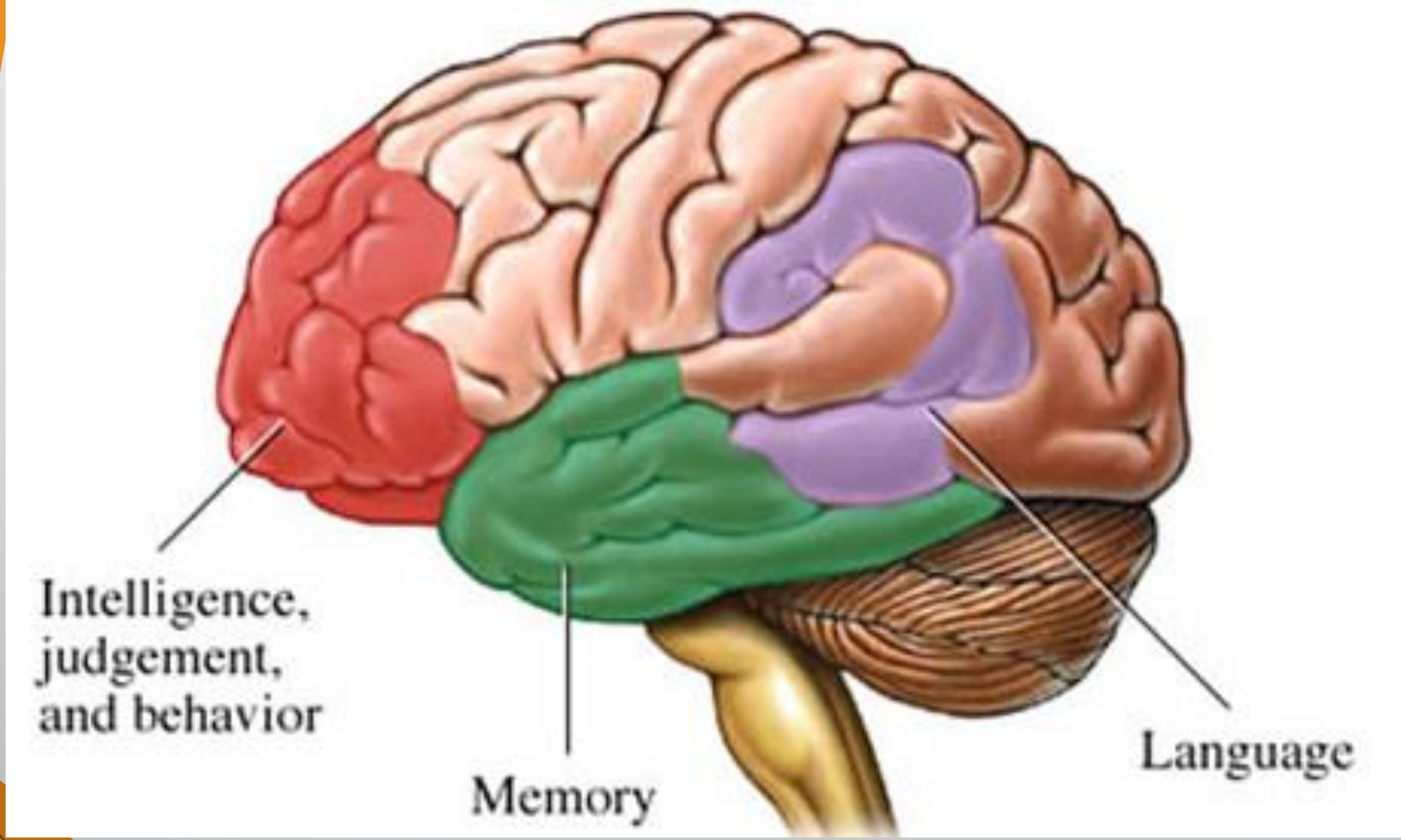
Wernicke's area
Understanding language

Broca's area
Expressing language

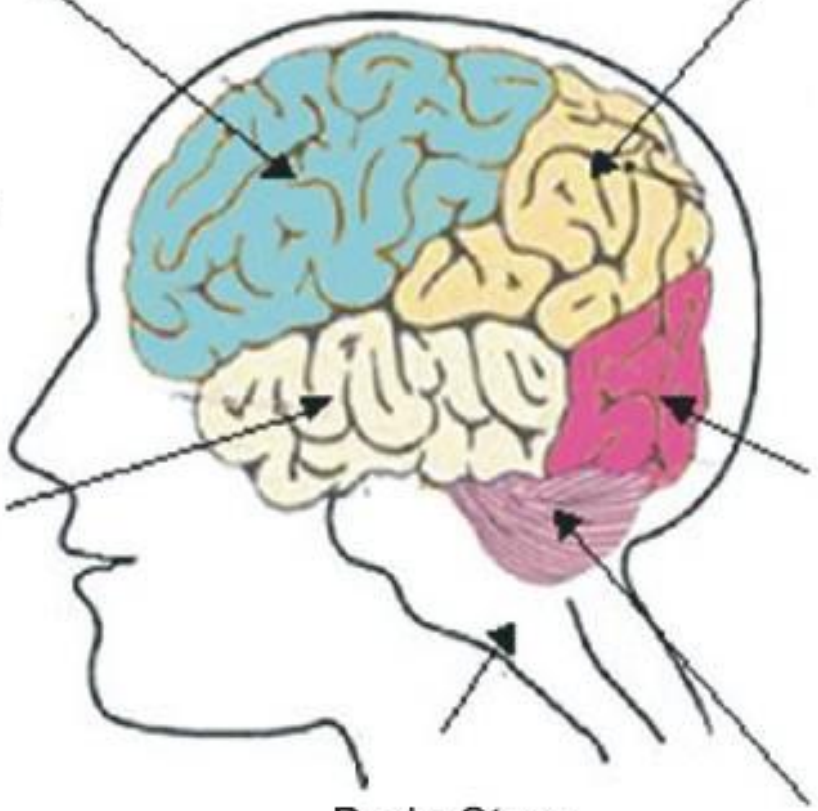
Occipital lobe
Vision

Frontal lobe
Planning, organising, emotional and behavioural control, personality, problem solving, attention, social skills, flexible thinking and conscious movement

Temporal lobe
Memory, recognising faces, generating emotions, language


Intelligence, judgement, and behavior
Memory
Language

Brain Mind Relation



Frontal Lobe

Planning
Reasoning
Problem solving
Morality
Personality
Social Skills
Recognising and
Regulating Emotions
Motor Functions
Motor speech area
of Broca

Parietal Lobe

Recognising sensation,
body position and objects
Sense of time and space
Reading and Comprehension area
Association between
functions of other
lobes

Temporal Lobe

Understanding
Language
Hearing
Speach
Memory
Learning
Sensory speech area
of Wernicke

Occipital Lobe

Vision and Integrating
visual information
(colour, shape and
distance)

Brain Stem

Regulation of heart
beats, respiration,
body temperature
and other essential
body functions

Cerebellum

Balance
Muscular co-ordination

©MSM

Anatomy and Functional Areas of the Brain

Functional Areas of the Cerebral Cortex

1 Visual Area:
- Sight
- Image recognition
- Image perception

2 Association Area
- Short-term memory
- Equilibrium
- Emotion

3 Motor Function Area
- Initiation of voluntary muscles

4 Broca's Area
- Muscles of speech

5 Auditory Area
- Hearing

6 Emotional Area
- Pain
- Hunger
- "Fight or flight" response

7 Sensory Association Area

8 Olfactory Area
- Smelling

9 Sensory Area
- Sensation from muscles and skin

10 Somatosensory Association Area
- Evaluation of weight, texture, temperature, etc. for object recognition

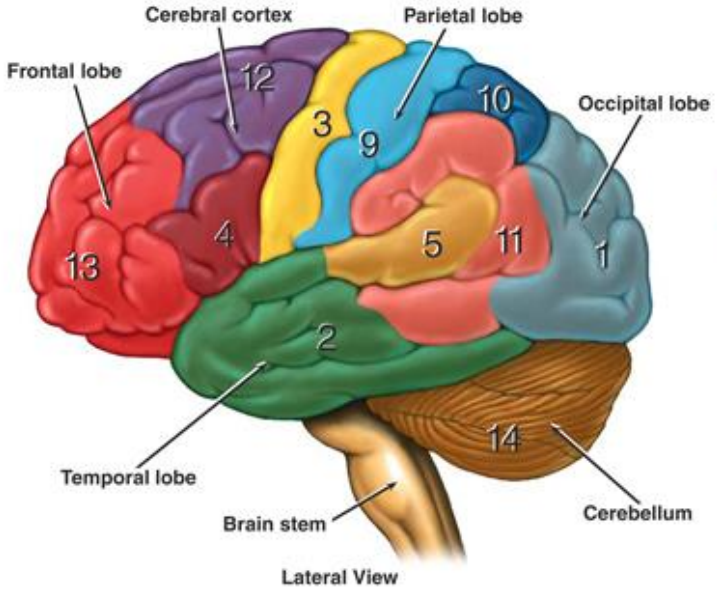
11 Wernicke's Area
- Written and spoken language comprehension

12 Motor Function Area
- Eye movement and orientation

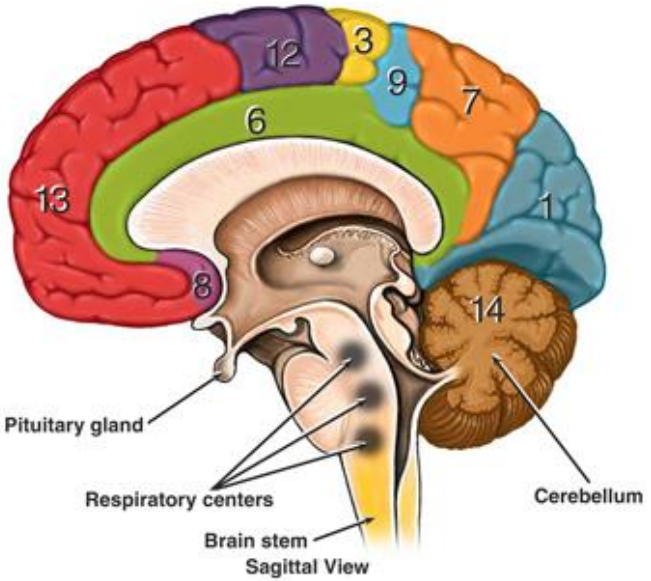
13 Higher Mental Functions
- Concentration
- Planning
- Judgment
- Emotional expression
- Creativity
- Inhibition

Functional Areas of the Cerebellum

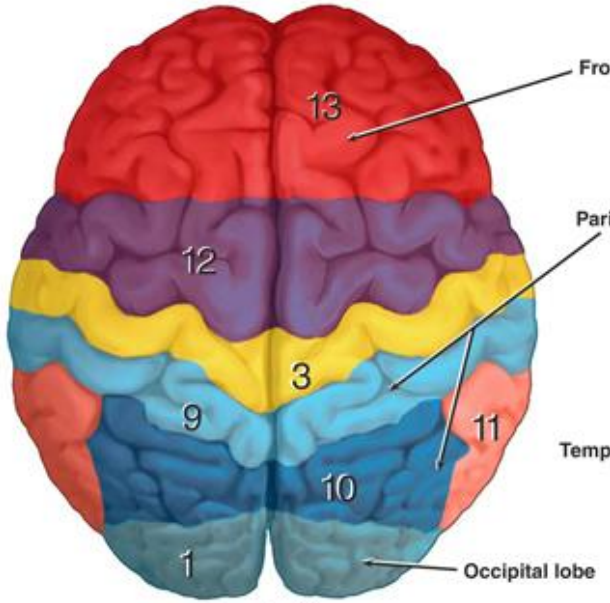
14 Motor Functions
- Coordination of movement
- Balance and equilibrium
- Posture



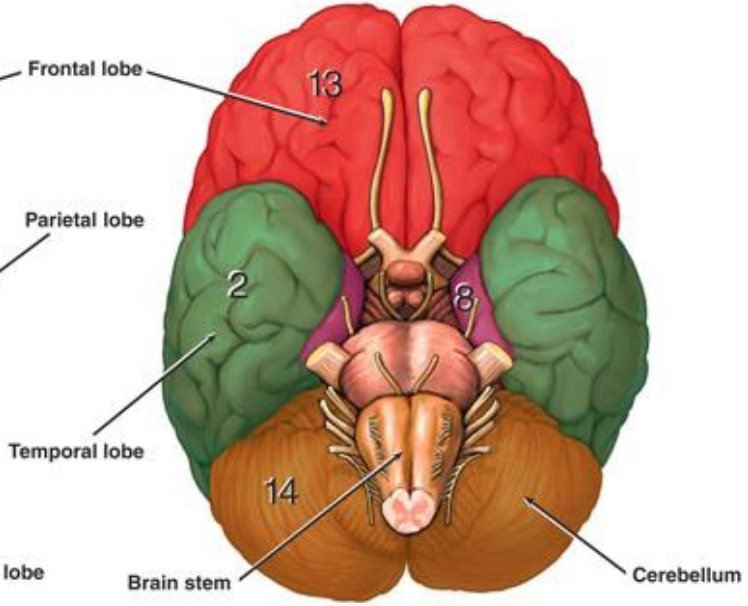
Lateral View



Sagittal View



Superior View



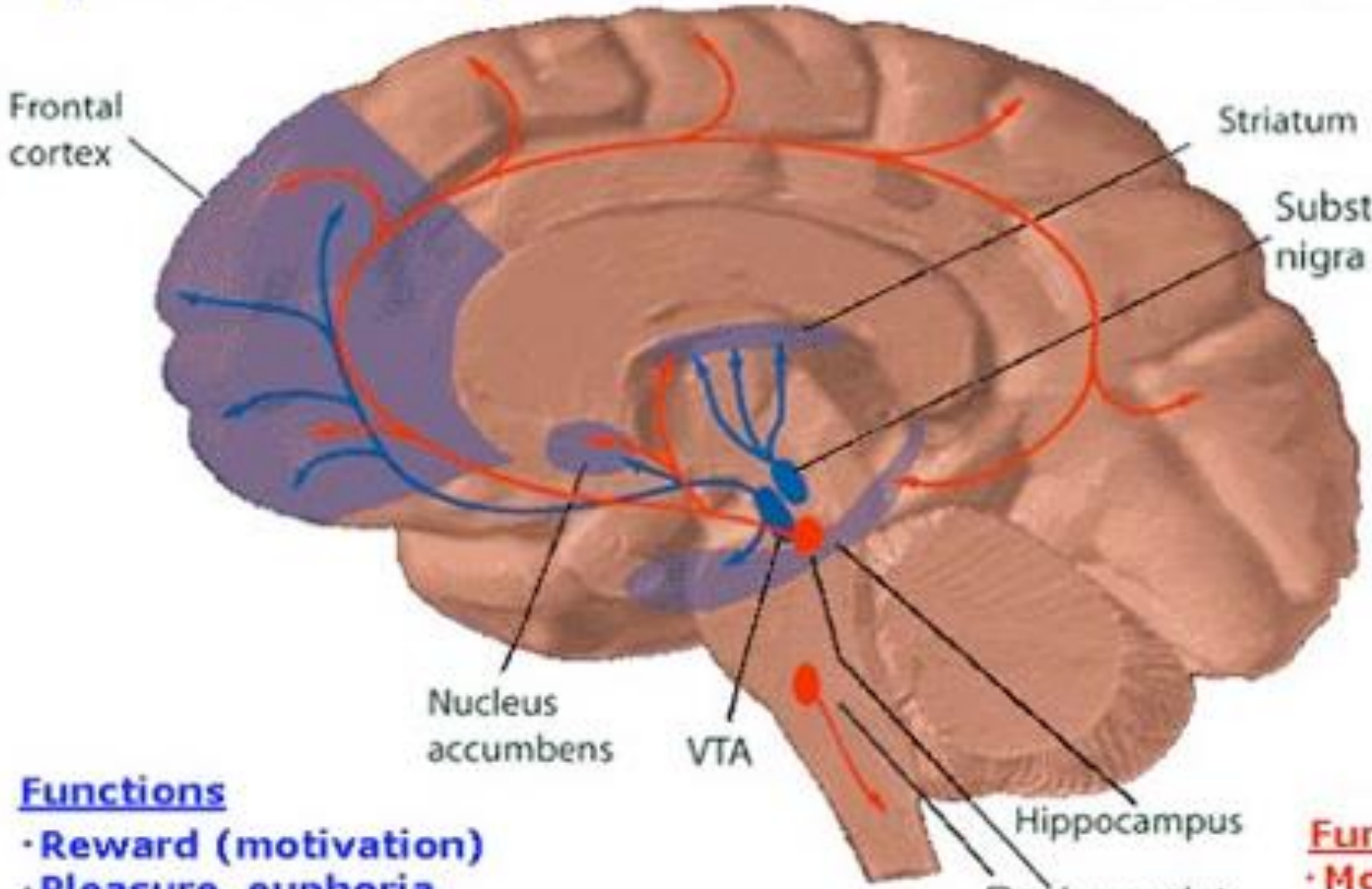
Inferior View

So What Does Neuroscience Tell us about Mental Health Disorders?

Name of Neurotransmitter	Related to:	Related to which Diseases:	Medications that fill in for it
Acetycholine	1. Memory Function 2. Autonomic nervous system regulation 3. Signal transmission from nerves to muscles	Alzheimer's	Nicotine Atropine Curare Botulinum toxin Aricept
Norepinephrine (noradrenaline)	1. Motivation 2. Energy level 3. Socializing 4. appetite 5. basal metabolic rate	Autonomic nervous system disorders (hypertension) Depressive Disorders Anxiety Disorders	Ephedrine Yohimbine Amphetamines Merida Effexor
Dopamine	1. Motor neuron control 2. Concentration 3. Food seeking or Sexual Desire 4. Socializing	Parkinson's Schizophrenia ADHD Addictions	L-dopa Amphetamines
Serotonin	1. Mood 2. Food intake regulation (vomiting) 3. Limbic system functioning 4. Pain 5. Sleep	Depressive Disorders Anxiety Disorders Appetite Disorders Migraines	Prozac Paxil Imitrex
Gamma-aminobutyric acid(GABA) (Inhibitory Neurotransmitter)	Affects: 1. Emotional Balance 2. Sleep Patterns 3. Anxiety	Anxiety Disorders Restlessness Sleeplessness Insomnia	Benzodiazepines Barbiturates
Glutamate (Excitatory Neurotransmitter)	Associated with potentiation of other neurotransmitters	Psychoses Epilepsy	Lamitrigine (Lamictal)
b-Endorphin	Affects perception of pain	Addictions	Morphine Heroine Codeine

Dopamine Pathways

Serotonin Pathways

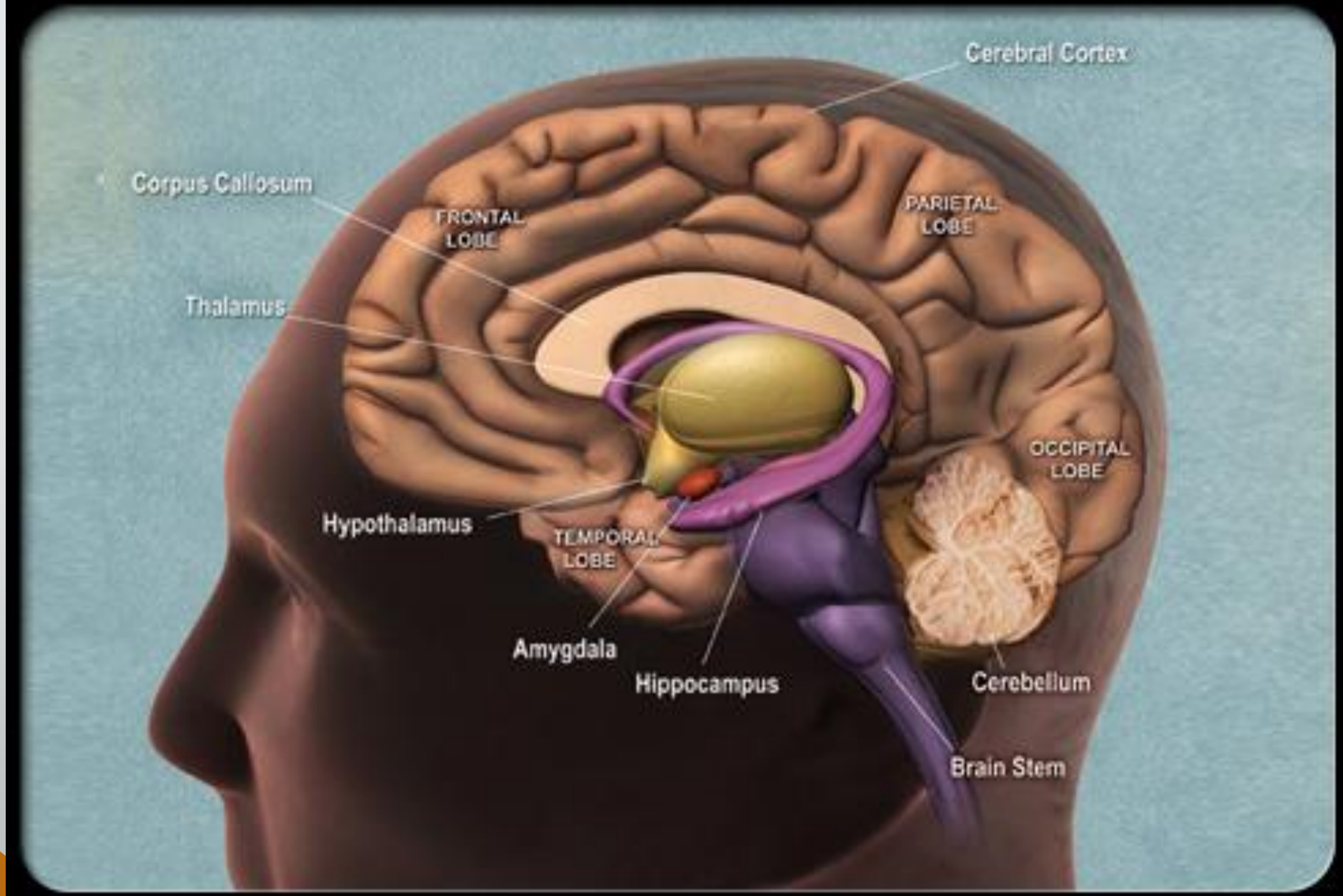


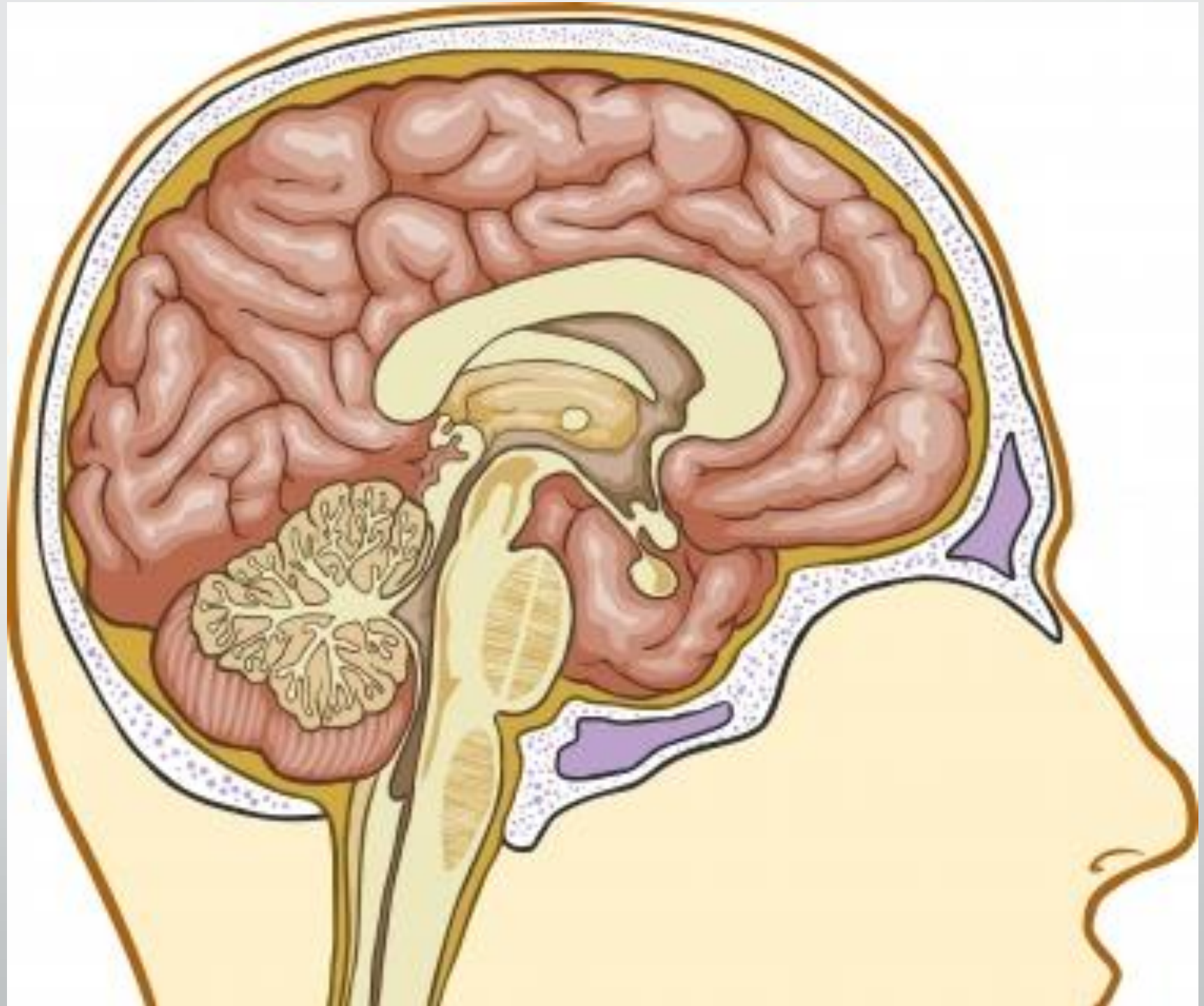
Functions

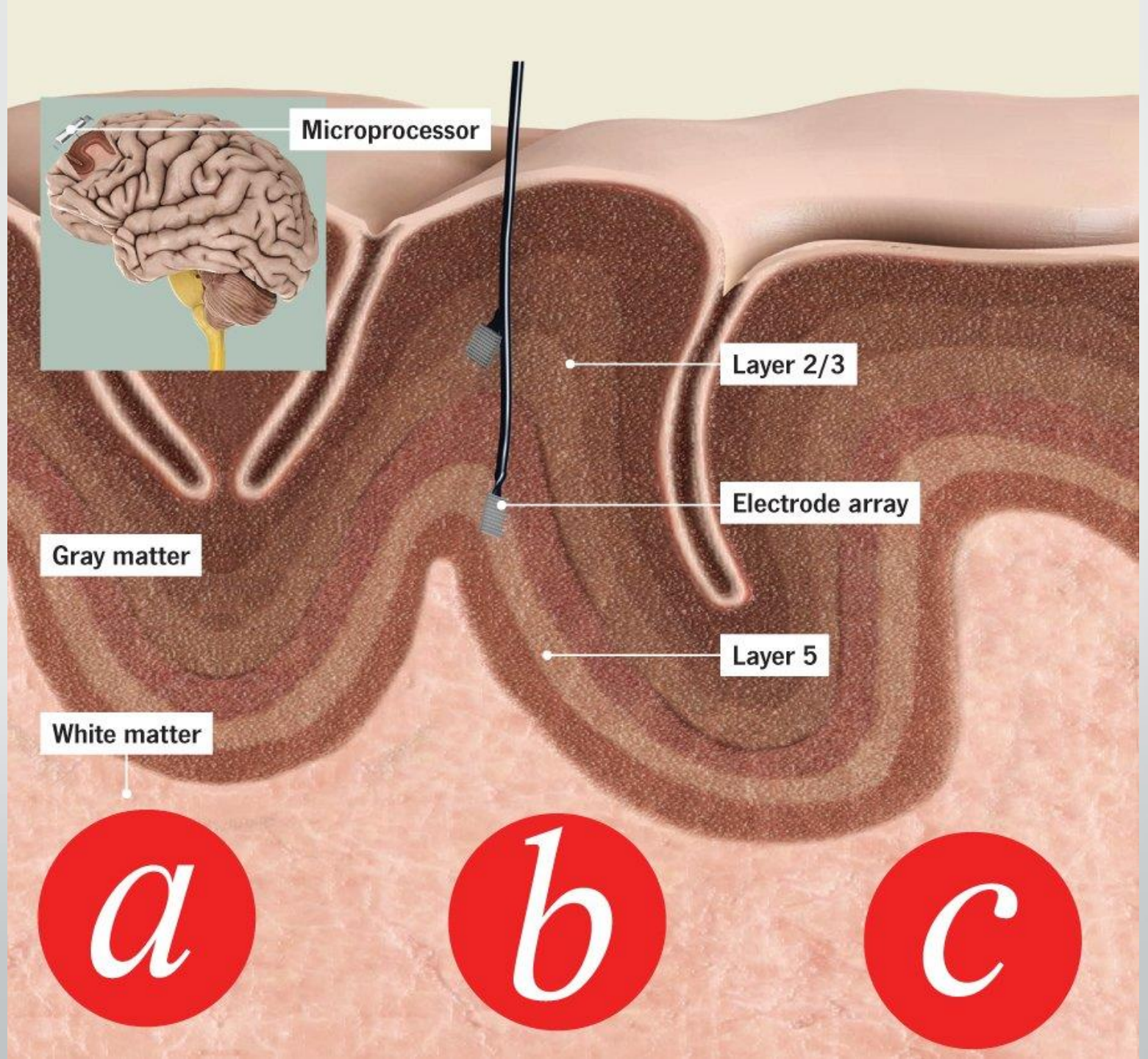
- Reward (motivation)
- Pleasure, euphoria
- Motor function (fine tuning)
- Compulsion
- Perseveration

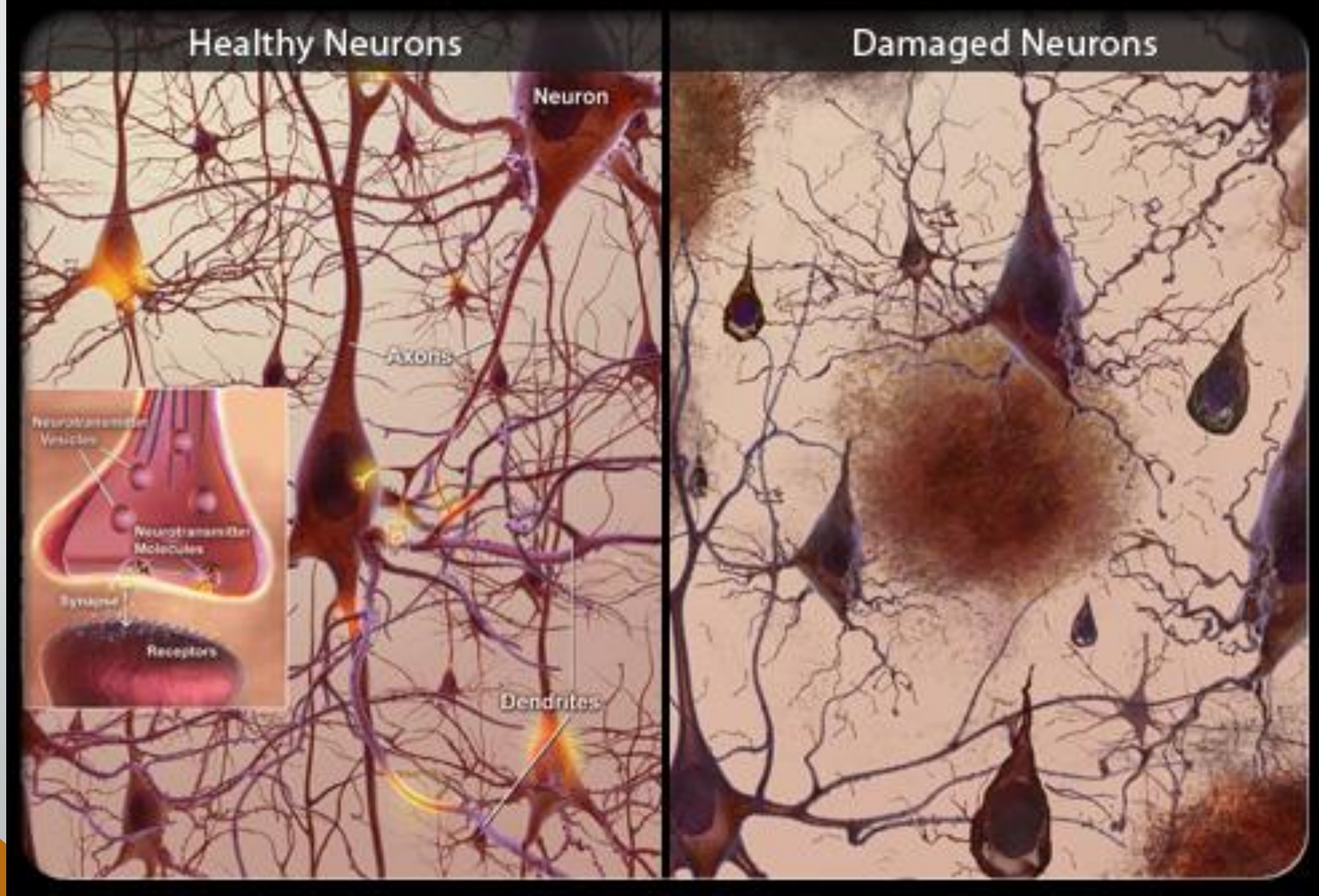
Functions

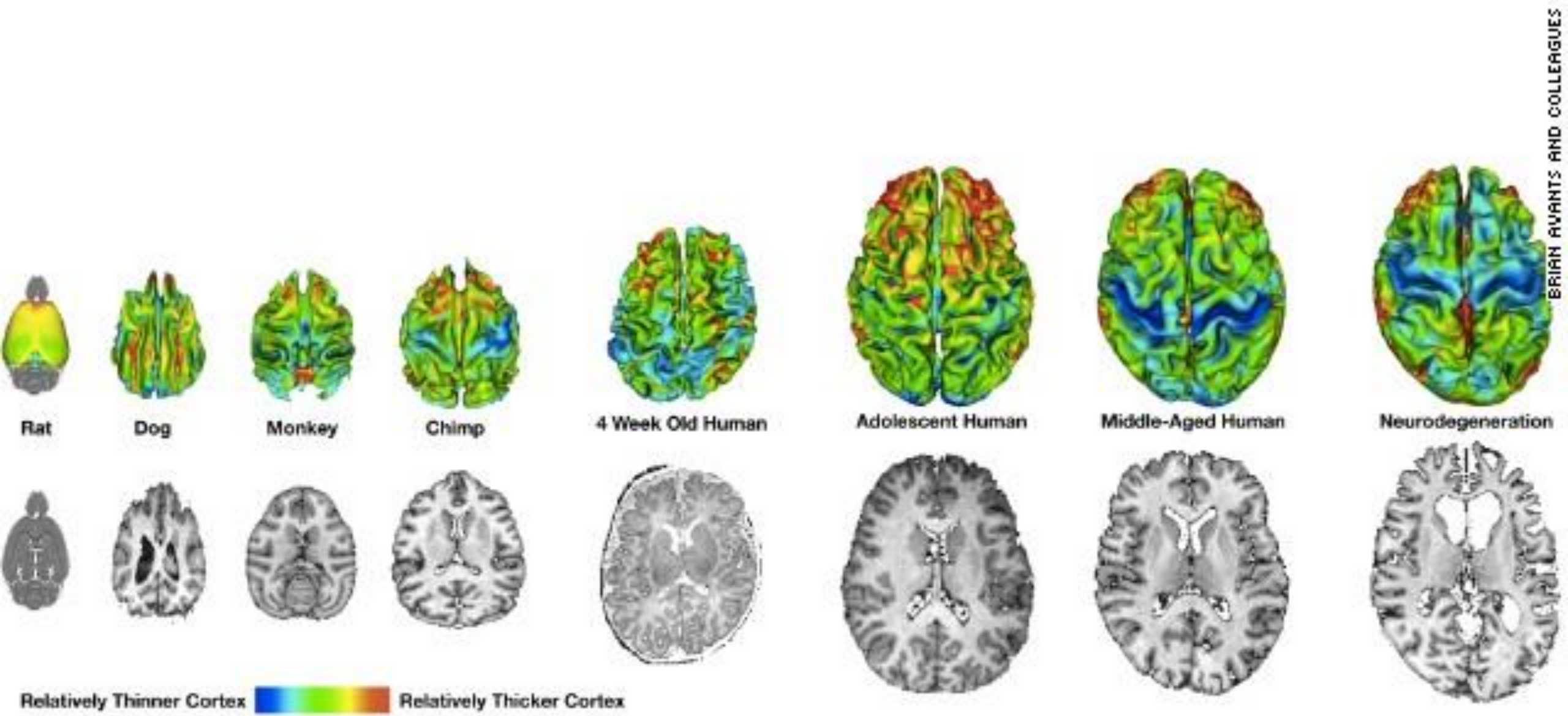
- Mood
- Memory processing
- Sleep
- Cognition

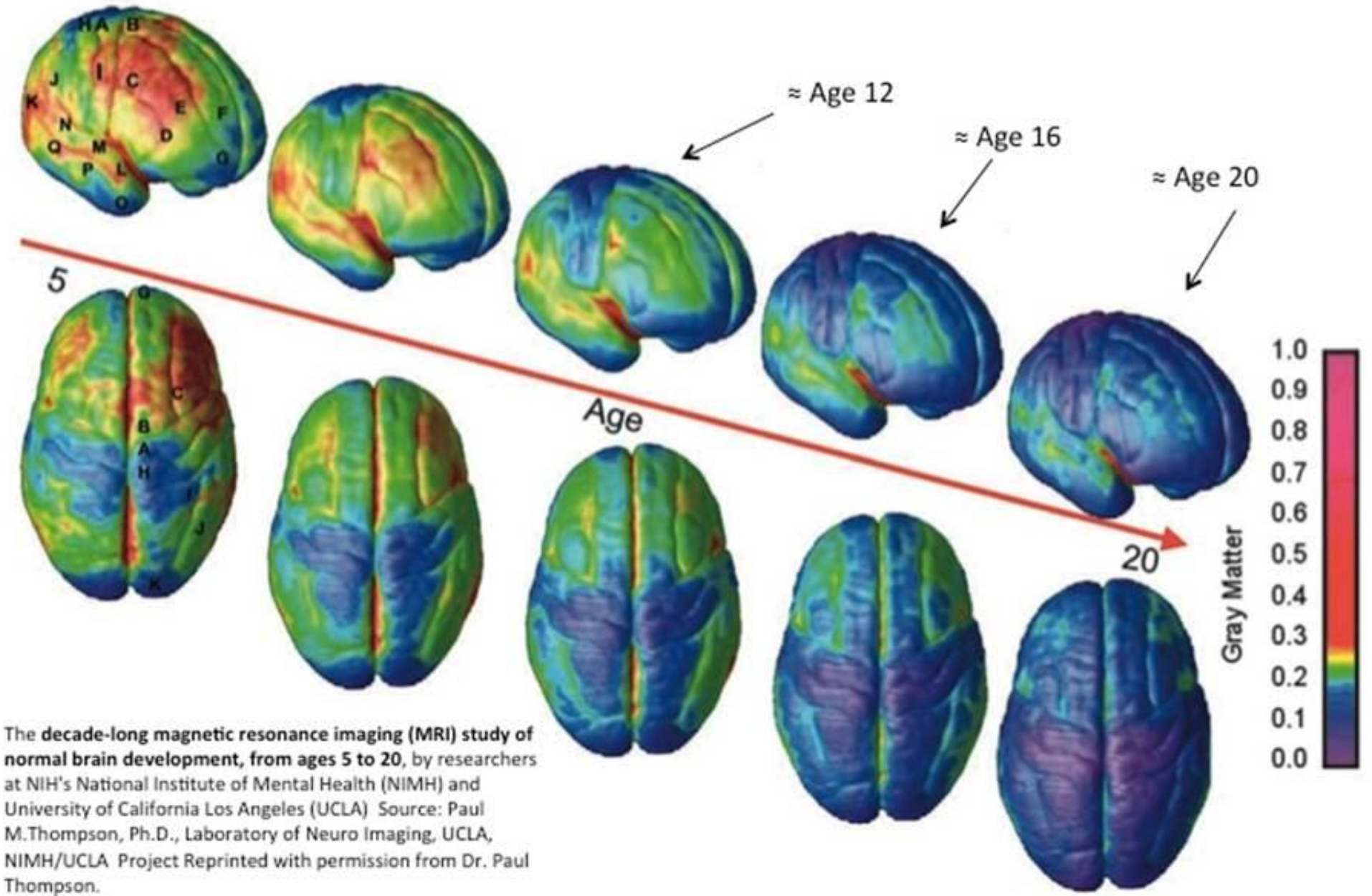

Cerebral Cortex
Corpus Callosum
FRONTAL LOBE
PARIETAL LOBE
Thalamus
OCCIPITAL LOBE
Hypothalamus
TEMPORAL LOBE
Amygdala
Hippocampus
Cerebellum
Brain Stem




Microprocessor
Layer 2/3
Electrode array
Gray matter
Layer 5
White matter
a
b
c


Healthy Neurons
Neuron
Axons
Dendrites
Receptors
Damaged Neurons


Rat
Dog
Monkey
Chimp
4 Week Old Human
Adolescent Human
Middle-Aged Human
Neurodegeneration
Relatively Thinner Cortex
Relatively Thicker Cortex
BRIAN AVANTS AND COLLEAGUES



The **decade-long magnetic resonance imaging (MRI) study of normal brain development, from ages 5 to 20**, by researchers at NIH's National Institute of Mental Health (NIMH) and University of California Los Angeles (UCLA) Source: Paul M.Thompson, Ph.D., Laboratory of Neuro Imaging, UCLA, NIMH/UCLA Project Reprinted with permission from Dr. Paul Thompson.

Brain Mapping Expands Understanding of Mental Health Disorders

Just one example of use of PET scans:

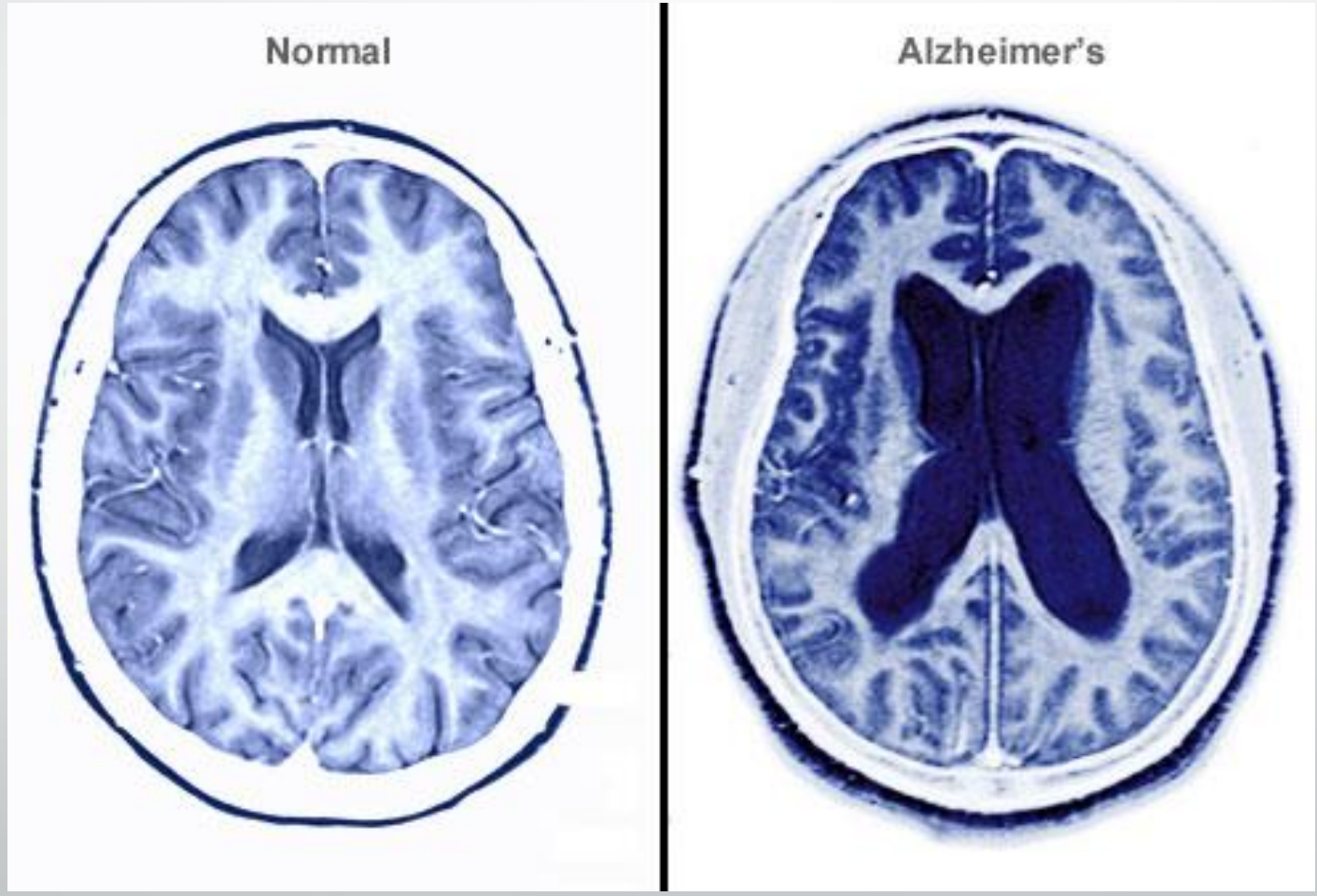
- Using the brain mapping technique called positron emission tomography (PET scan)
- people who are willing to work hard for rewards had a higher release of dopamine in areas of the brain known to play a role in reward and motivation, the striatum and ventromedial prefrontal cortex.
- On the other hand, those who were less willing to work hard for a reward had high dopamine levels in another area of the brain that plays a role in emotion and risk perception, the anterior insula.

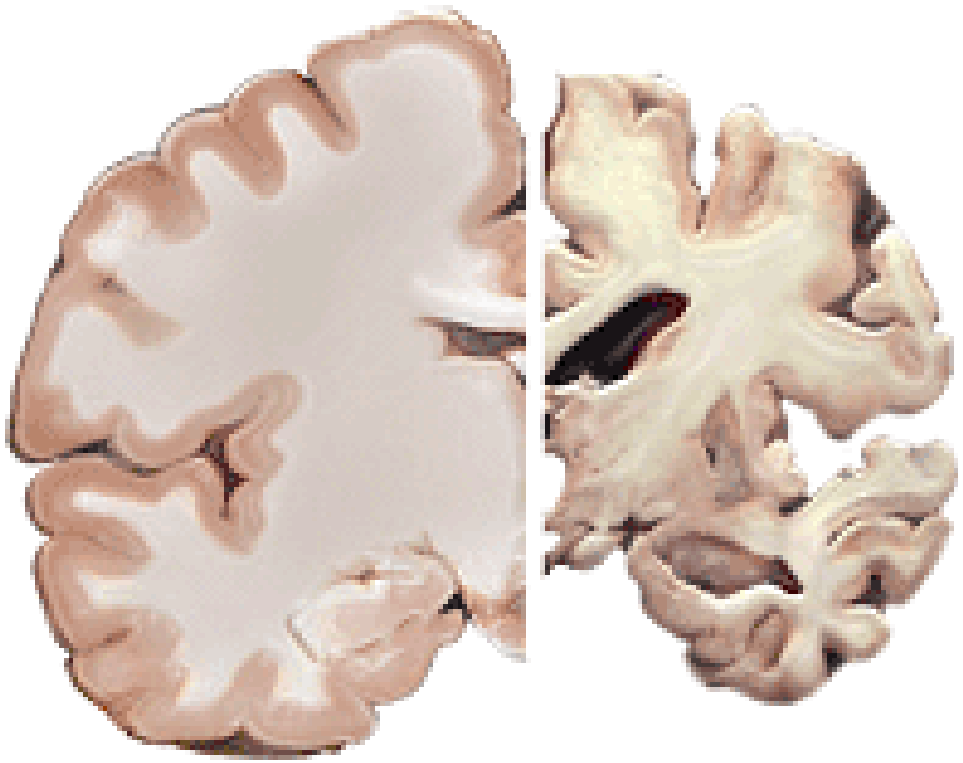
Comparing fMRI, PET, ERP, & MEG

- fMRI has best spatial resolution & localization
- ERP and MEG have best temporal resolution (PET has worst temporal resolution)
- PET use of radioactive compounds is both a disadvantage (for obvious reasons) and an advantage (can radioactively label many different compounds).
- Cost and availability: ERP is the least expensive, then fMRI and MEG, and then PET.

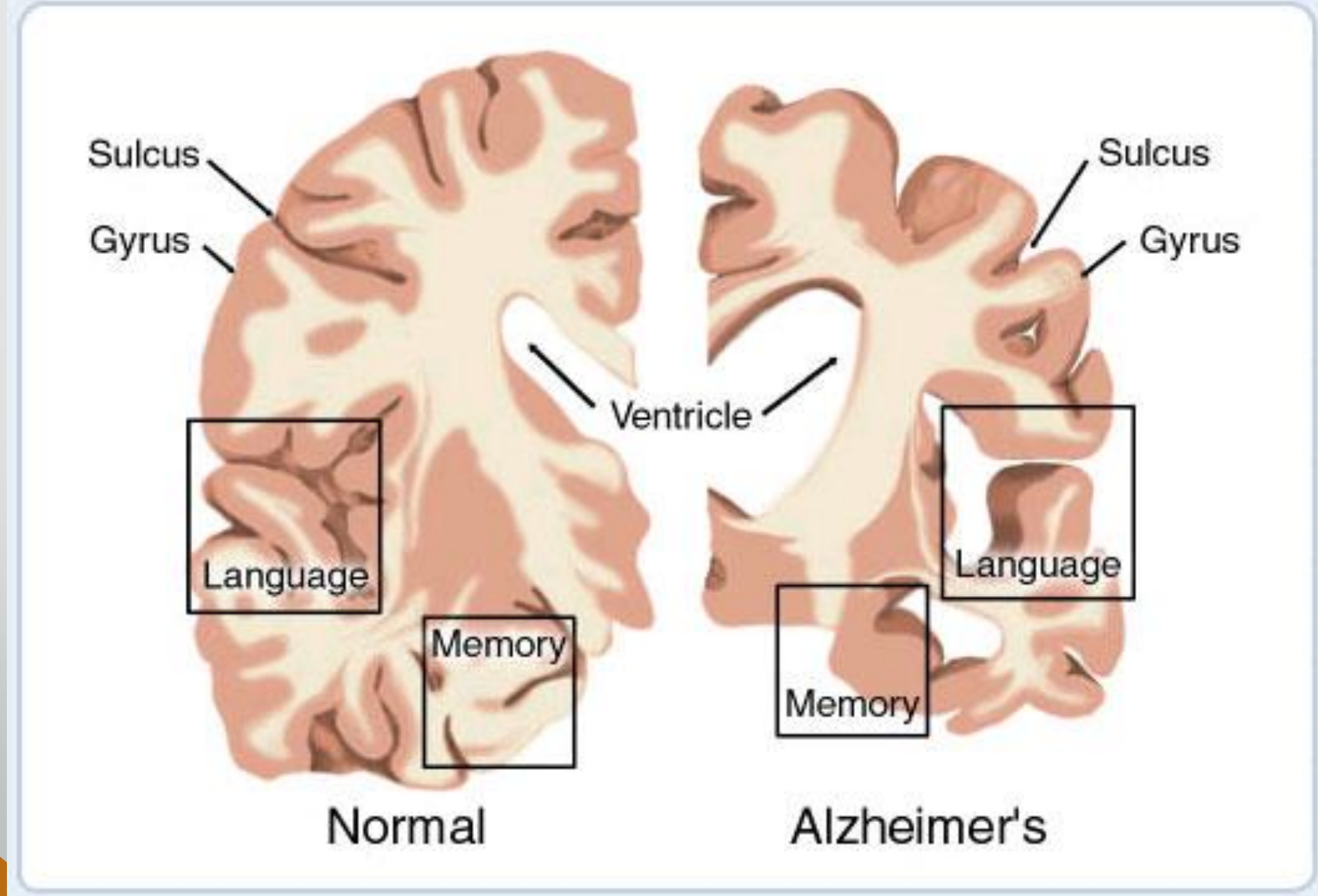
fMRI has become the method of choice

Alzheimer's Disease



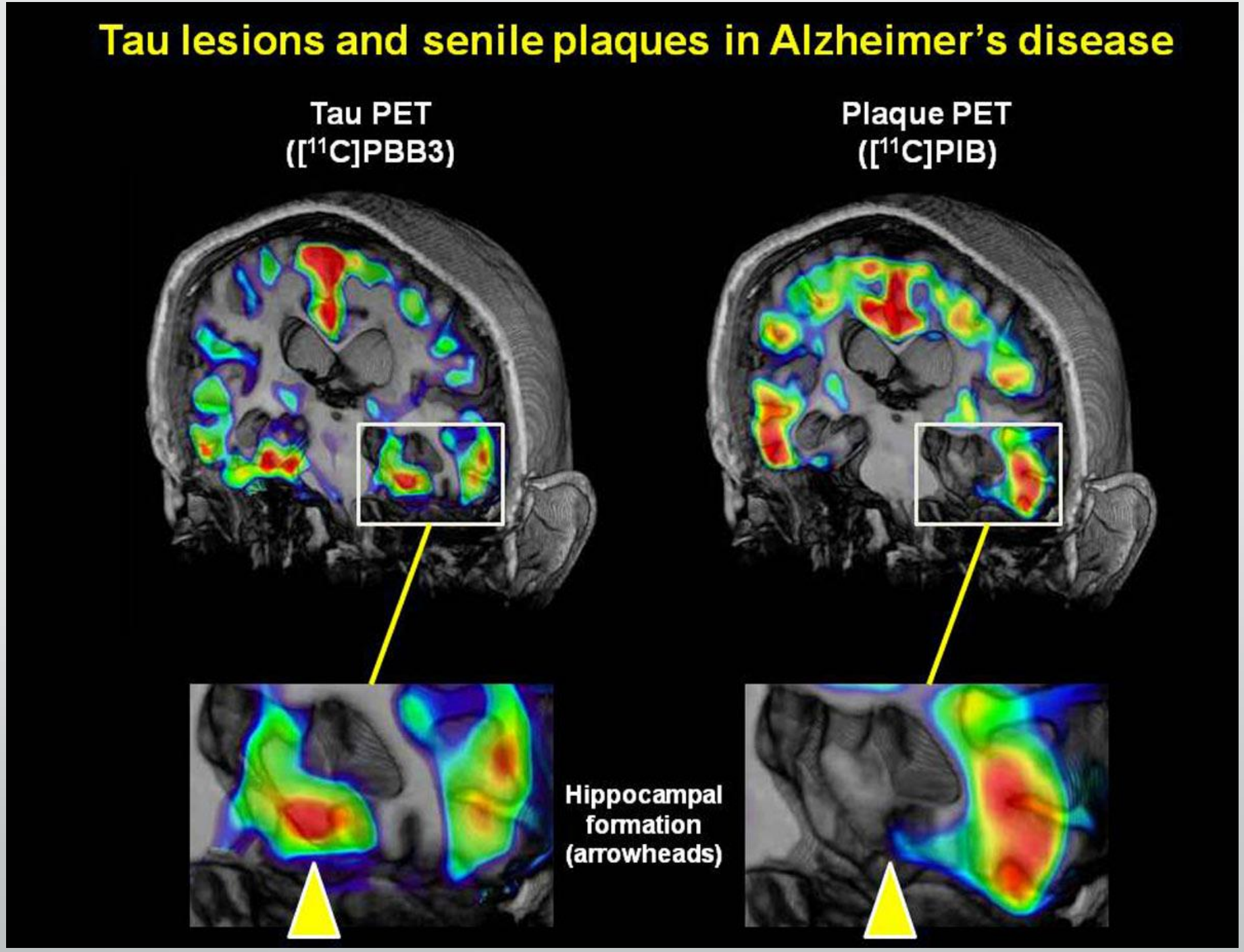


Neuronal cell loss leading to extensive shrinkage in an Alzheimer's brain (right), as compared to a nondemented, healthy human brain (left). Courtesy NIA.


Sulcus
Gyrus
Ventricle
Language
Memory
Sulcus
Gyrus
Language
Memory
Normal
Alzheimer's

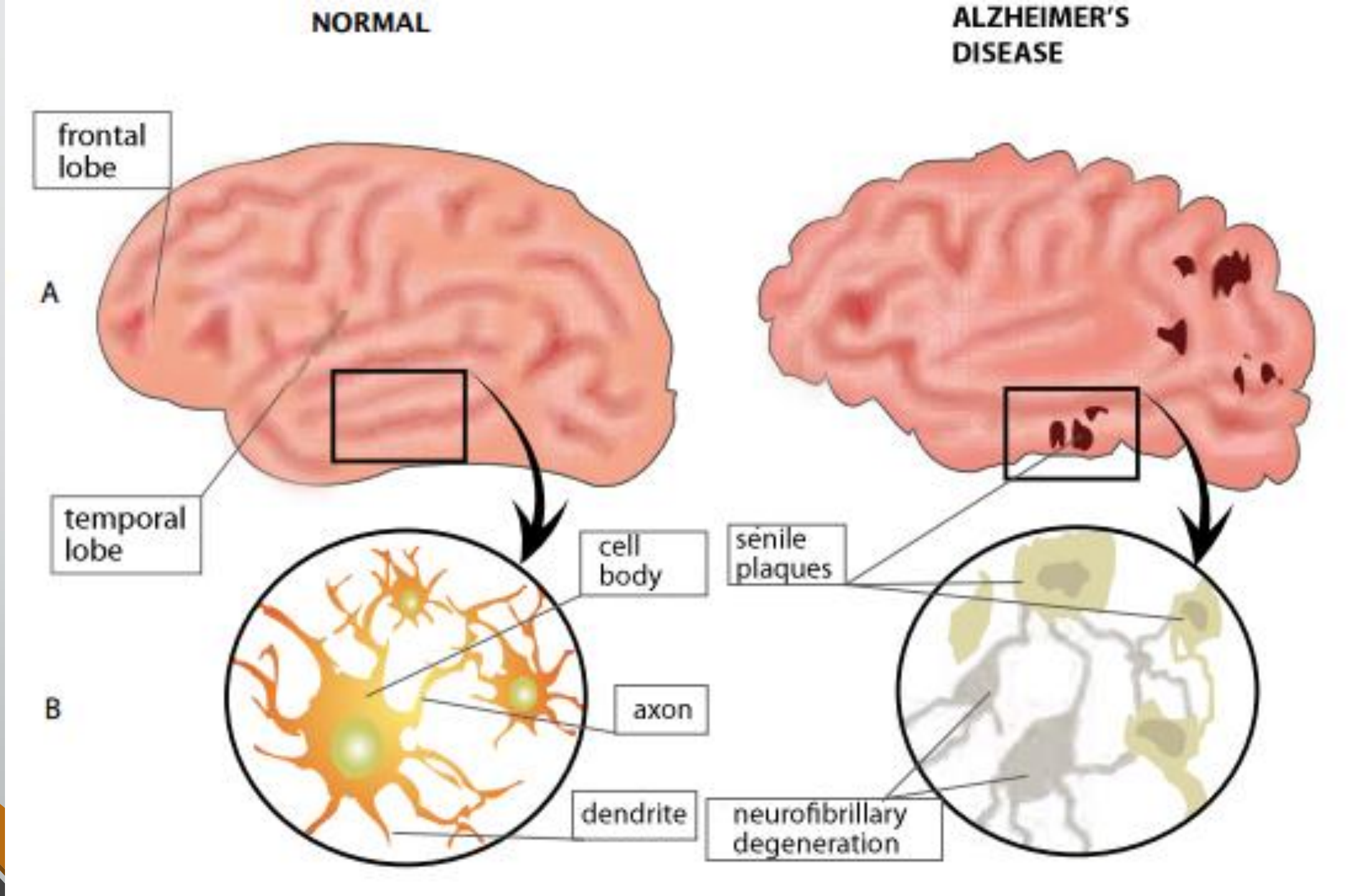
Alzheimer’s and the Brain

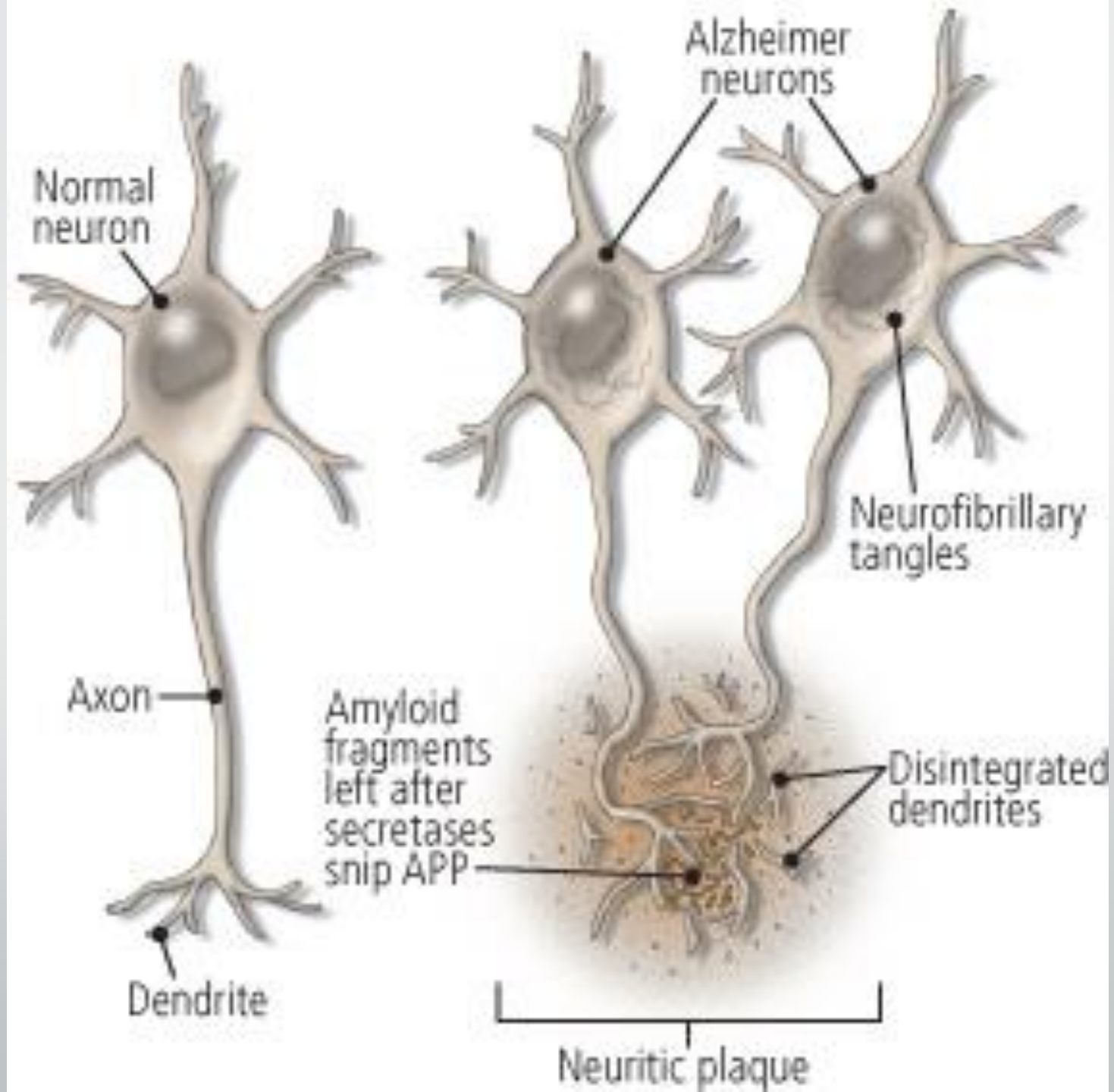
- Alzheimer's disease leads to nerve cell death and tissue loss throughout the brain.
- As the disease progresses, brain tissue shrinks and the ventricles (chambers within the brain that contain cerebrospinal fluid) become larger.
- The damage disrupts communication between brain cells, crippling memory, speech, and comprehension.
- Alzheimer's disease takes a different path in every patient.
- In some people the symptoms worsen quickly, leading to severe memory loss and confusion within a few years.
- In others, the changes may be more gradual with the disease taking 20 years to run its course.
- The average length of survival after a diagnosis of Alzheimer's is three to nine years.

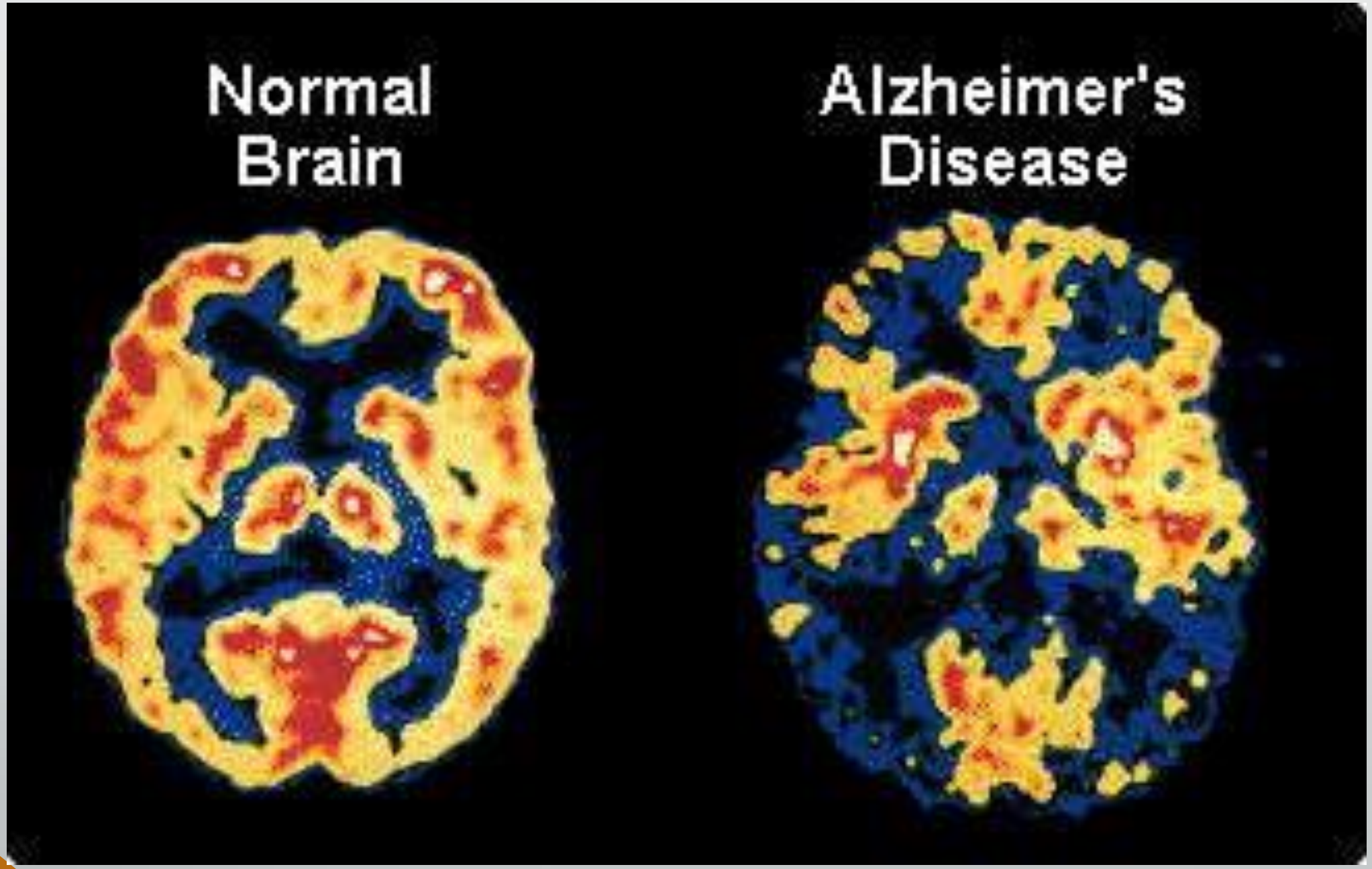

Tau lesions and senile plaques in Alzheimer's disease
Tau PET
([11C]PBB3)
Plaque PET
([11C]PIB)
Hippocampal formation (arrowheads)

Early Stage Alzheimer's Symptoms

- Short-term memory loss is the most common early symptom of Alzheimer's disease.
- Difficulty performing familiar tasks.
- Disorientation.
- Increasing problems with planning and managing.
- Trouble with language
- Rapid, unpredictable mood swings.
- Lack of motivation.
- Changes in sleep


NORMAL
ALZHEIMER'S DISEASE
frontal lobe
A
temporal lobe
cell body
senile plaques
B
axon
dendrite
neurofibrillary degeneration


Alzheimer neurons
Normal neuron
Neurofibrillary tangles
Axon
Amyloid fragments left after secretases snip APP
Disintegrated dendrites
Dendrite
Neuritic plaque


Normal
Brain
Alzheimer's
Disease

Middle & Later Stage Alzheimer's Symptoms

Middle Stage Symptoms

- Once a person enters the middle stage, Alzheimer’s disease symptoms begin to demand constant attention and care.

Symptoms linked to the middle stages of Alzheimer’s disease include:

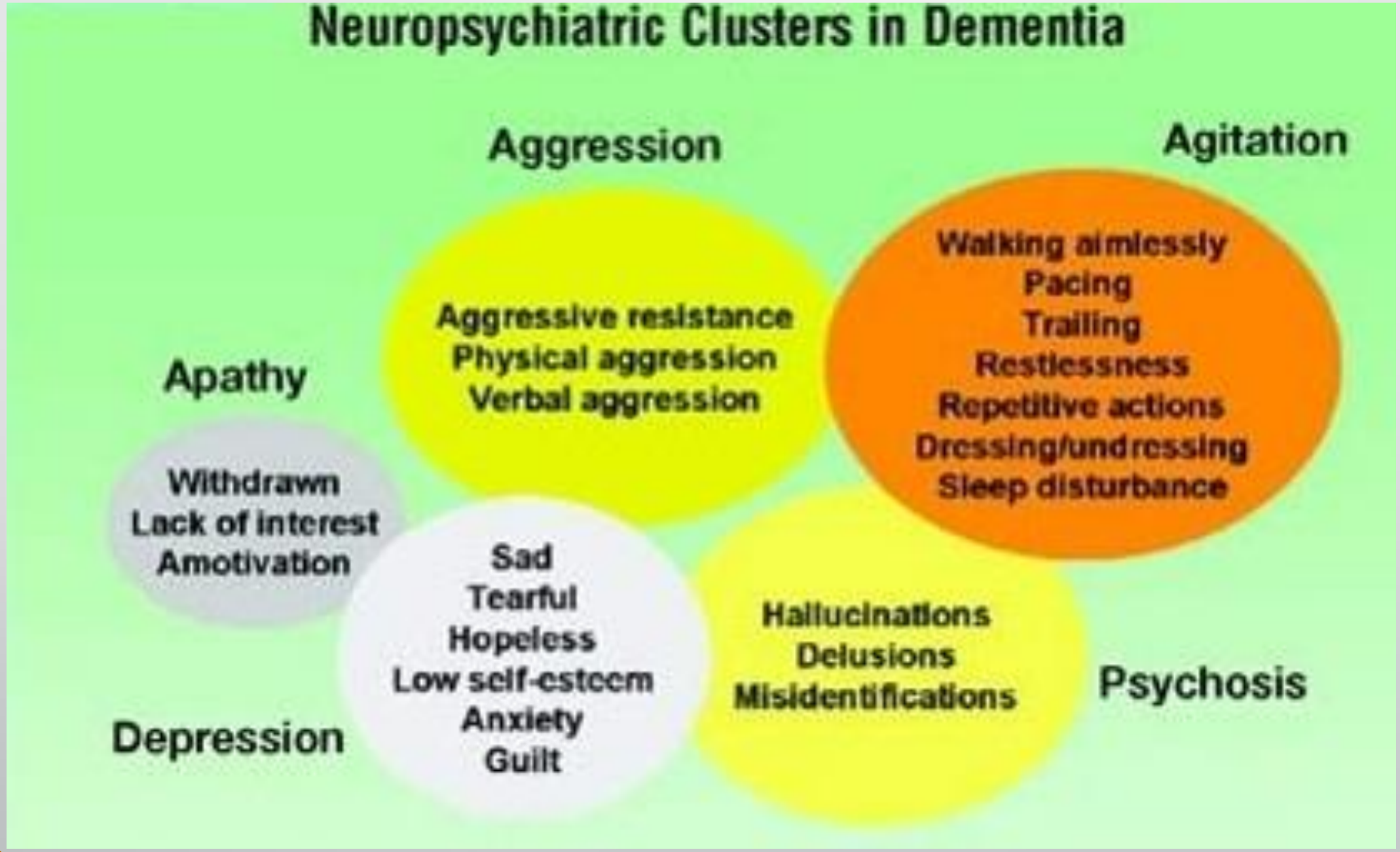
- Difficulty completing everyday tasks, such as getting dressed, going to bathroom, or preparing meals
- Hallucinations
- Strong feelings of paranoia and anger
- Wandering

Later Stage Symptoms

- In the later stages, a person with Alzheimer’s disease is unable to care for himself or herself at all.

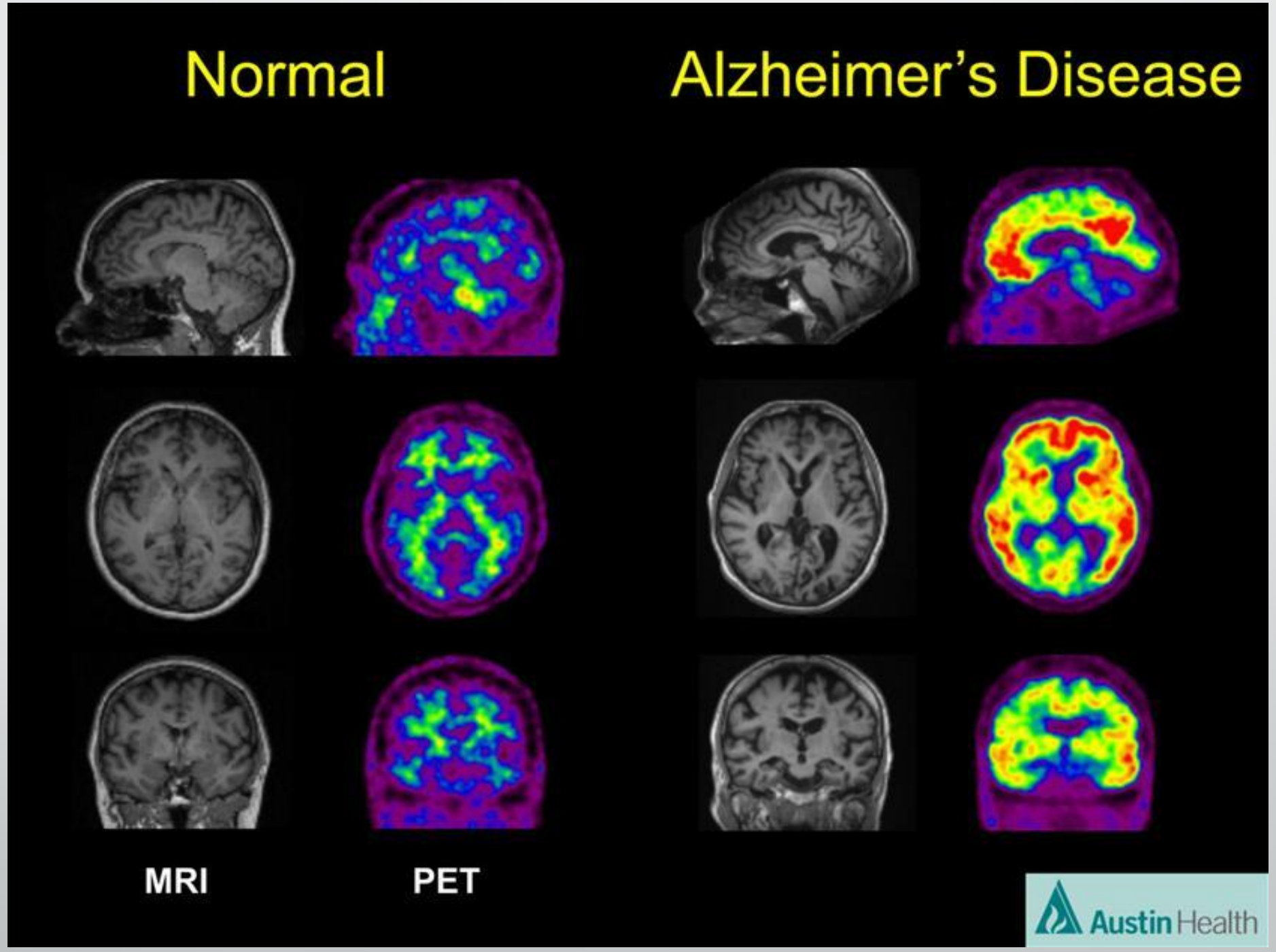
Late-stage Alzheimer's disease symptoms:

- Inability to communicate with or recognize other people
- Inability to walk
- Difficulty swallowing
- Inability to smile


Neuropsychiatric Clusters in Dementia
Aggression
Agitation
Aggressive resistance
Physical aggression
Verbal aggression
Walking aimlessly
Pacing
Trailing
Restlessness
Repetitive actions
Dressing/undressing
Sleep disturbance
Apathy
Withdrawn
Lack of interest
Amotivation
Sad
Tearful
Hopeless
Low self-esteem
Anxiety
Guilt
Hallucinations
Delusions
Misidentifications
Psychosis
Depression

Is Alzheimer's Disease Hereditary?

- Genetic research has turned up evidence of a link between Alzheimer's disease and genes on four chromosomes, labeled numerically as 1, 14, 19, and 21.
- The APOE gene on chromosome 19 has been linked to late-onset Alzheimer's disease, which is the most common form of the disease. Dozens of studies around the world have confirmed that inheritance of one particular variant of the APOE gene, termed APOE4, increases the lifetime risk of developing Alzheimer's disease.
- One of the puzzles surrounding APOE is why some people with the APOE4 variant do not develop Alzheimer's disease and why, conversely, many people develop the disease even though they have not inherited APOE4 . APOE, in other words, although clearly influencing the risk of developing Alzheimer's, is not a consistent genetic marker for the disease.


Normal
Alzheimer's Disease
MRI
PET
Austin Health

What Is the Role of Genetics in Familial Alzheimer's Disease?

- Alzheimer's disease strikes early and fairly often in certain families, often enough to be singled out as a separate form of the disease and given a label: early-onset familial Alzheimer's disease, or FAD. Combing through the DNA of these families, researchers have found an abnormality in one gene on chromosome 21 that is common to a few of the families. And they have linked a much larger proportion of early-onset families to recently identified and related genes on chromosomes 1 and 14.
- The chromosome 21 gene also intrigues Alzheimer's researchers because of its role in Down syndrome. People with Down syndrome have an extra copy of chromosome 21 and, as they grow older, usually develop abnormalities in the brain like those found in Alzheimer's disease, though often at a younger age.
- Few researchers think that the search for Alzheimer's genes is over. Most investigators are convinced that there are many more genes involved in Alzheimer's disease and, moreover, that other conditions must also be present for the disease to develop. One of these conditions may be a problem with the way in which nerves turn sugar, or glucose, into energy, a process known as glucose metabolism.