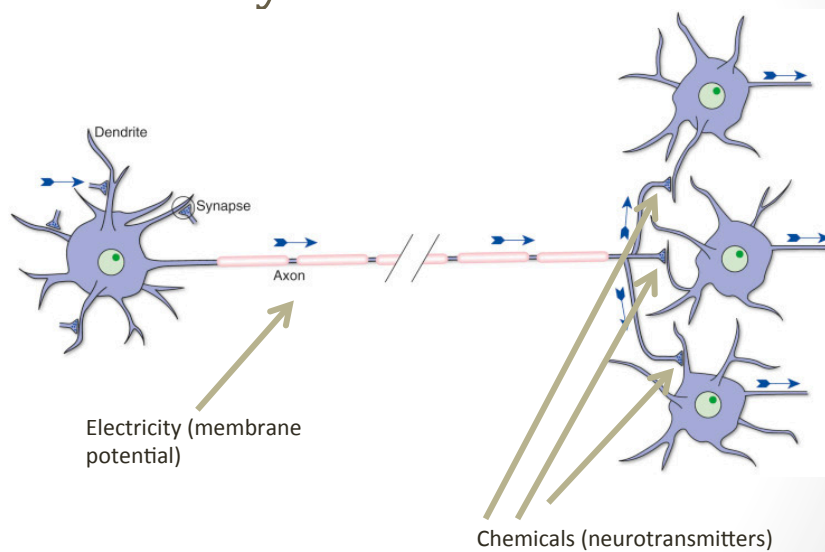
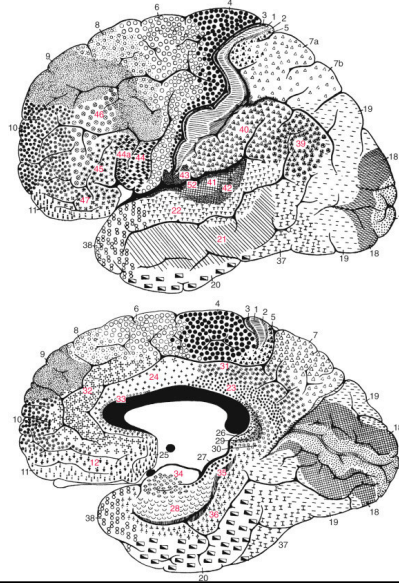


# Brain Systems

## Reminder: chemicals and electricity



## Reminder: smaller divisions



Brodmann, in Vanderah

{ 3 }

## Brain systems

- Senses
- Motor (including cerebellum)
- Autonomic
- Memory
- Emotion (except fear)
- Fear
- Executive

{ 4 }

## SENSES

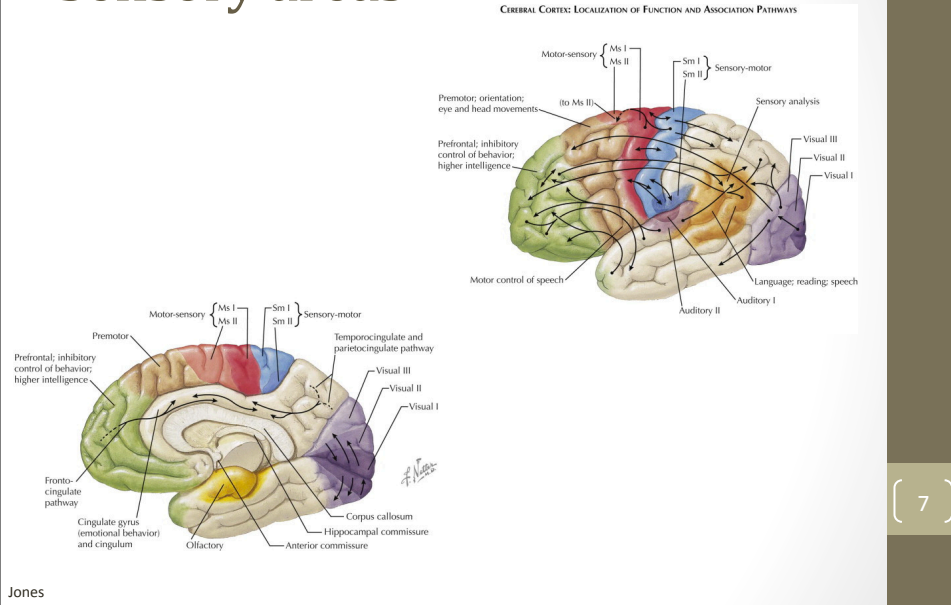
[ 5 ]

## Senses

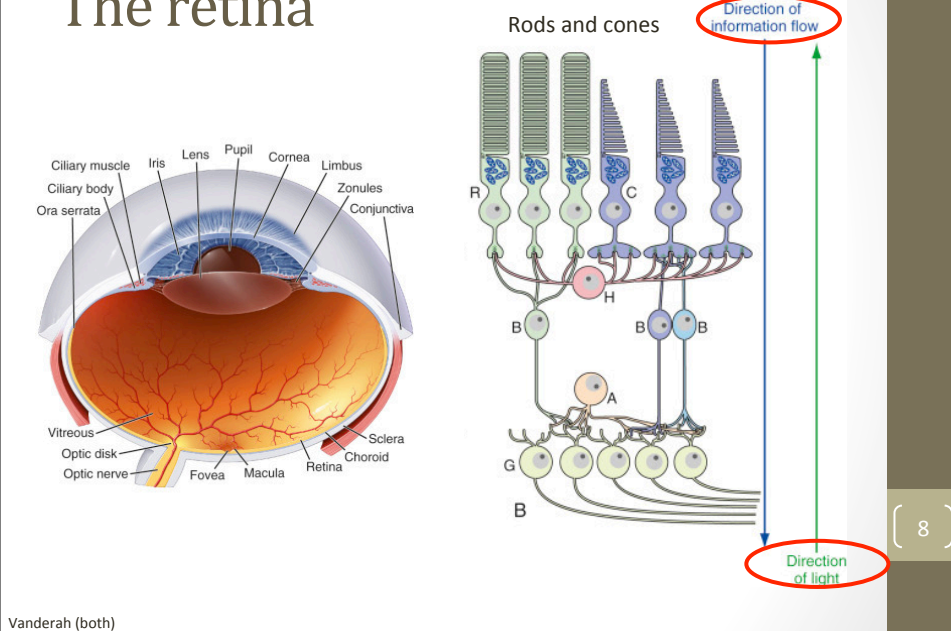
- **Touch**
- **Proprioception**
- **Vision**
- **Hearing**
- **Vestibular (orientation/rotation)**
- Smell
- Taste
- Pain
- Itch
- Temperature
- Hunger
- Thirst
- Circadian rhythm

[ 6 ]

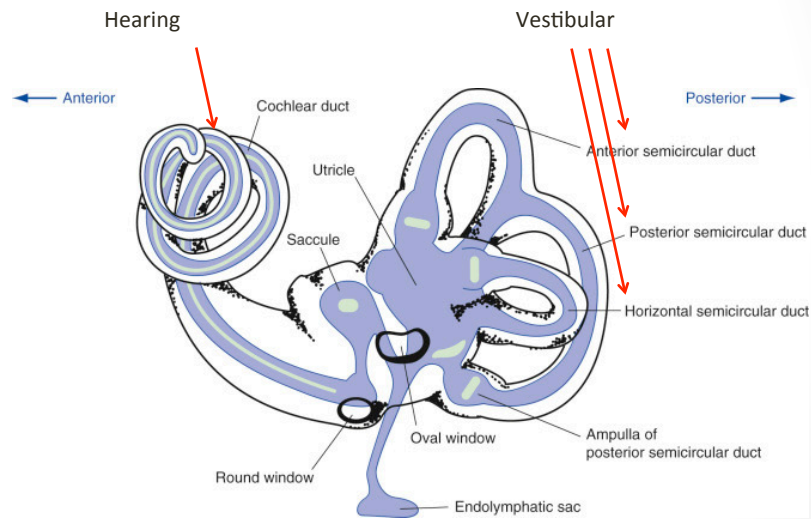
# Sensory areas



# The retina



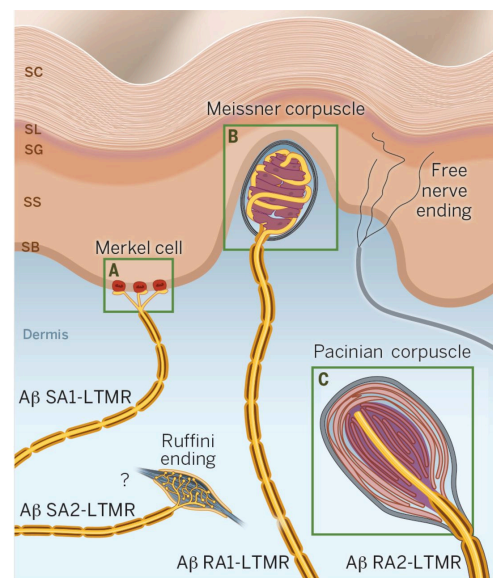
## The inner ear – double duty



Vanderah

[ 9 ]

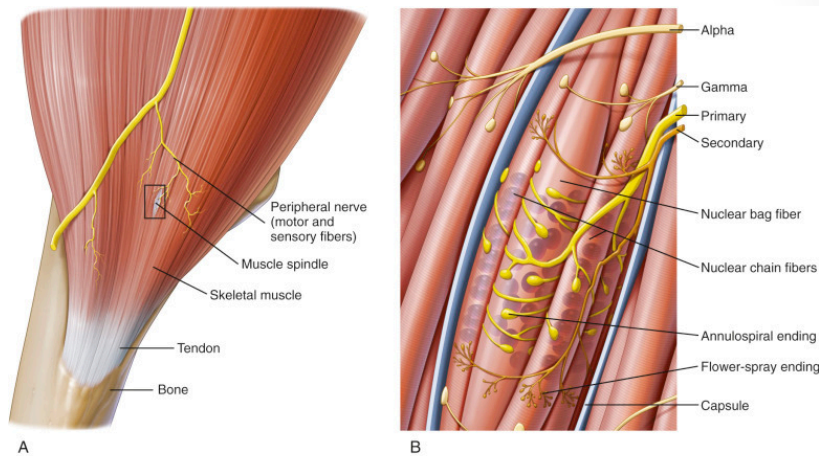
## Touch receptors



Zimmerman 2014

[ 10 ]

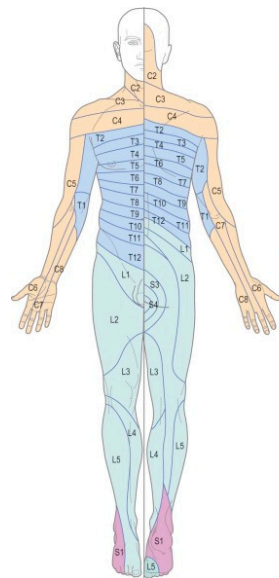
## Proprioceptors



( 11 )

Crossman

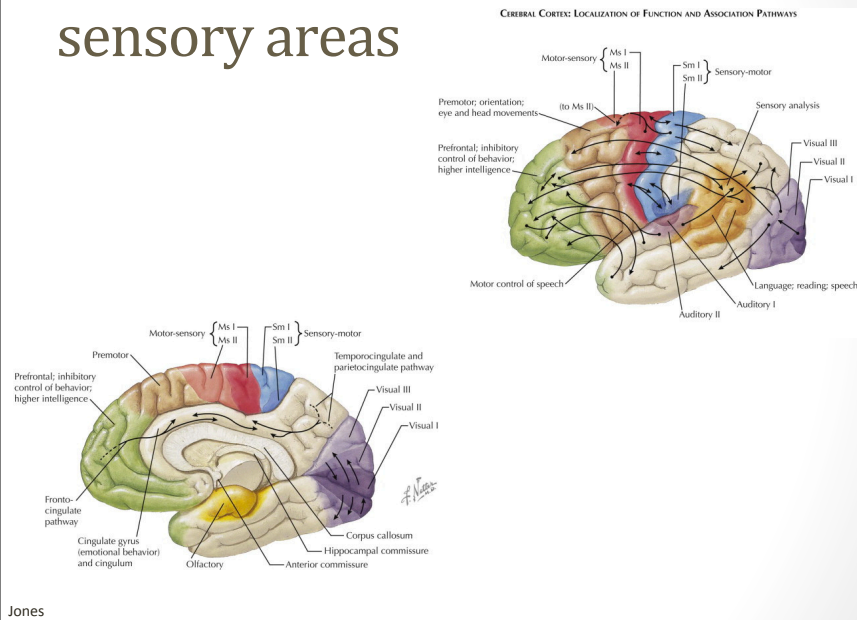
## Dermatome



( 12 )

Mancall

## Recap: sensory areas



( 13 )

## Neural engineering - sensory

- What is the need?
- What is the desired outcome?
- What do you want to build?
- Where do you need to target?
- Challenges?

( 14 )

## MOTOR CONTROL

[ 15 ]

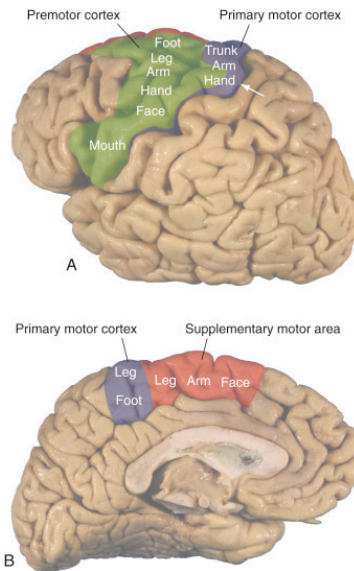
## Muscles and motor control

- Somatic nervous system – skeletal muscle
  - Spinal reflexes – skeletal muscle
- Autonomic nervous system – smooth muscle
- Autonomic nervous system – cardiac muscle

[ 16 ]



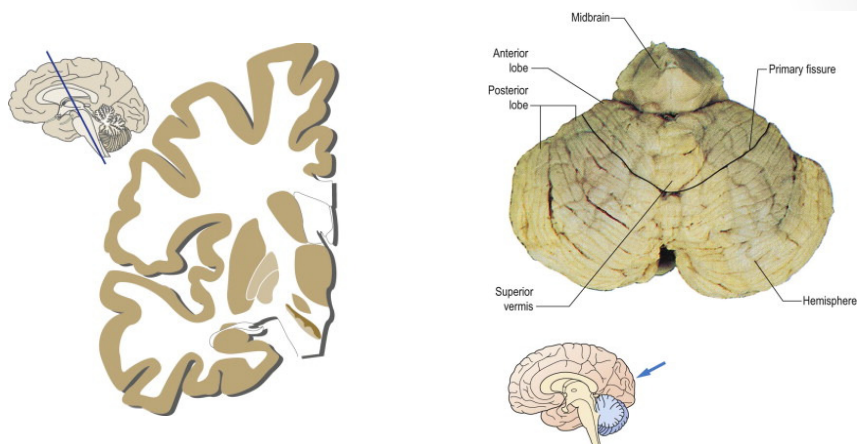
## Motor cortical regions



Vanderah

[ 17 ]

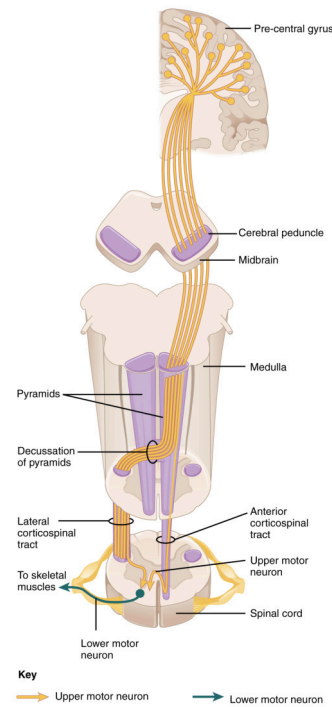
## Motor support regions



Nolte, Crossman

[ 18 ]

## Motor pathways



OpenStax

[ 19 ]

## Neural engineering - motor

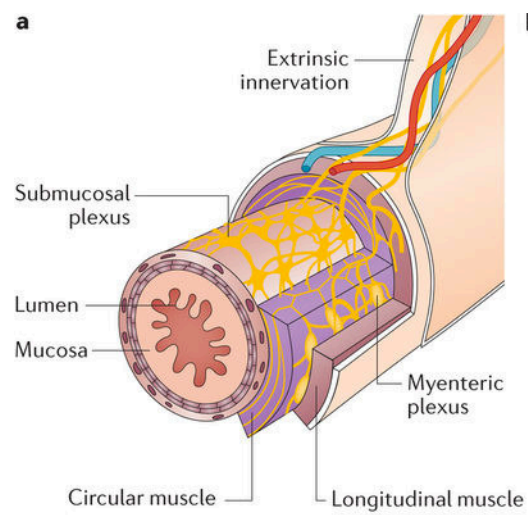
- What is the need?
- What is the desired outcome?
- What do you want to build?
- Where do you need to target?
- Challenges?

[ 20 ]

## AUTONOMIC FUNCTIONS

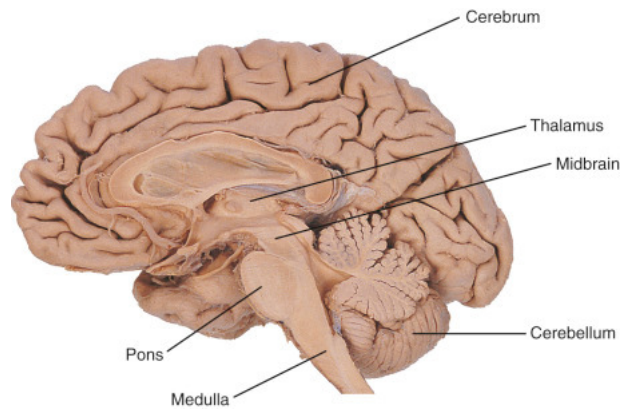
[ 21 ]

## Digestion, bowels, and bladder



[ 22 ]

## Why not engineer respiration? Heart rate?



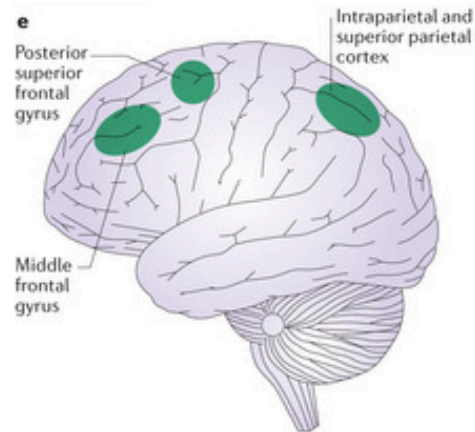
[ 23 ]

Vanderah

## MEMORY AND LEARNING

[ 24 ]

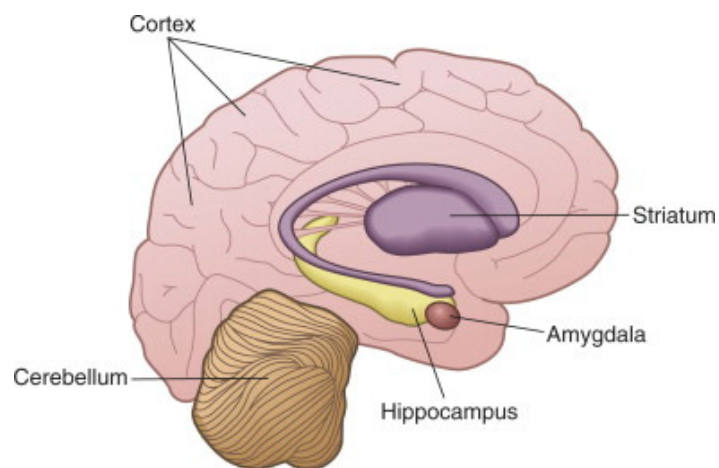
## Memory – short term



[ 25 ]

Constantinidis 2016

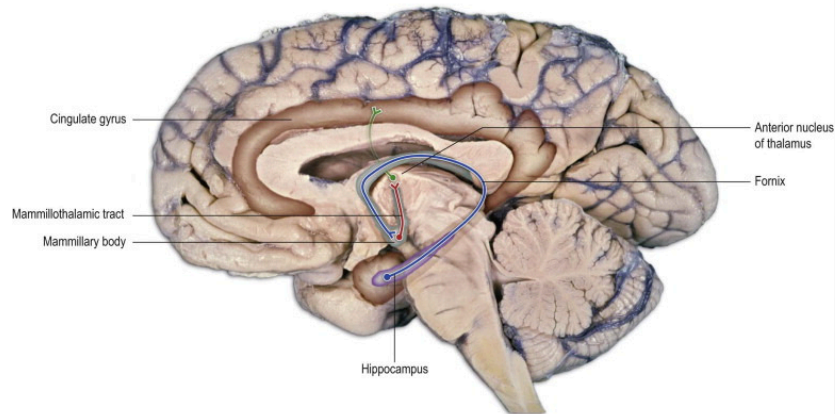
## Memory - hippocampus



[ 26 ]

Squire

## Memory – long-term storage



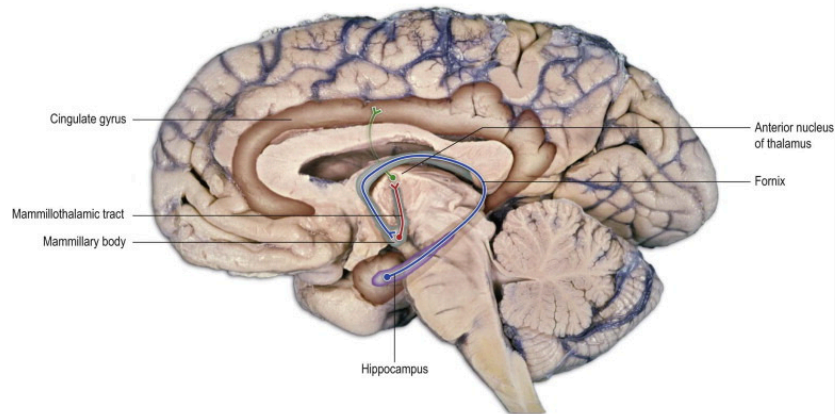
( 27 )

Crossman

## EMOTIONS

( 28 )

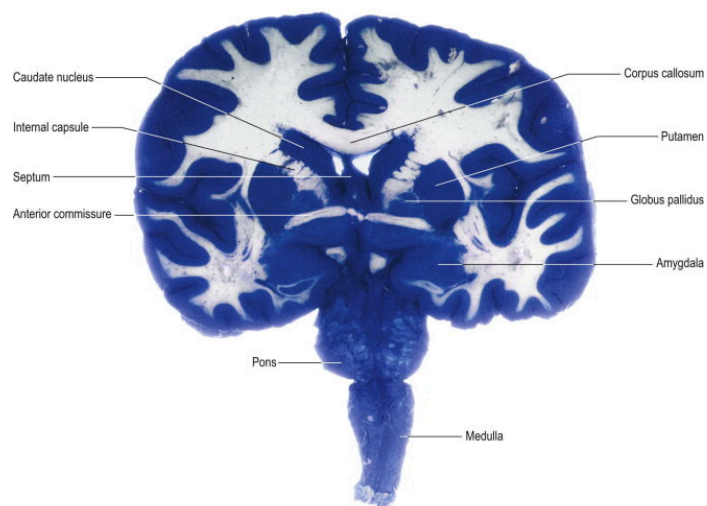
## The limbic system



[ 29 ]

Crossman

## Fear



[ 30 ]

Crossman

## EXECUTIVE FUNCTION

[ 31 ]

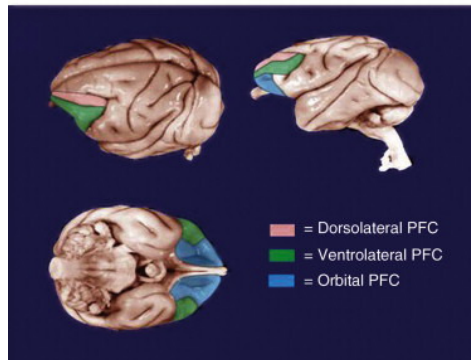
## Executive function

- Planning
- Problem-solving
- Language
- Attention
- Decision-making
- Risk assessment
- Personality
- Short-term memory manipulation
- Impulse control
- Behavioral inhibition

[ 32 ]



## Executive function - prefrontal



Squire

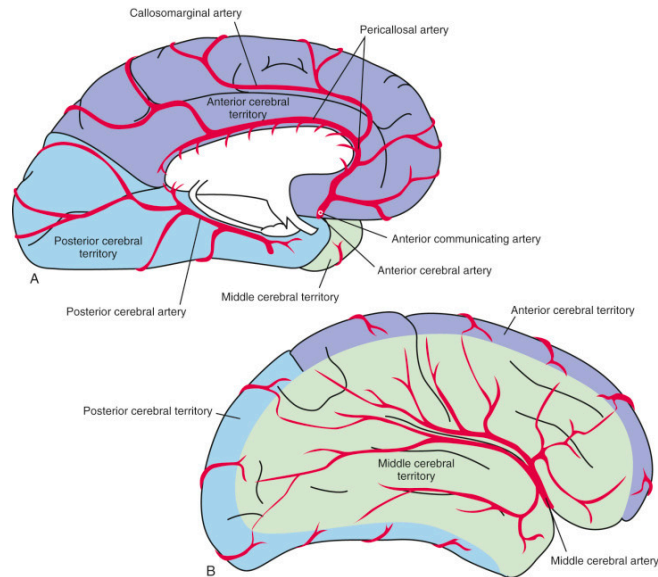
Humans vs monkeys

( 33 )

## BLOOD AND CEREBROSPINAL FLUID

( 34 )

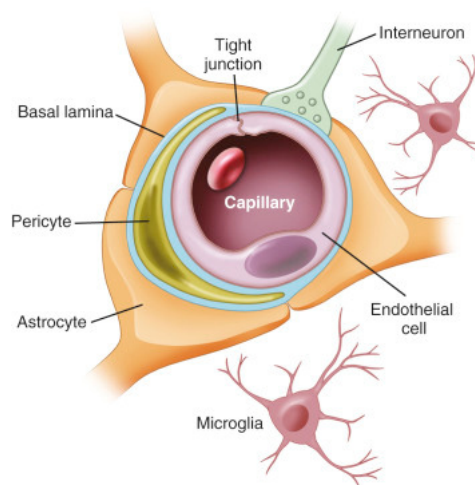
## Circulation in brain



Vanderah

[ 35 ]

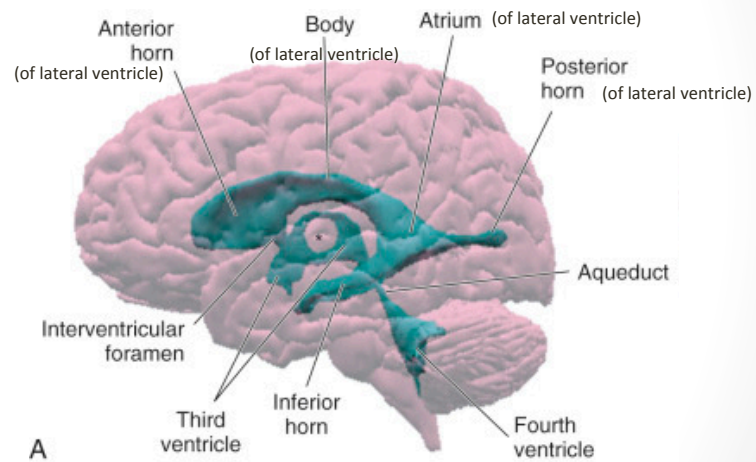
## Blood-brain barrier



Prager

[ 36 ]

## Cerebrospinal fluid and ventricles



Vanderah

( 37 )