Computational Neuroscience

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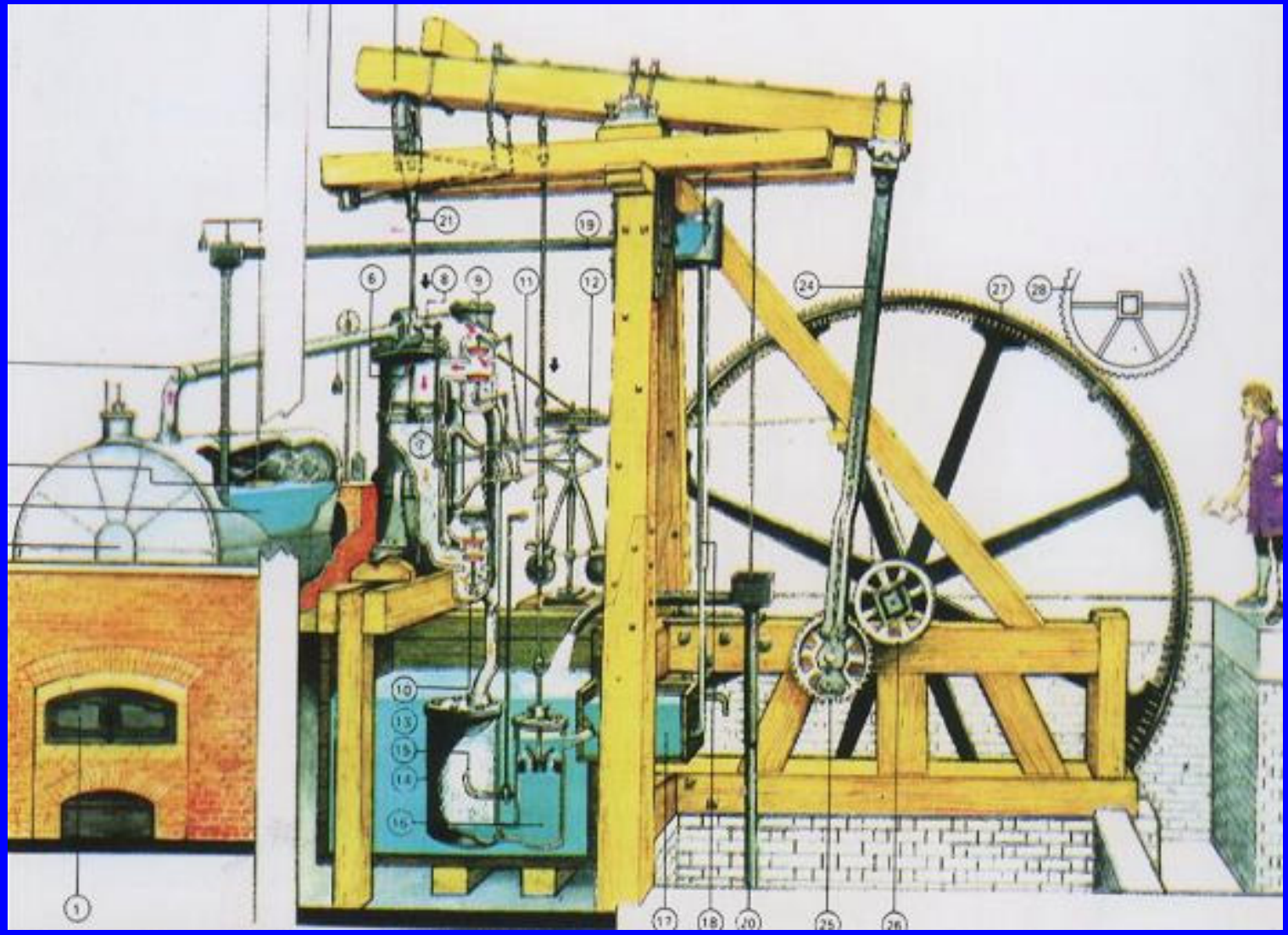
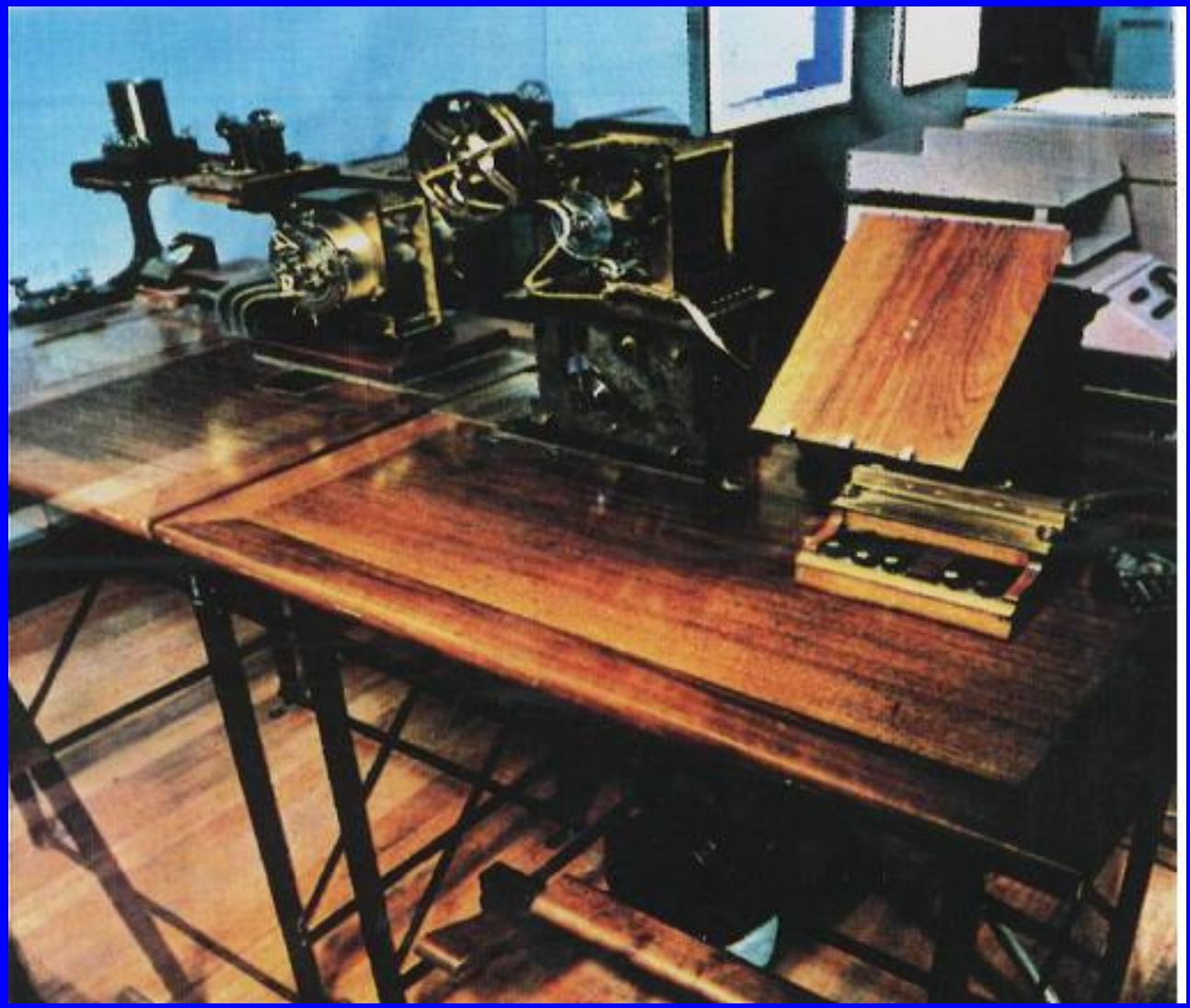
Dept of CS
Tel Aviv University

CS and the Brain ?



CS and the Brain ?

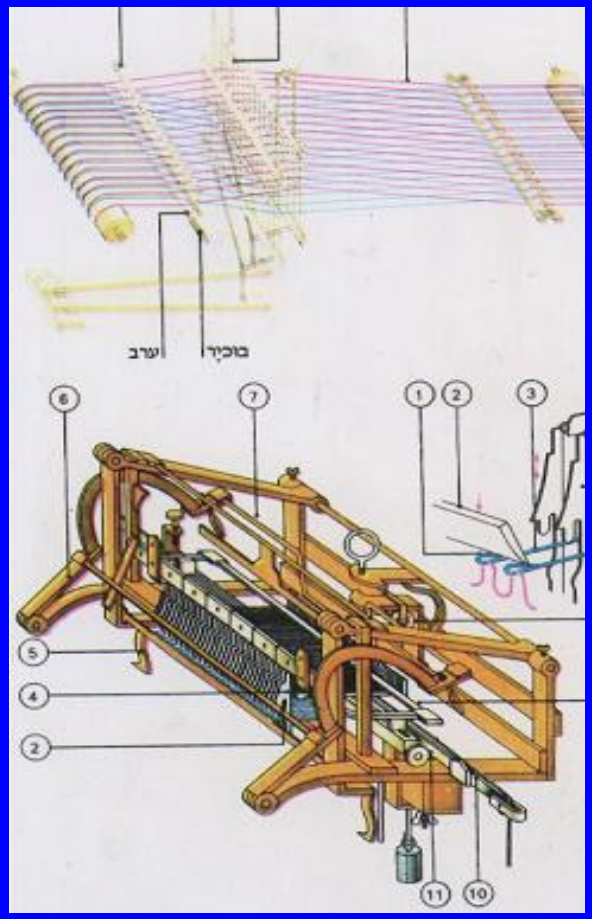


CS and the Brain ?

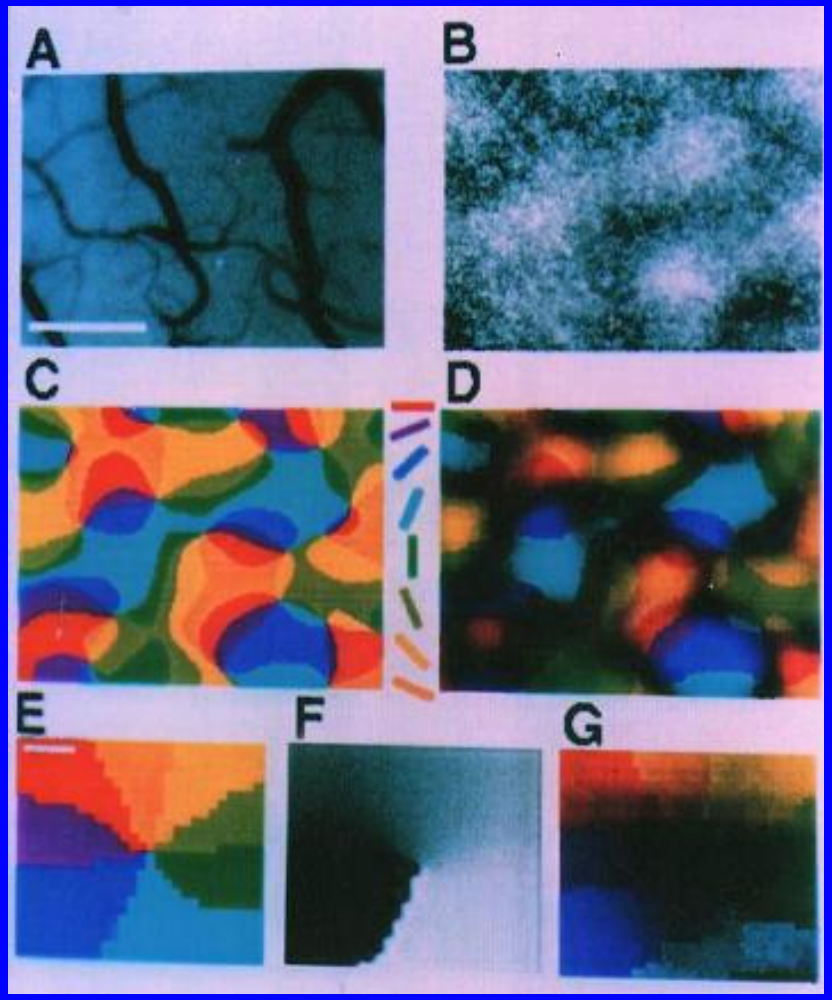
``..enchanted loom, where millions of flashing shuttles weave a dissolving pattern”

Sherrington, 1906

CS and the Brain ?



CS and the Brain ?



CS and the Brain ?

Thinking Machines Inc.

CS and the Brain ?

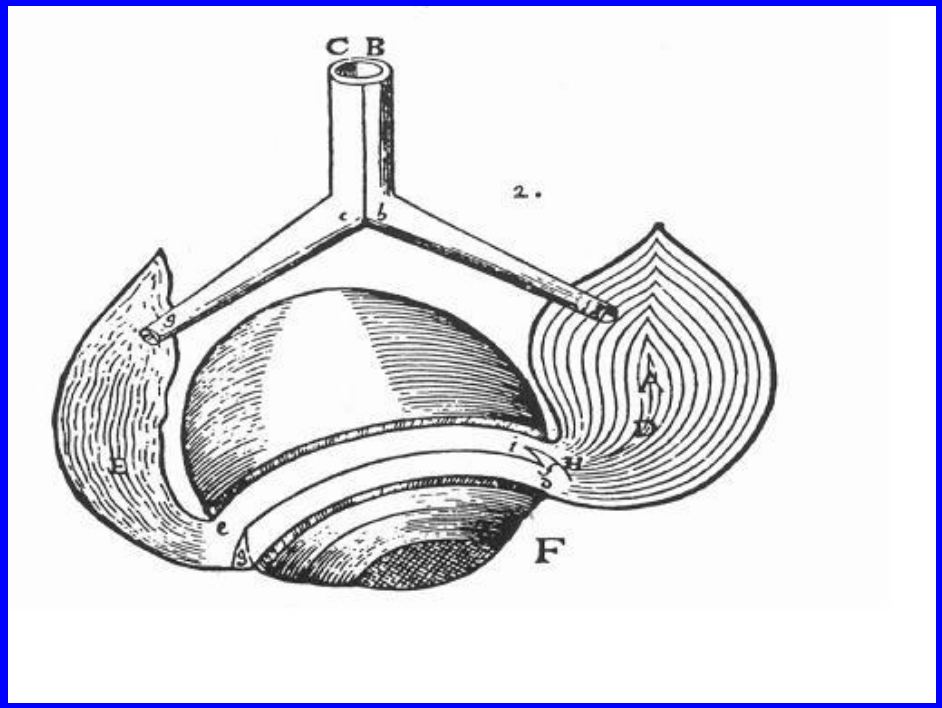
AI

Models of the Mind
Models of the Brain

CS and the Brain ?

Cognitive: Language, Chess
Sensory: Vision, Audition

CS and the Brain ?

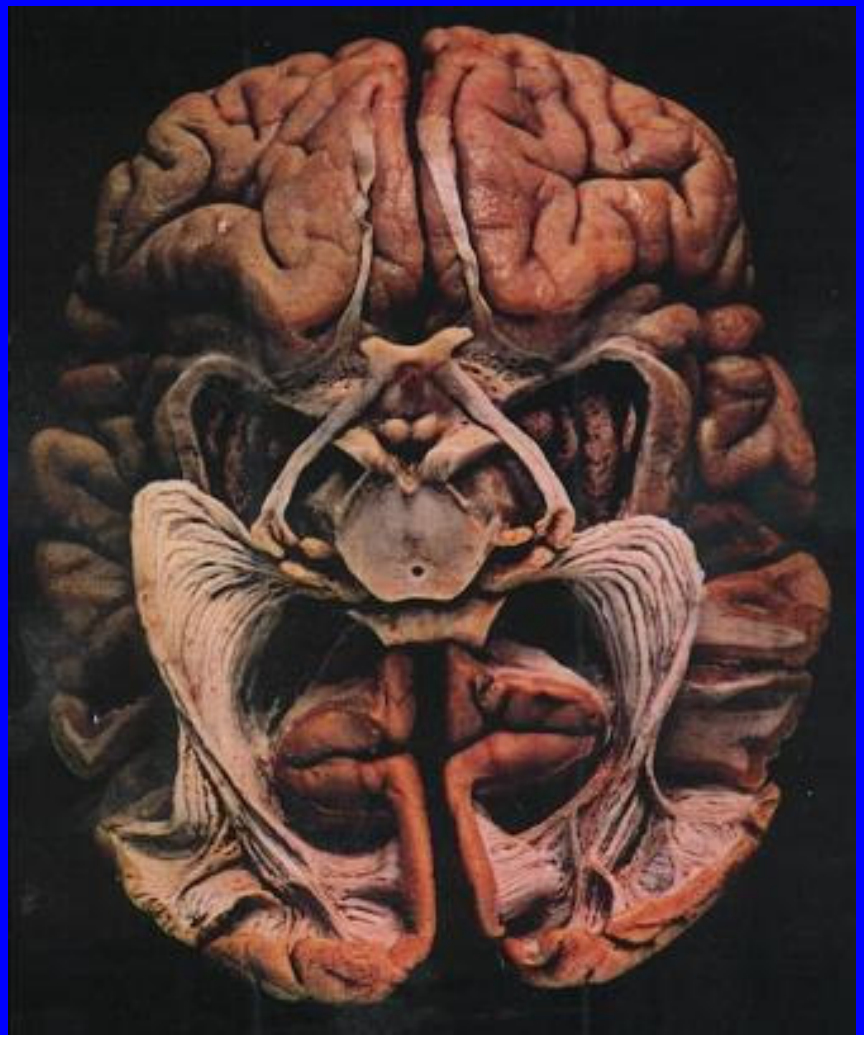


Descartes (1664)

CS and the Brain ?

Fludd (1619)

Computational Vision: the only machine..



Goal of the course

- General knowledge of the CNS
- Computational models of the

  Brain

  Sensory systems

  Visual System

Sylabus

- Historical analogies - CS & the brain
- Mind-Body problem
- The brain, nerve cells, synapses, action potentials
- Formal models of neural networks
- Physiological measurements
- Psychophysics

Sylabus

- The Visual system
- Retina
- Mapping the retina to V1
- Cortical columns
- Stereoscopic Vision
- The Auditory system: sound localization
- The Auditory system: I/O functions

Sylabus

- Visual Attention
- Brain Computer Interface

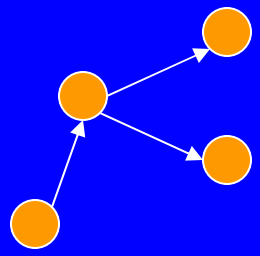
Textbooks

- The Computational Brain (Churchland & Sejnowski)
- Sensation & perception (Coren, Porac, Ward)
- Basic neuroscience (Guyton)
- Neuroscience (Kandel & Schwartz)
- Vision (Marr)
- Introduction to the theory of neural computation (Hertz, Krogh, Palmer)
- Vision in man and machine (Levine)

Computational models of the brain: sneak preview

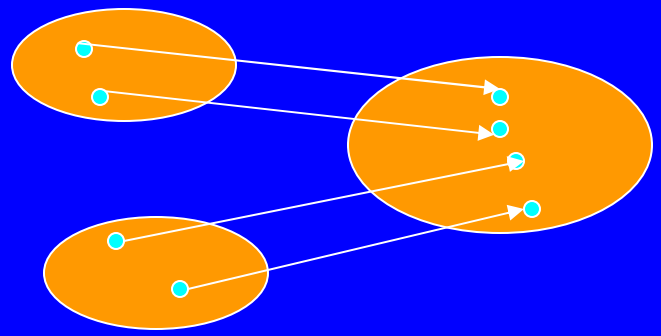
Networks:

Connectivity counts



Maps:

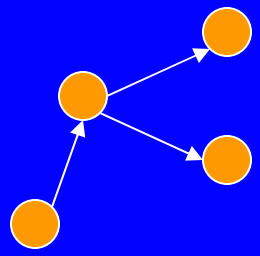
Location counts



Computational models of the brain

Networks:

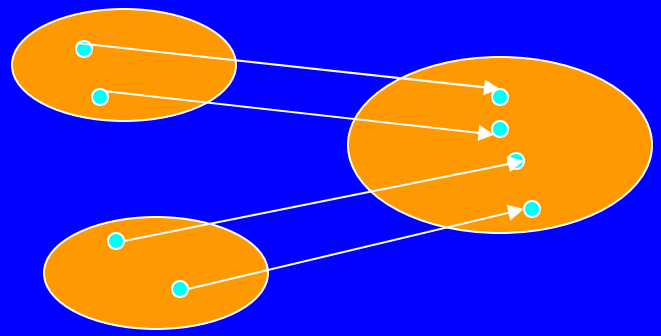
Connectivity counts



Algorithms

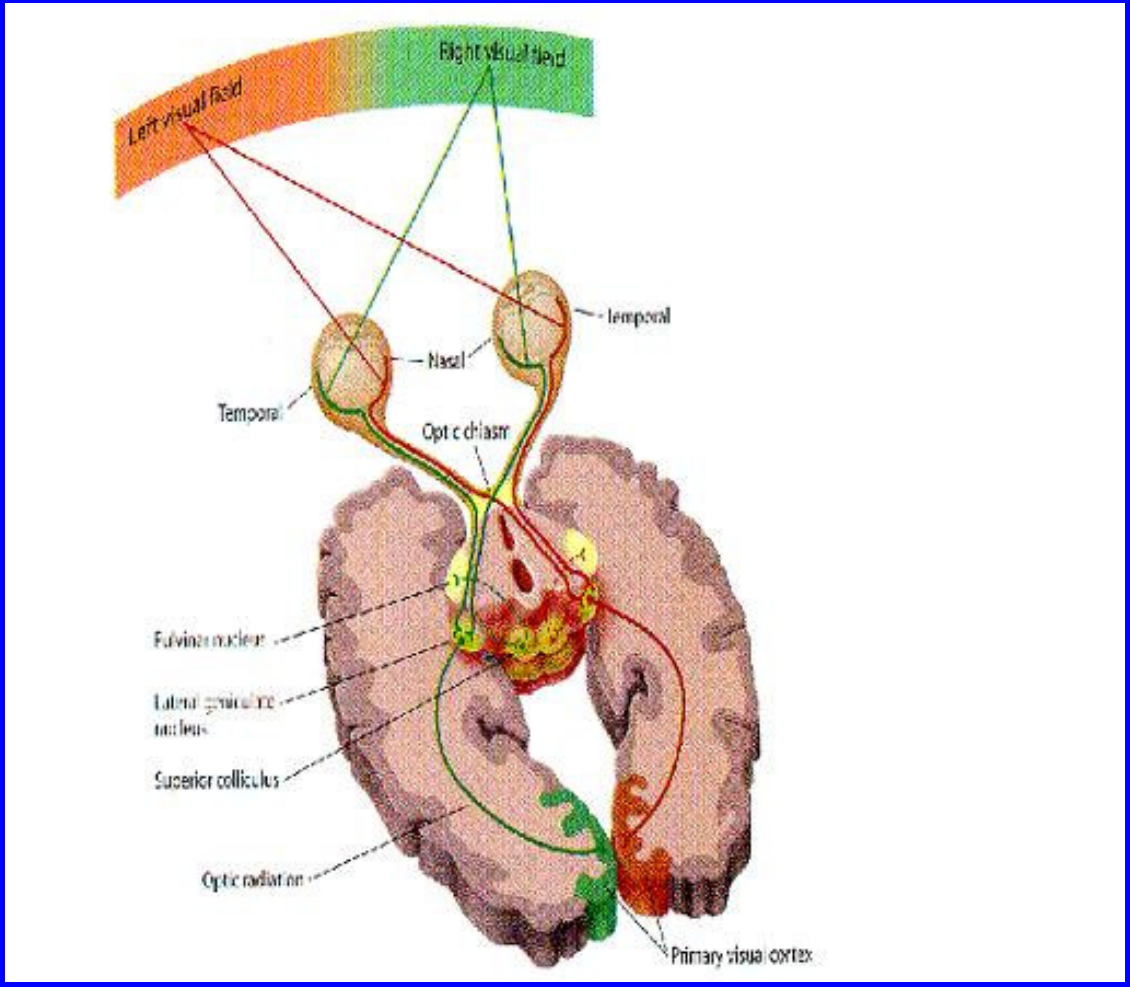
Maps:

Location counts

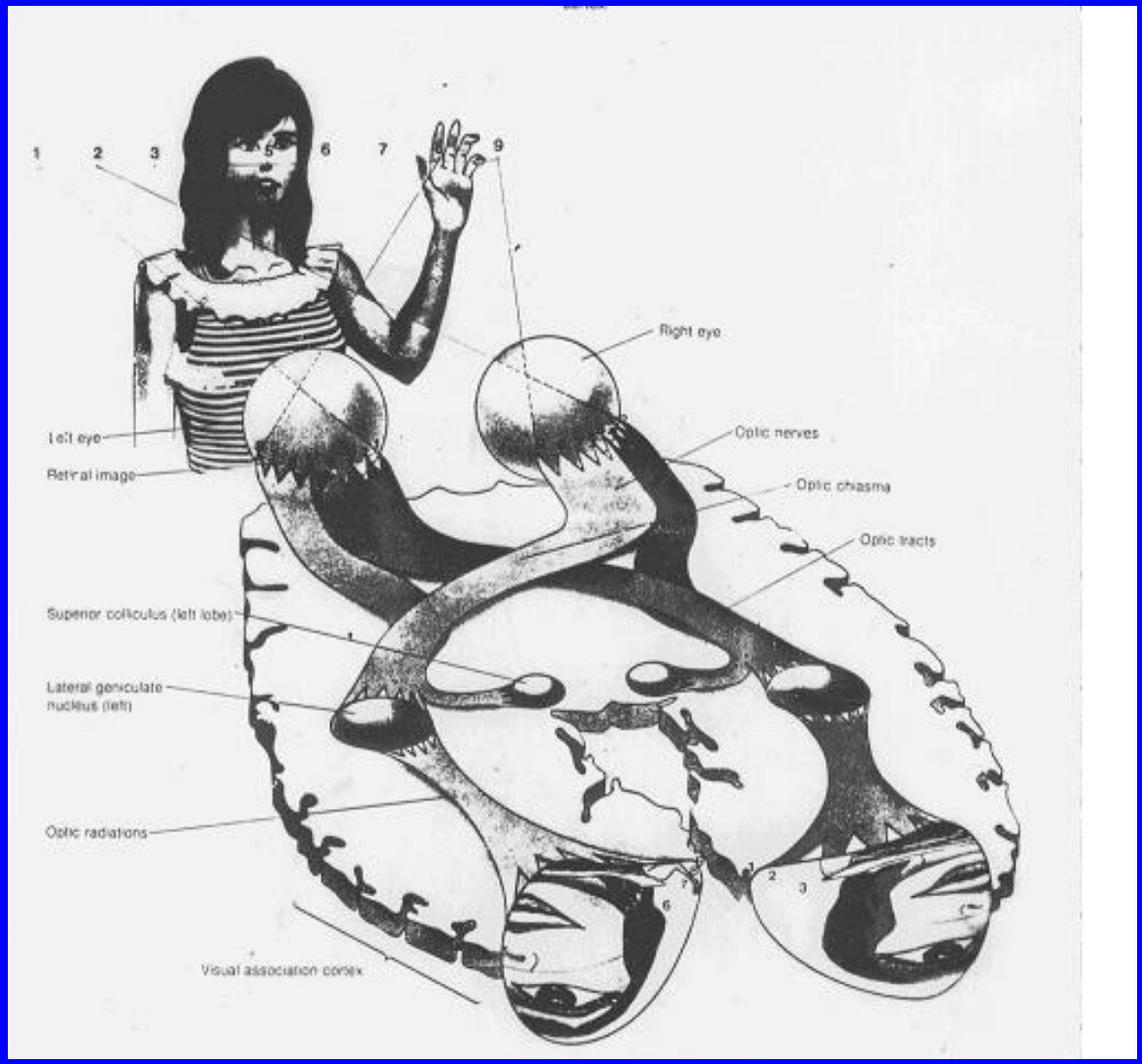


Data Structures

The Visual Pathway

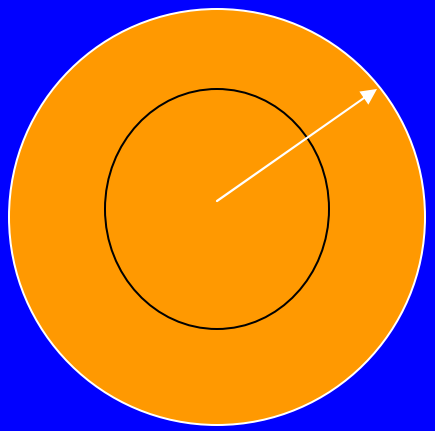


The Visual Pathway



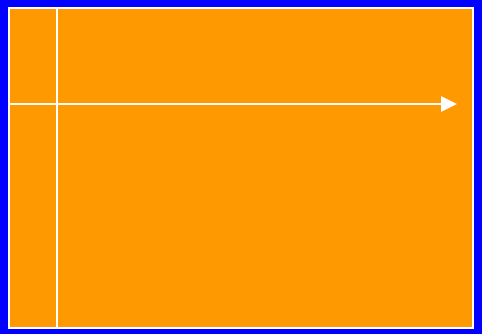
The Visual Pathway: log mapping

Log Polar mapping



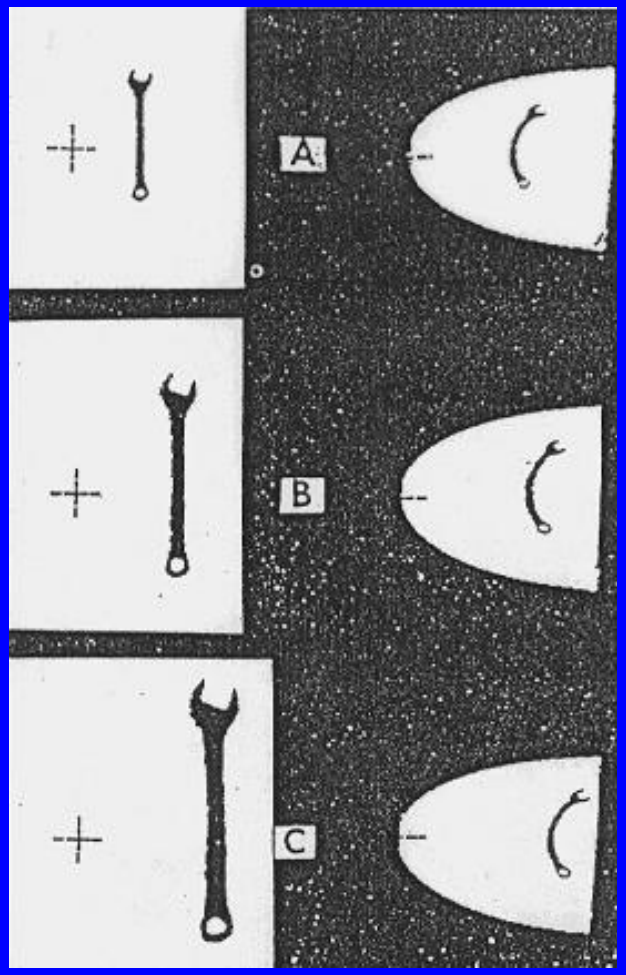
R , O

O

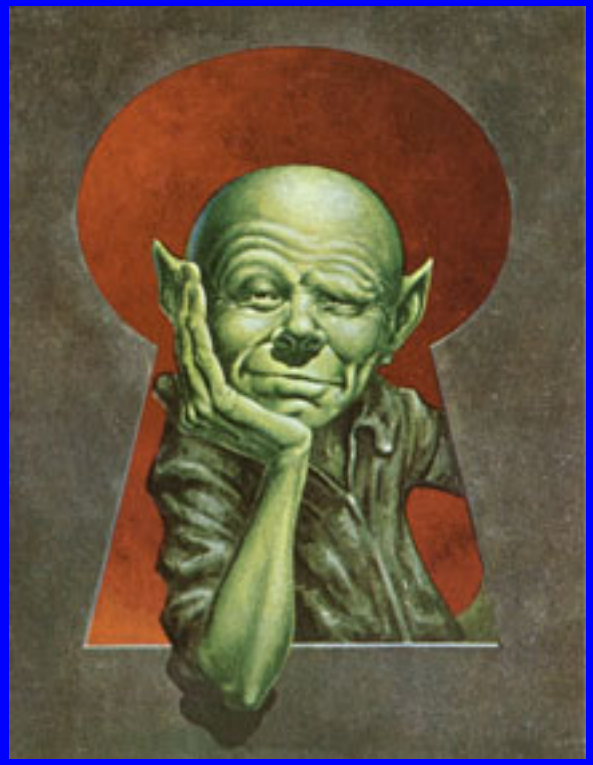


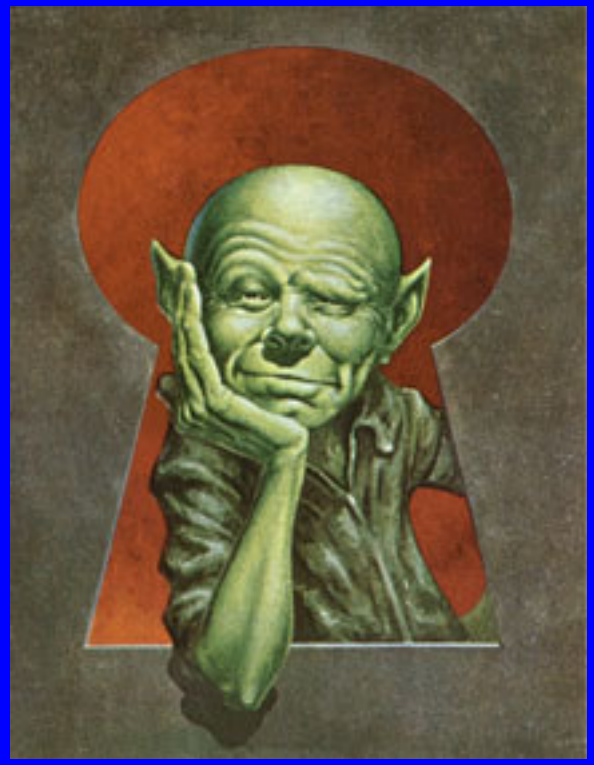
log R

Log Polar mapping: computational benefits

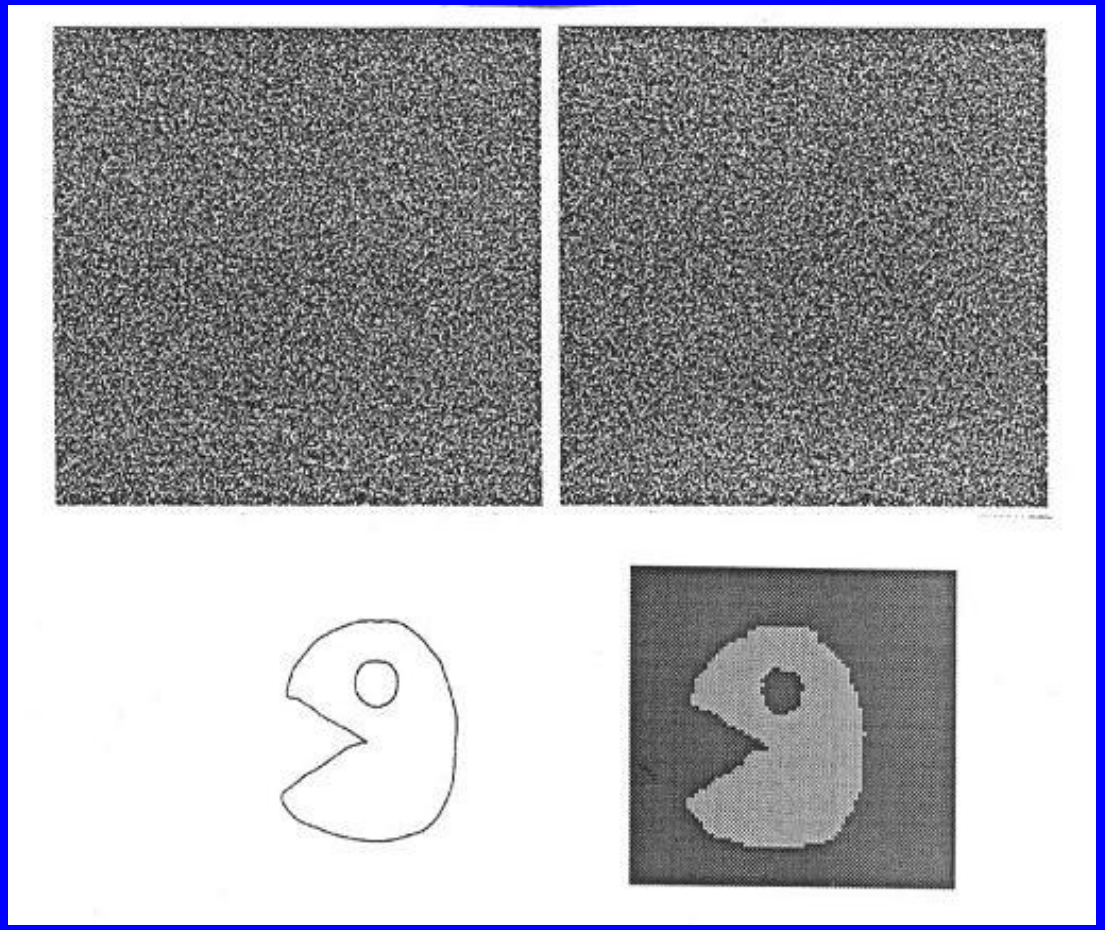


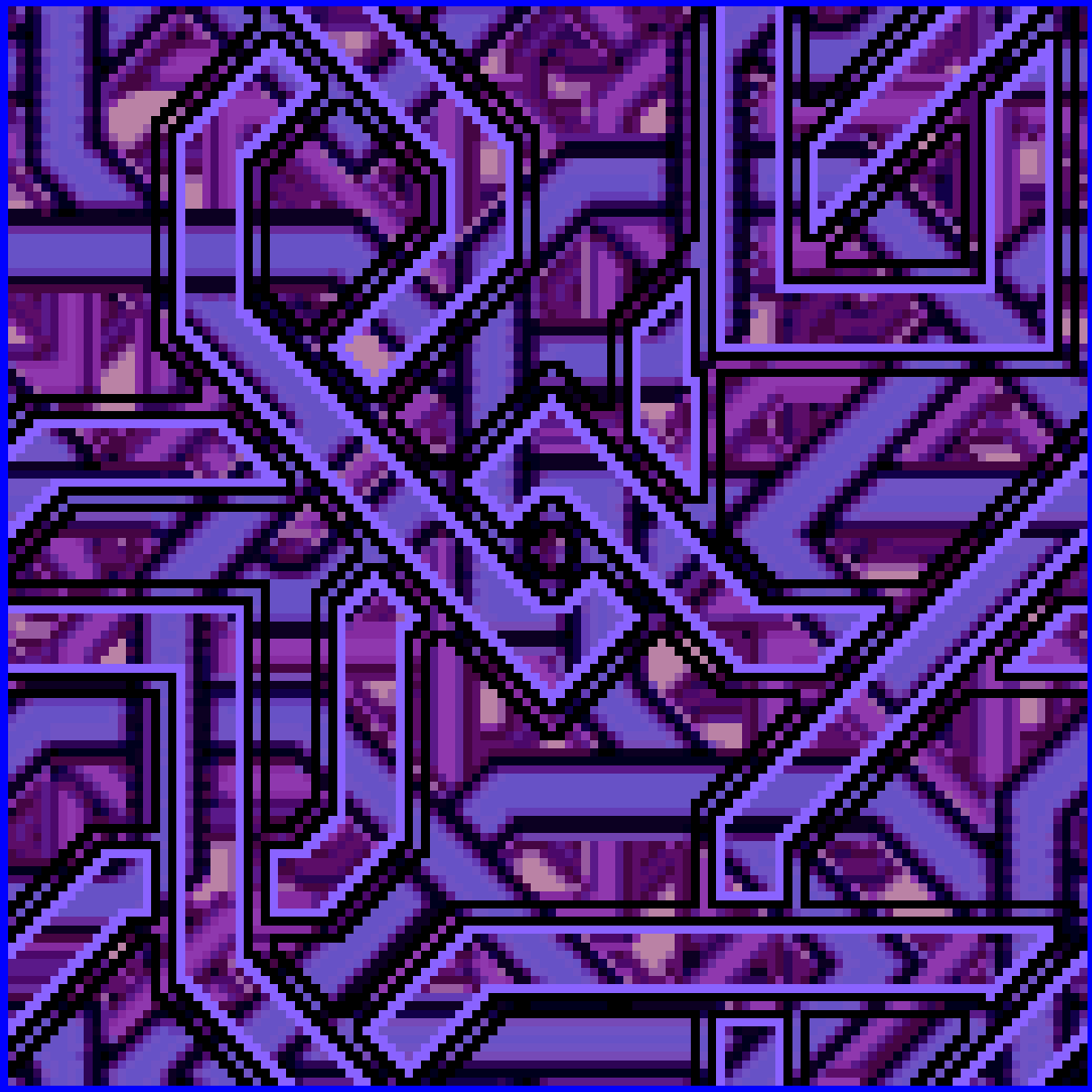
Stereovision

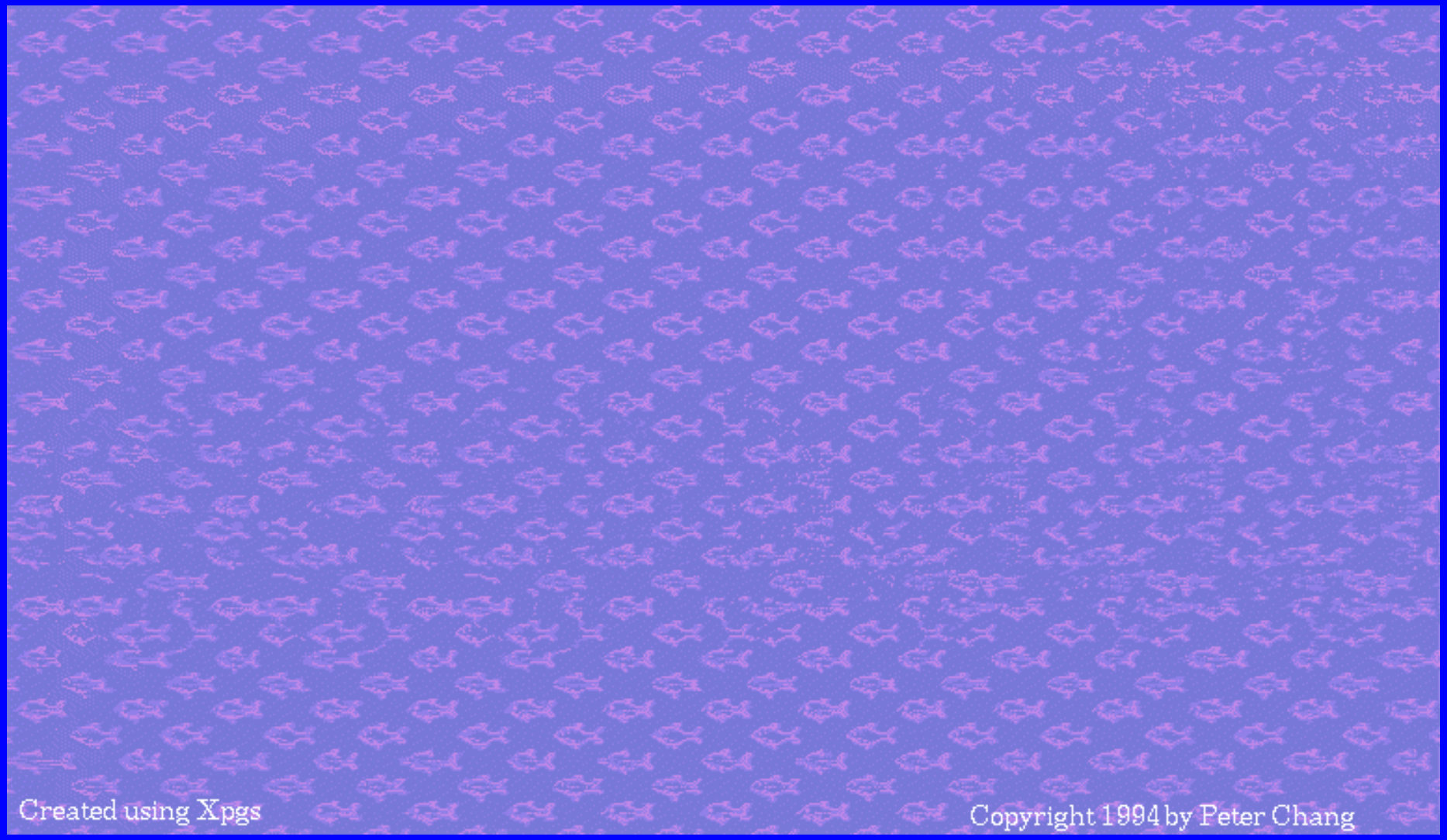




Stereo Algorithm



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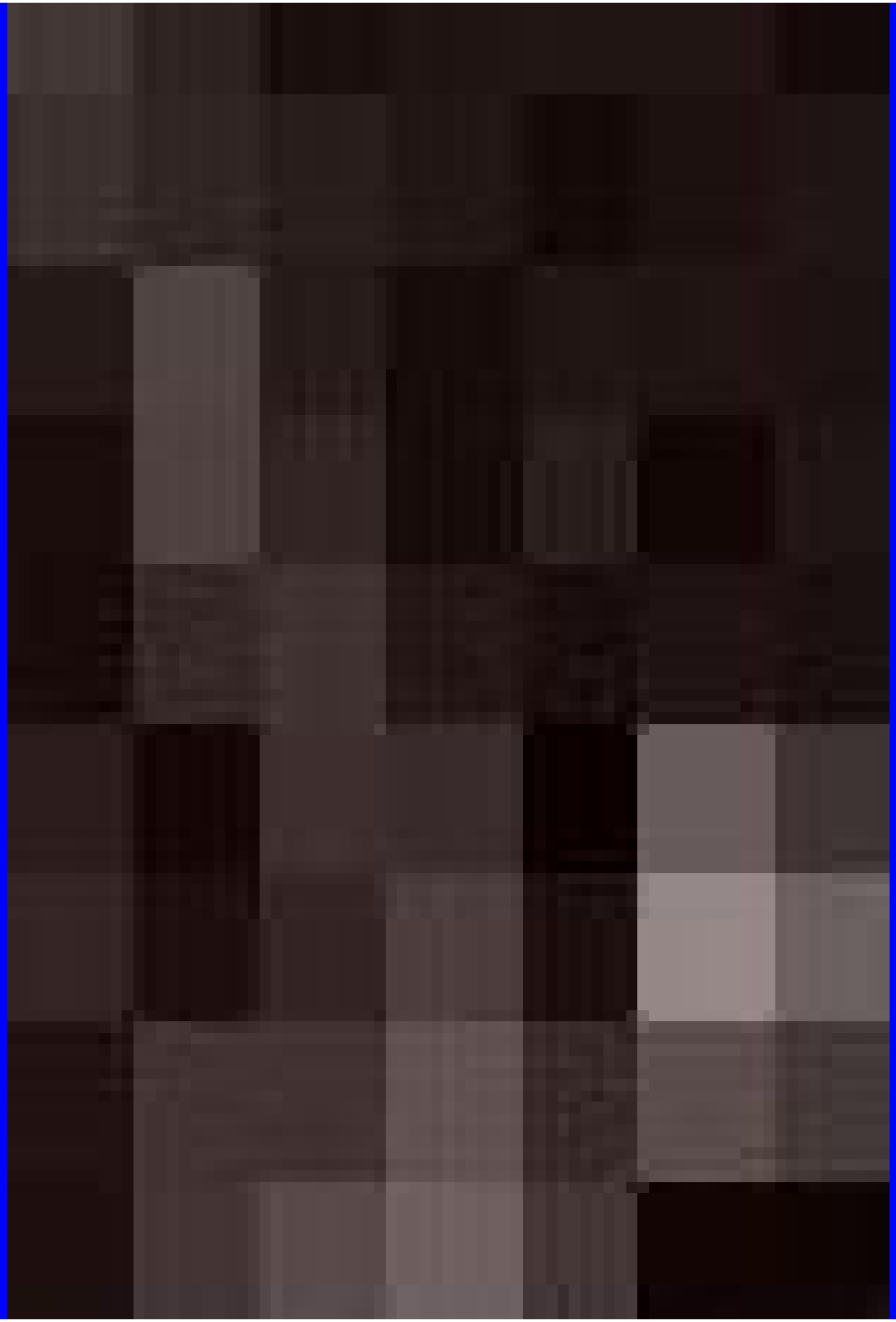
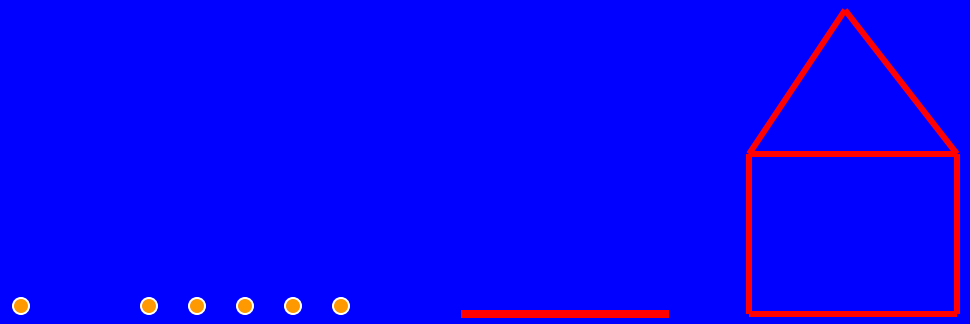
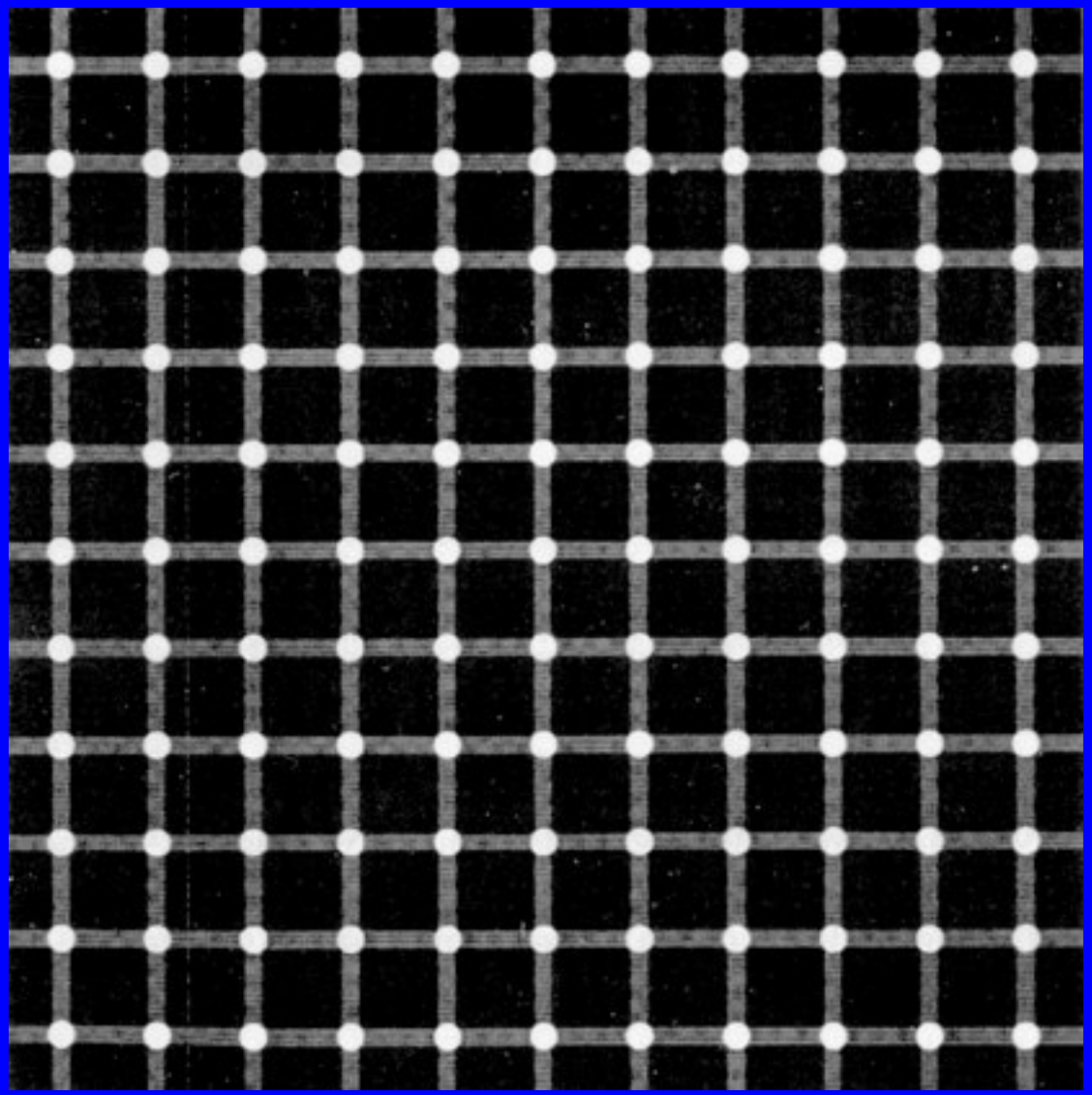
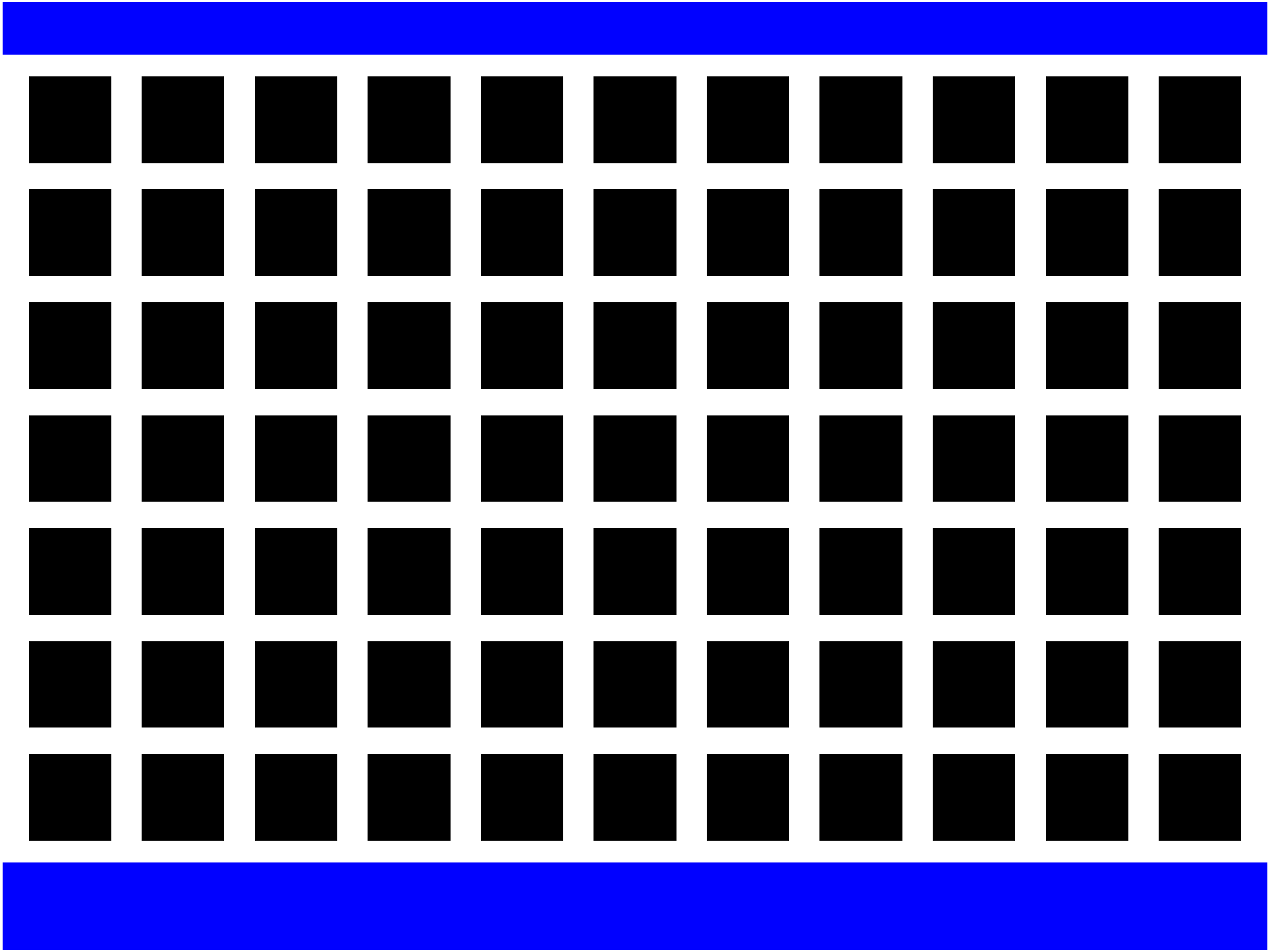
Copyright 1994 by Peter Chang

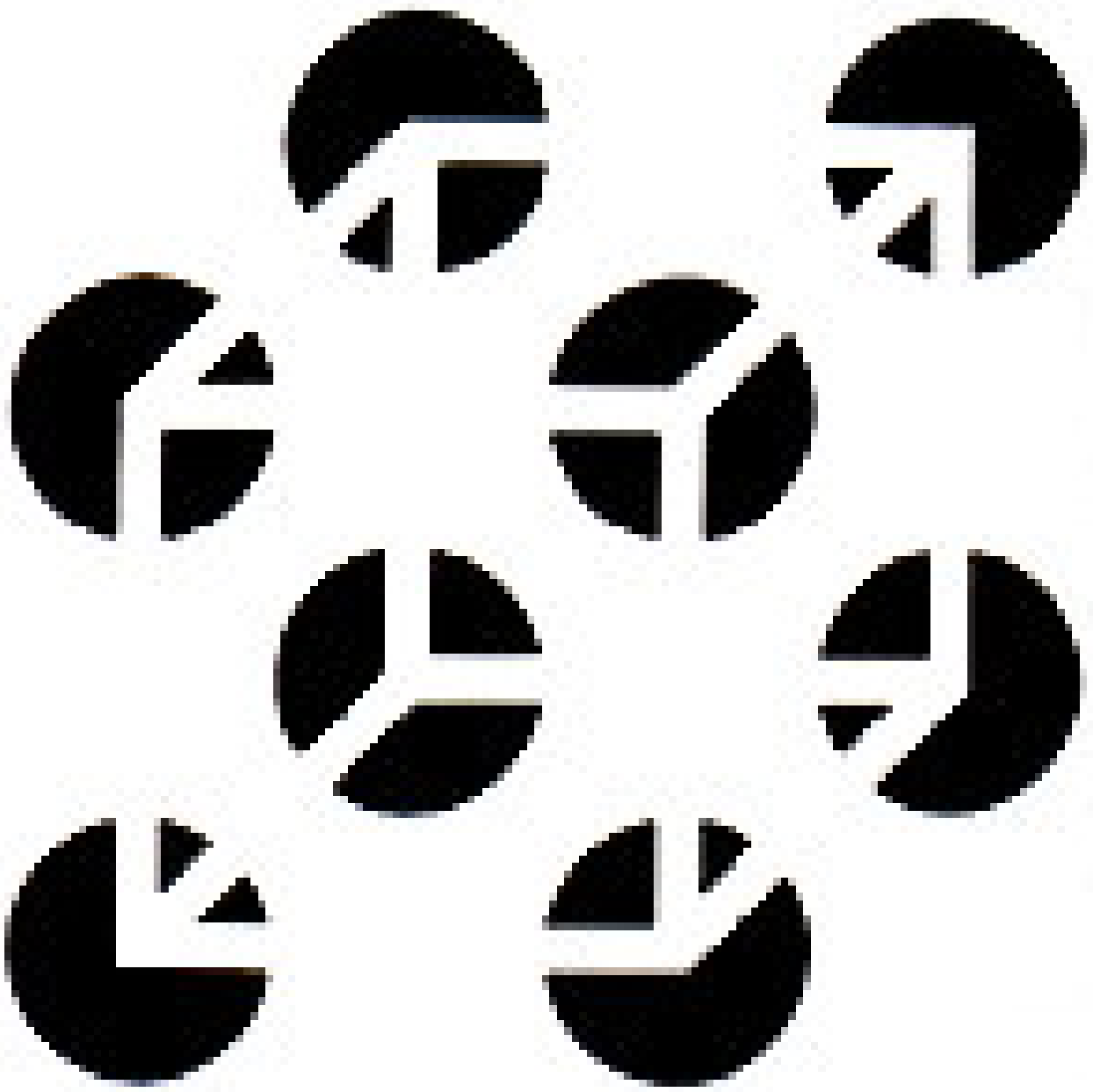


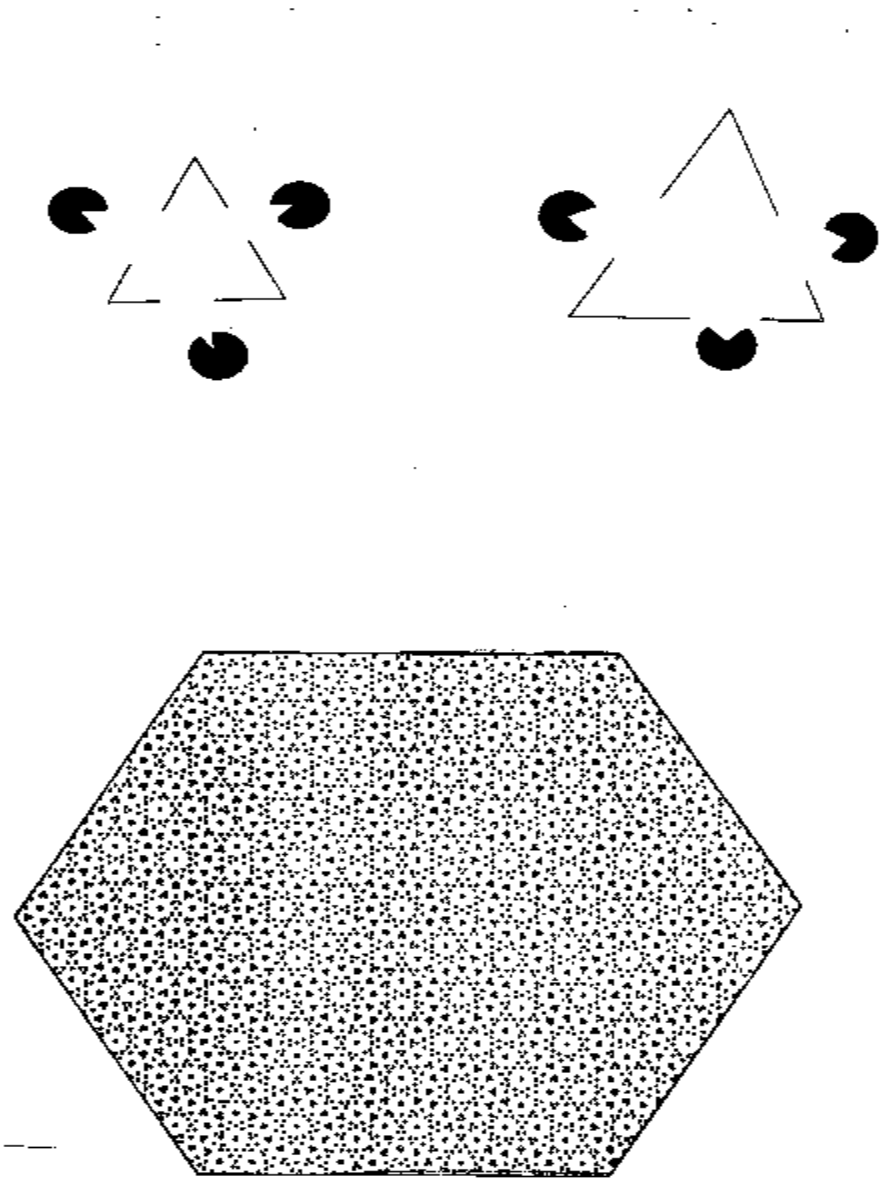
Artificial Vision:

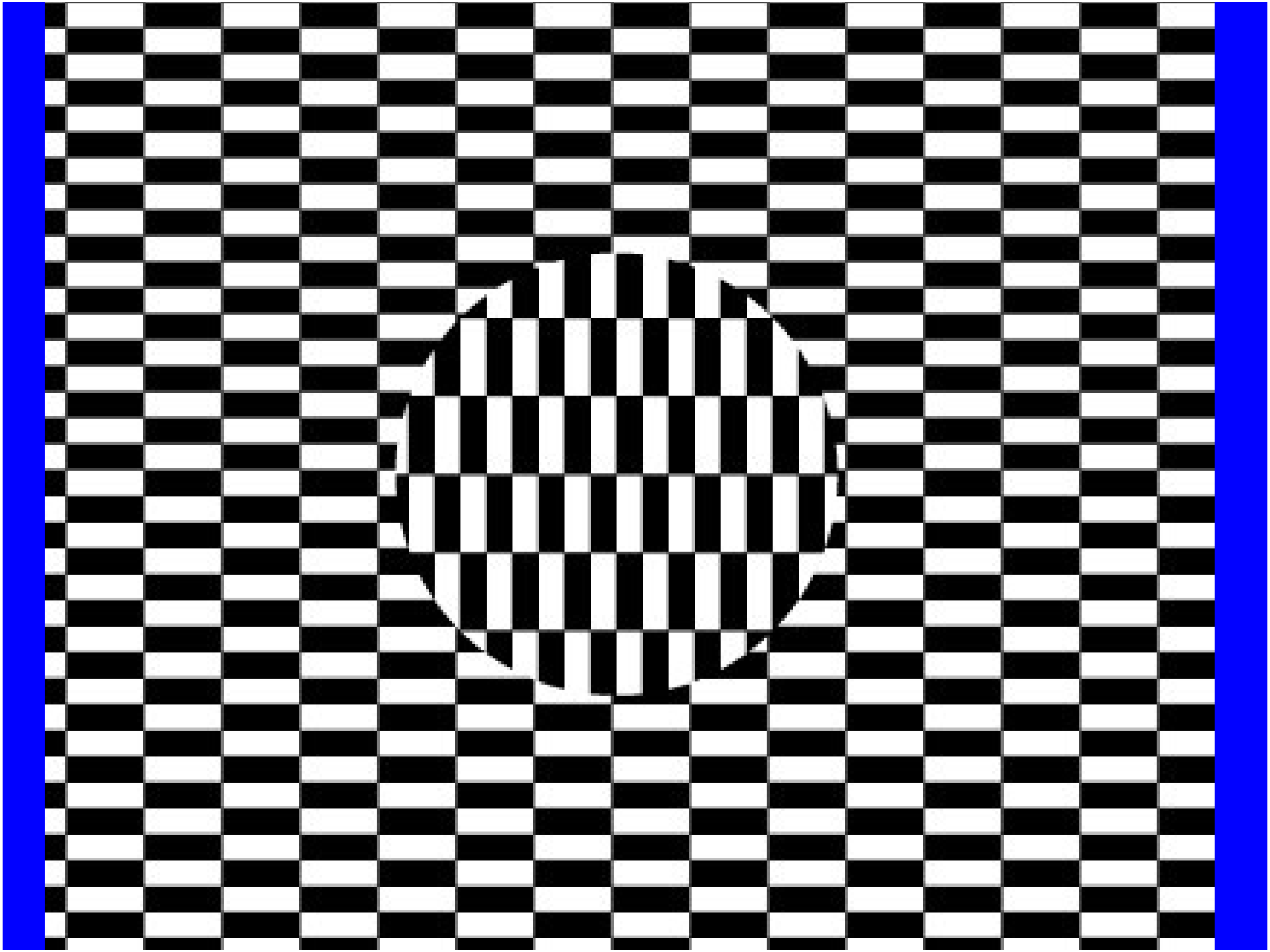


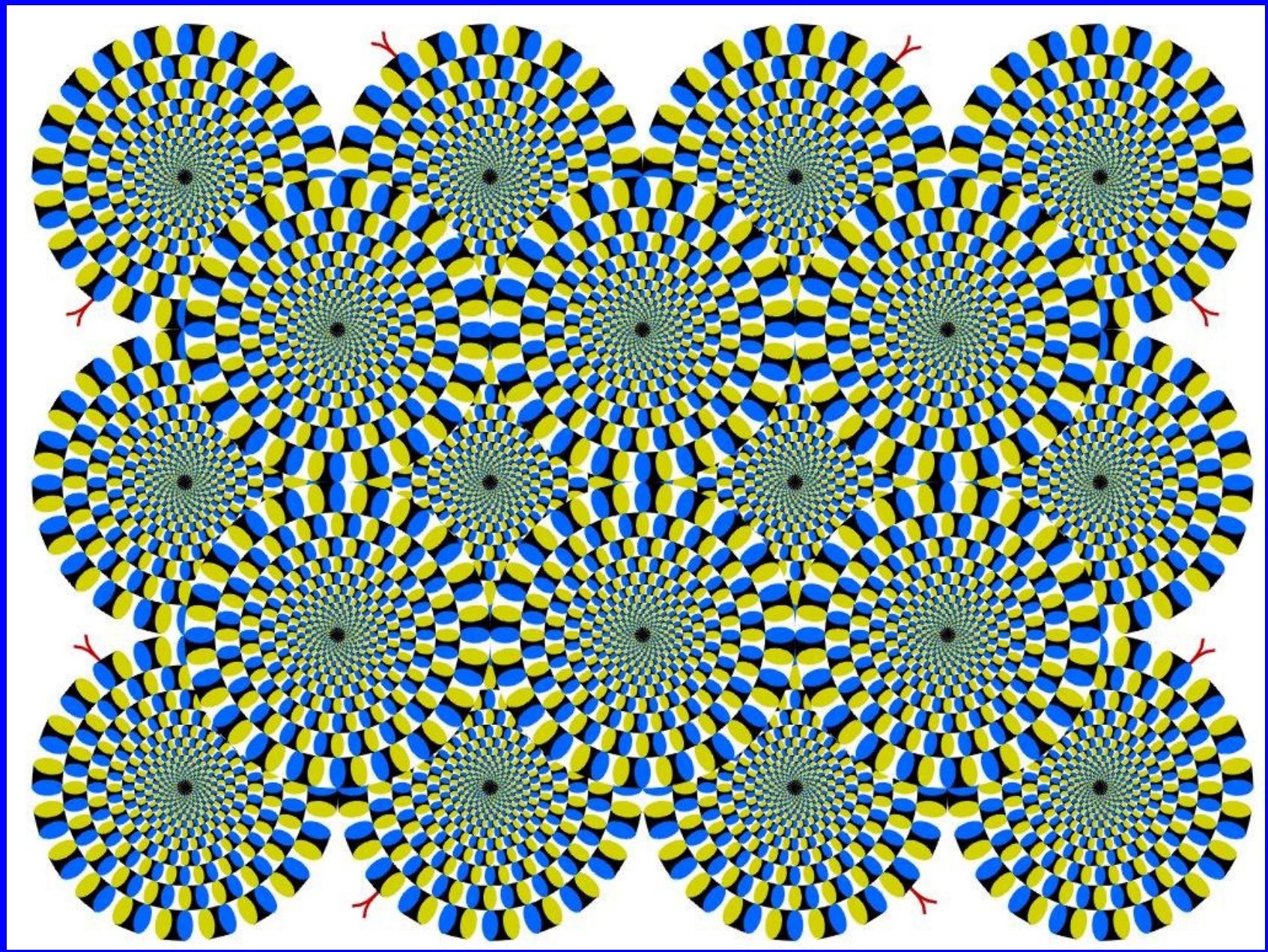


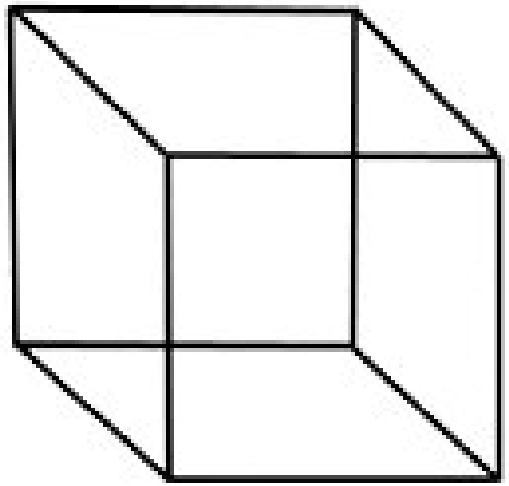


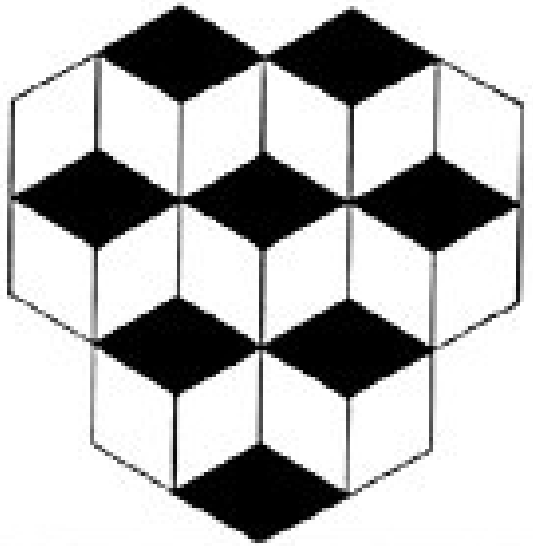


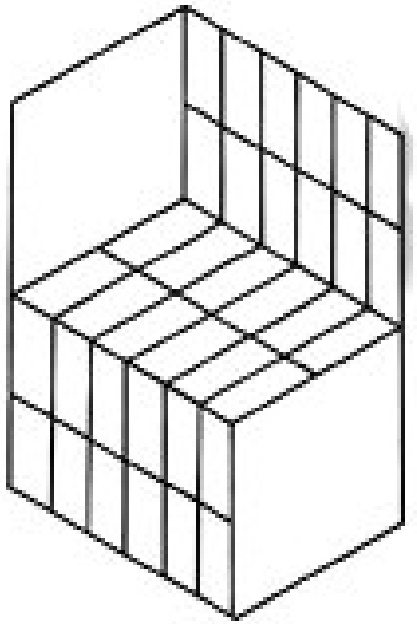


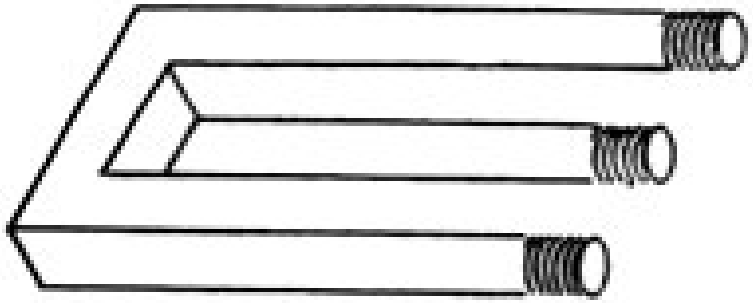


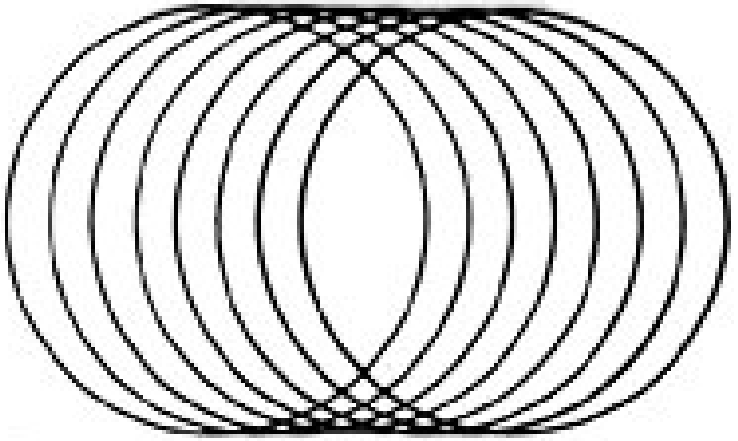










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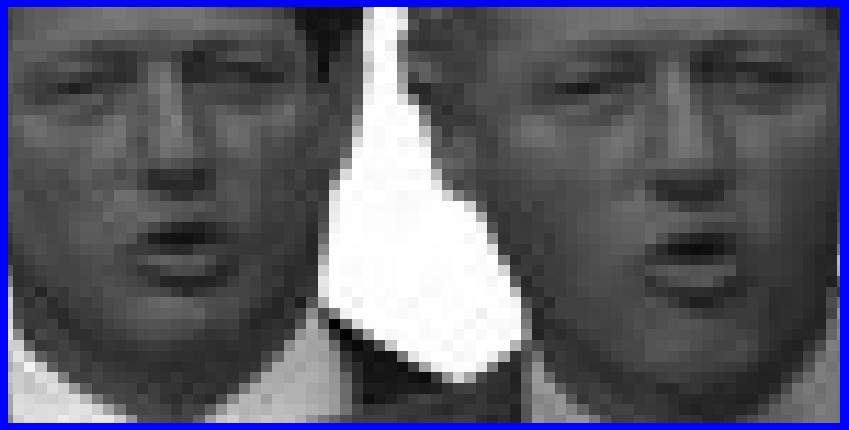
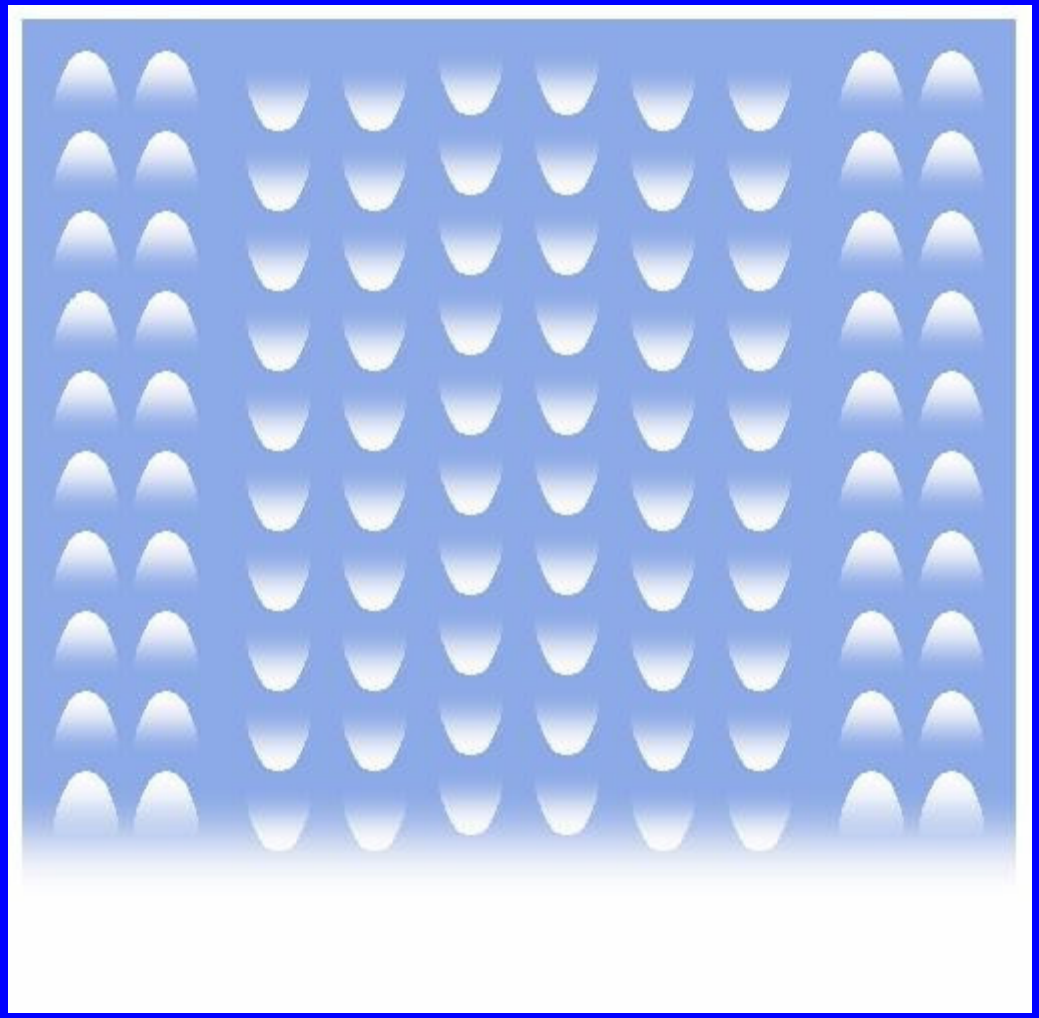
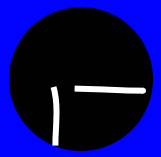
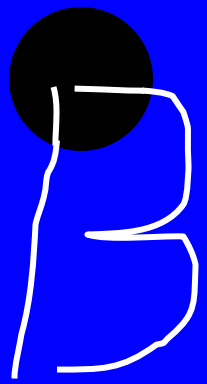
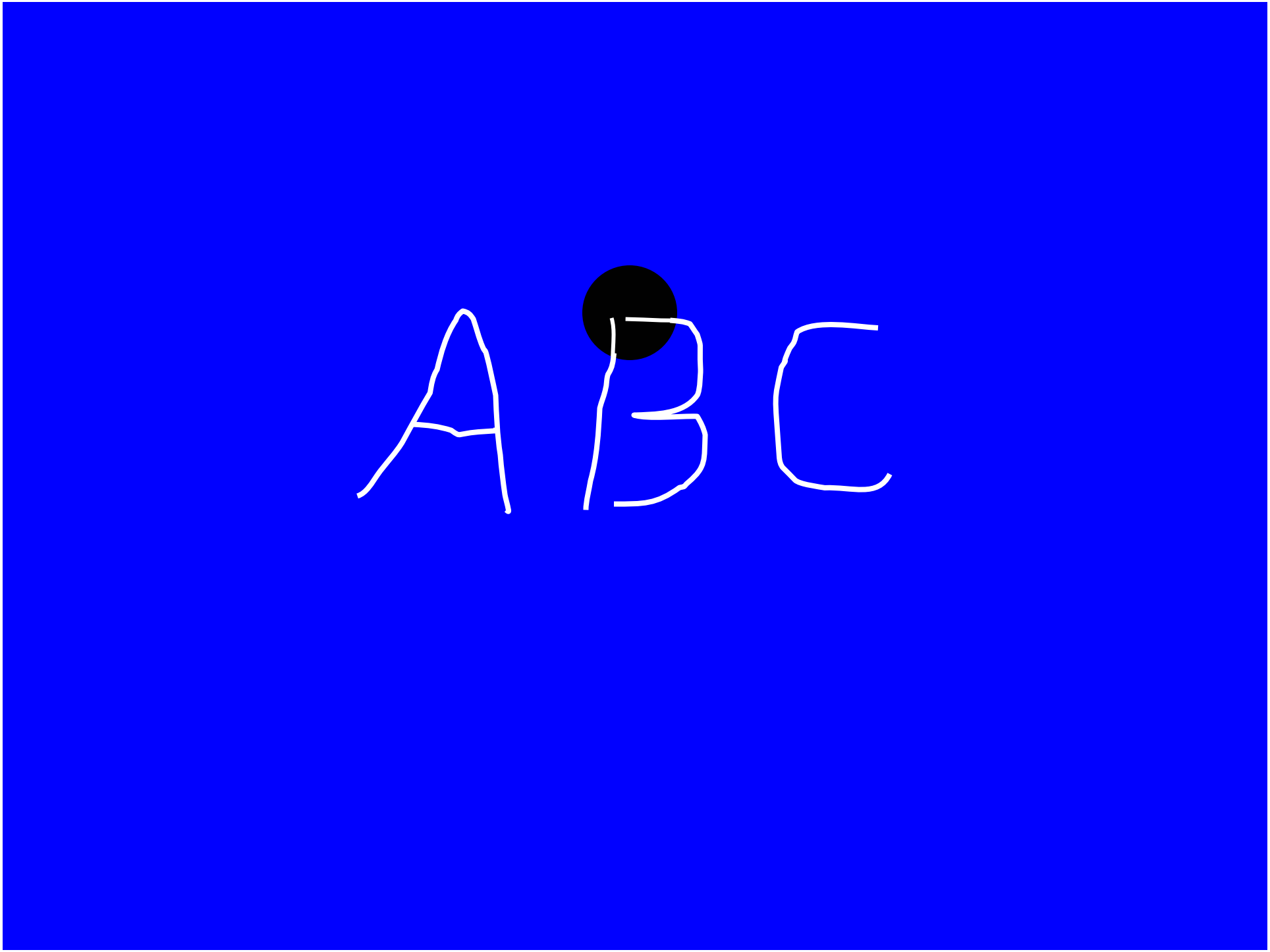


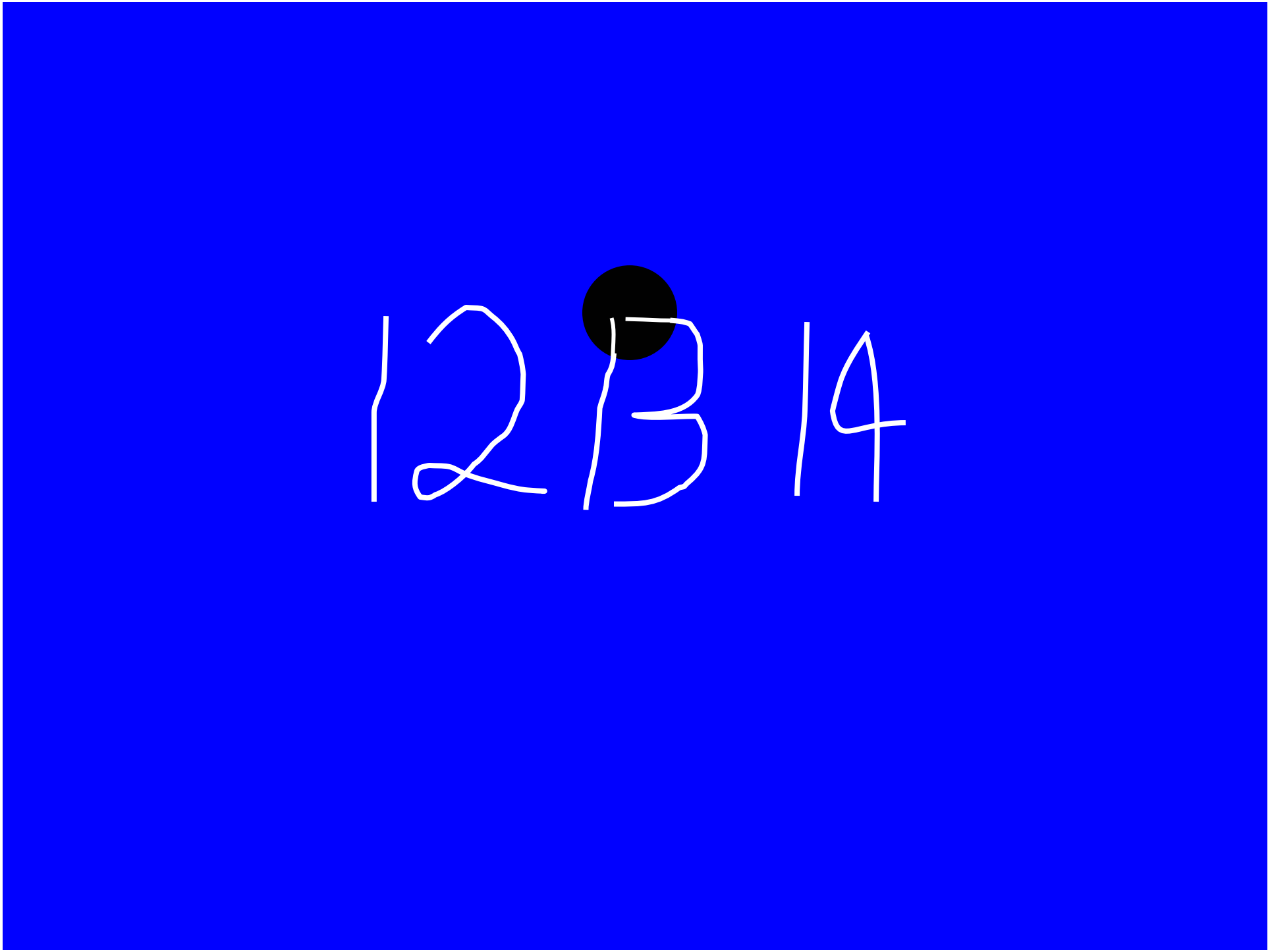

Impossible Window ©1997 IllusionWorks

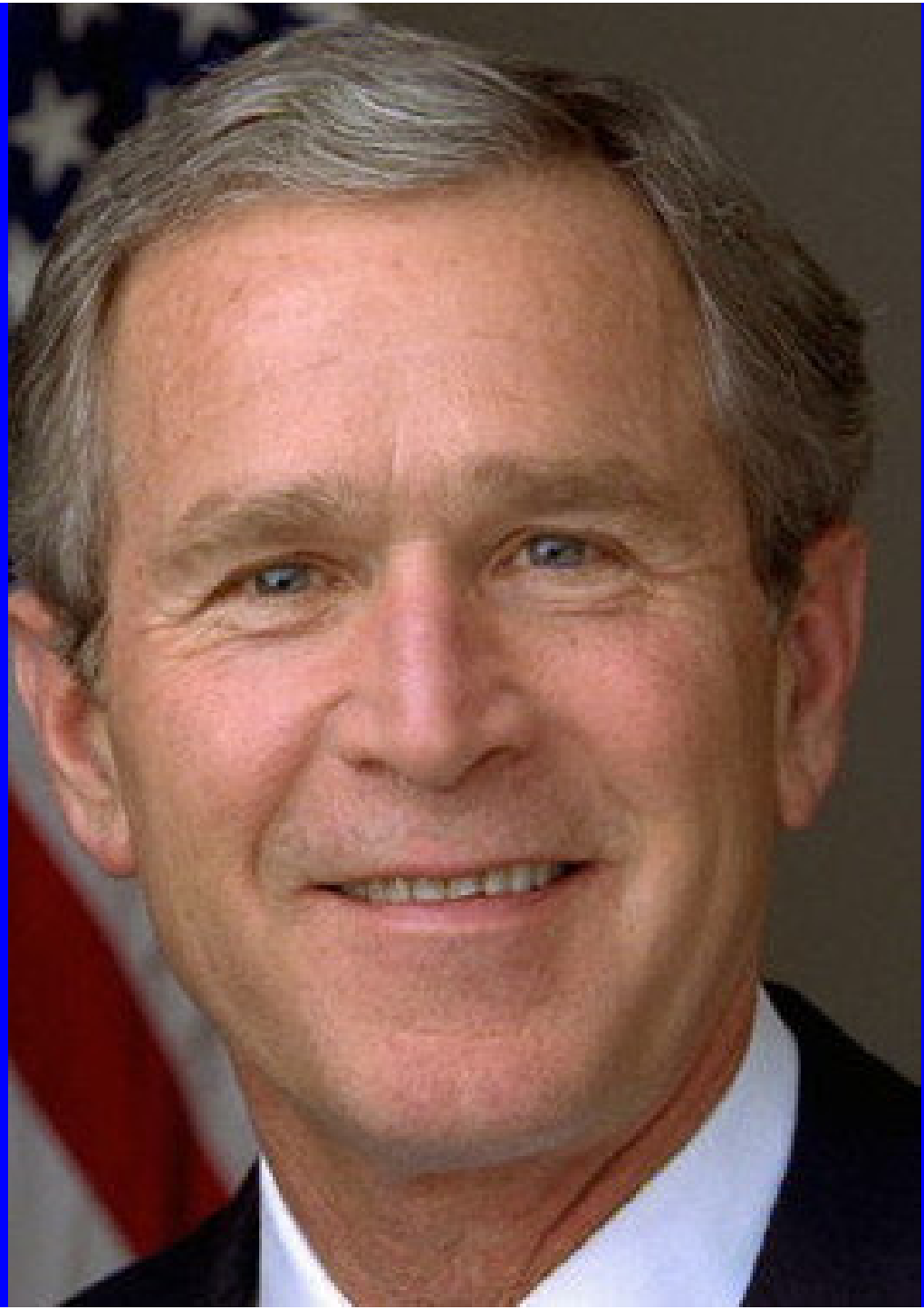




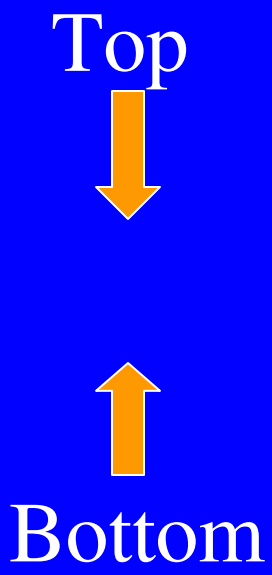



ABC


1 2 3 4

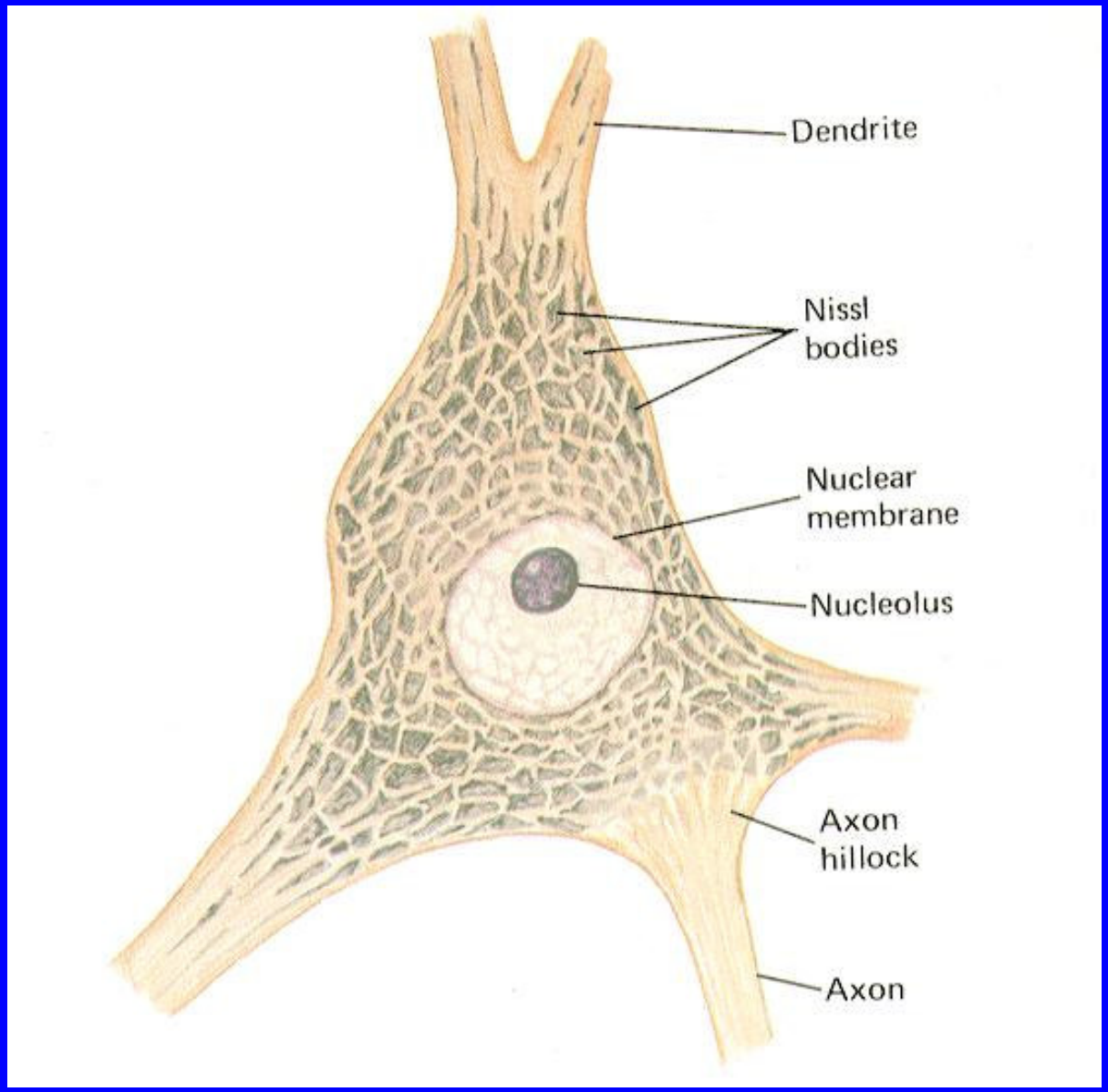



Local Features
Global Structures


Top
Bottom

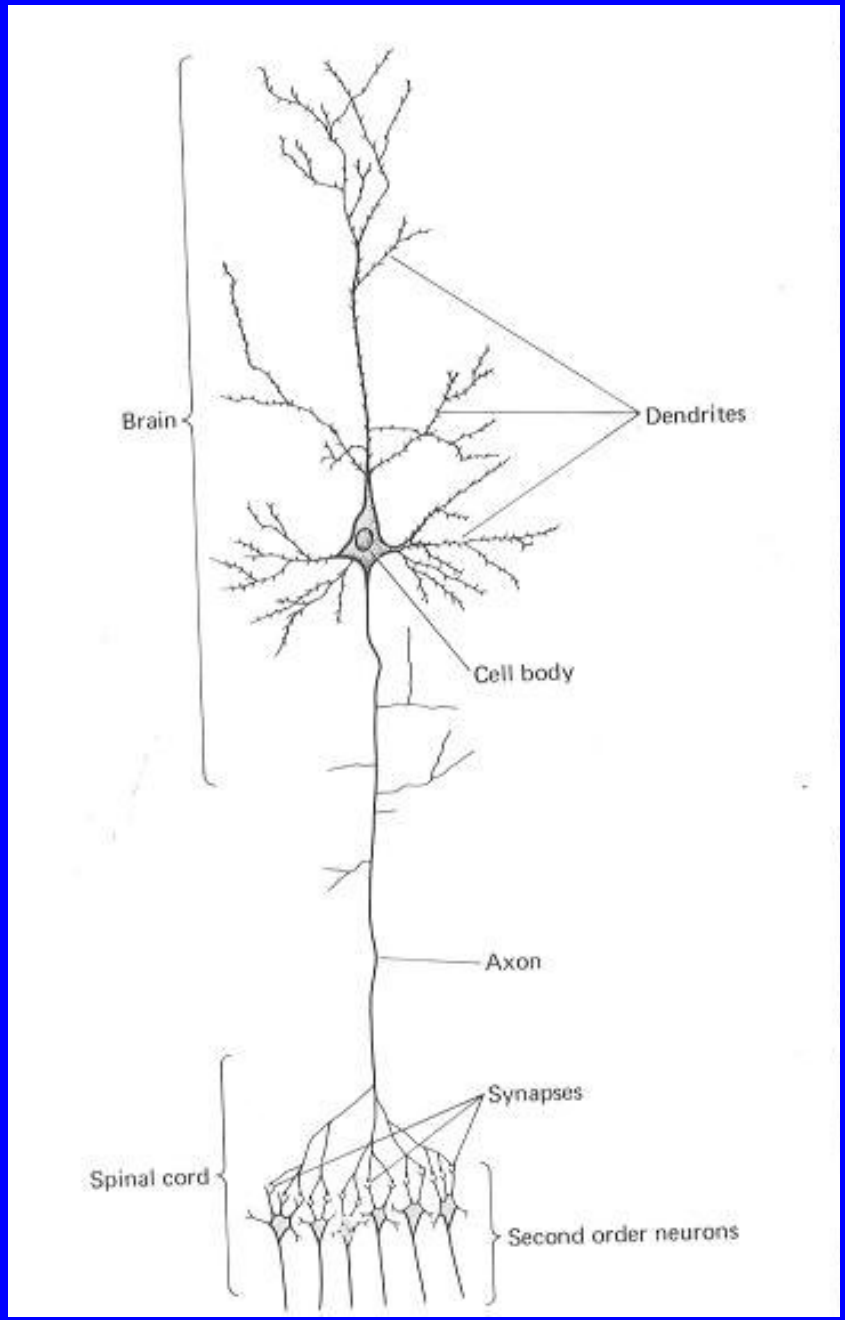
Basic facts

- CNS & PNS
- Afferent & Efferent
- Neural tissue: neurons, neuroglia (cns) Schwann (pns)


Dendrite
Nissl bodies
Nuclear membrane
Nucleolus
Axon hillock
Axon

Basic facts

- CNS neurons (10**11):
- body
- dendrites
- synapses
- axon (to neurons/muscles/glands)
- presynaptic terminal
- transmitter


Brain
Dendrites
Cell body
Axon
Synapses
Spinal cord
Second order neurons

The basic circuit

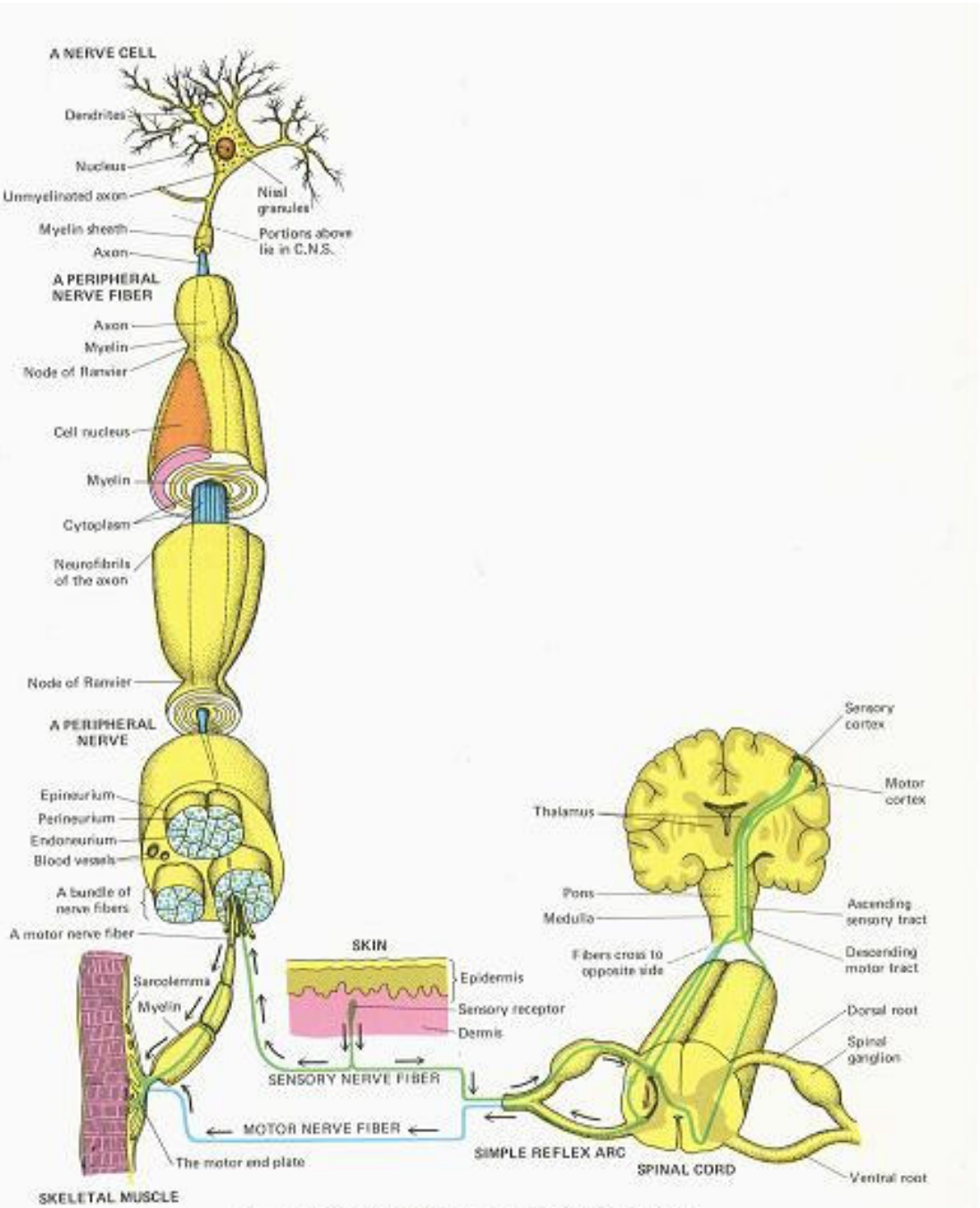
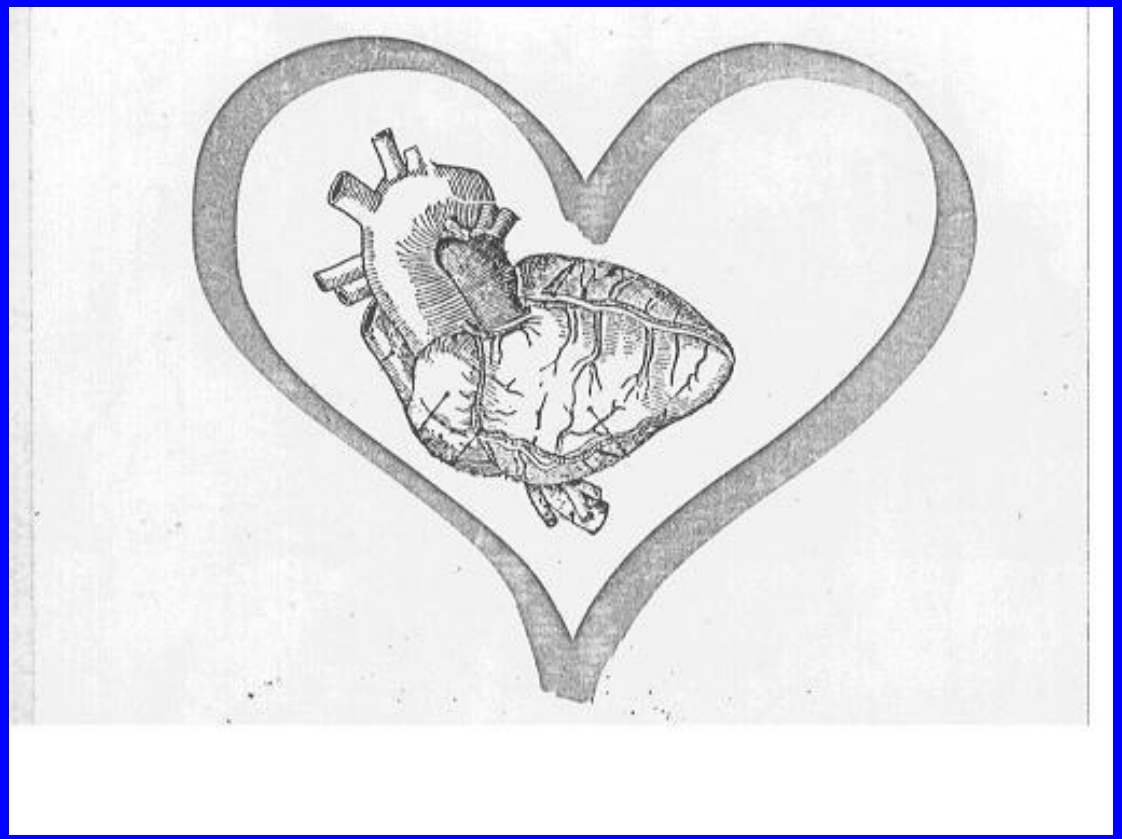


Figure 1–5. The functional components of the nervous system.

The basic functional circuit

- Touch - perception
- Throwing an object - avoidance
- Reading aloud
- Reading silently
- Anything ?
- Memory

The Mind Body problem



The Mind Body problem
or: the Psychophysical problem

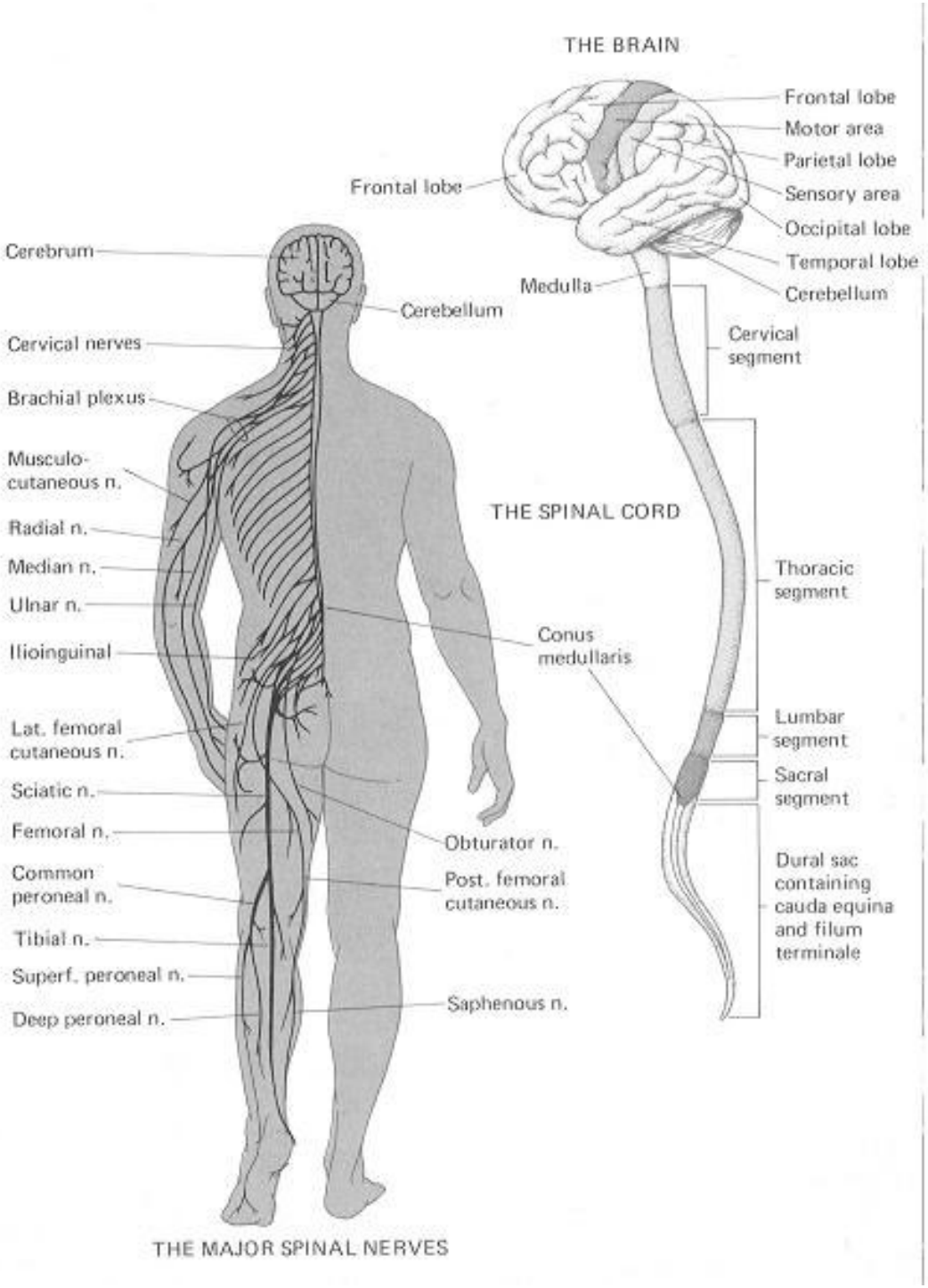
"the psychophysical link, which is most evident in our mind, is scientifically impossible"

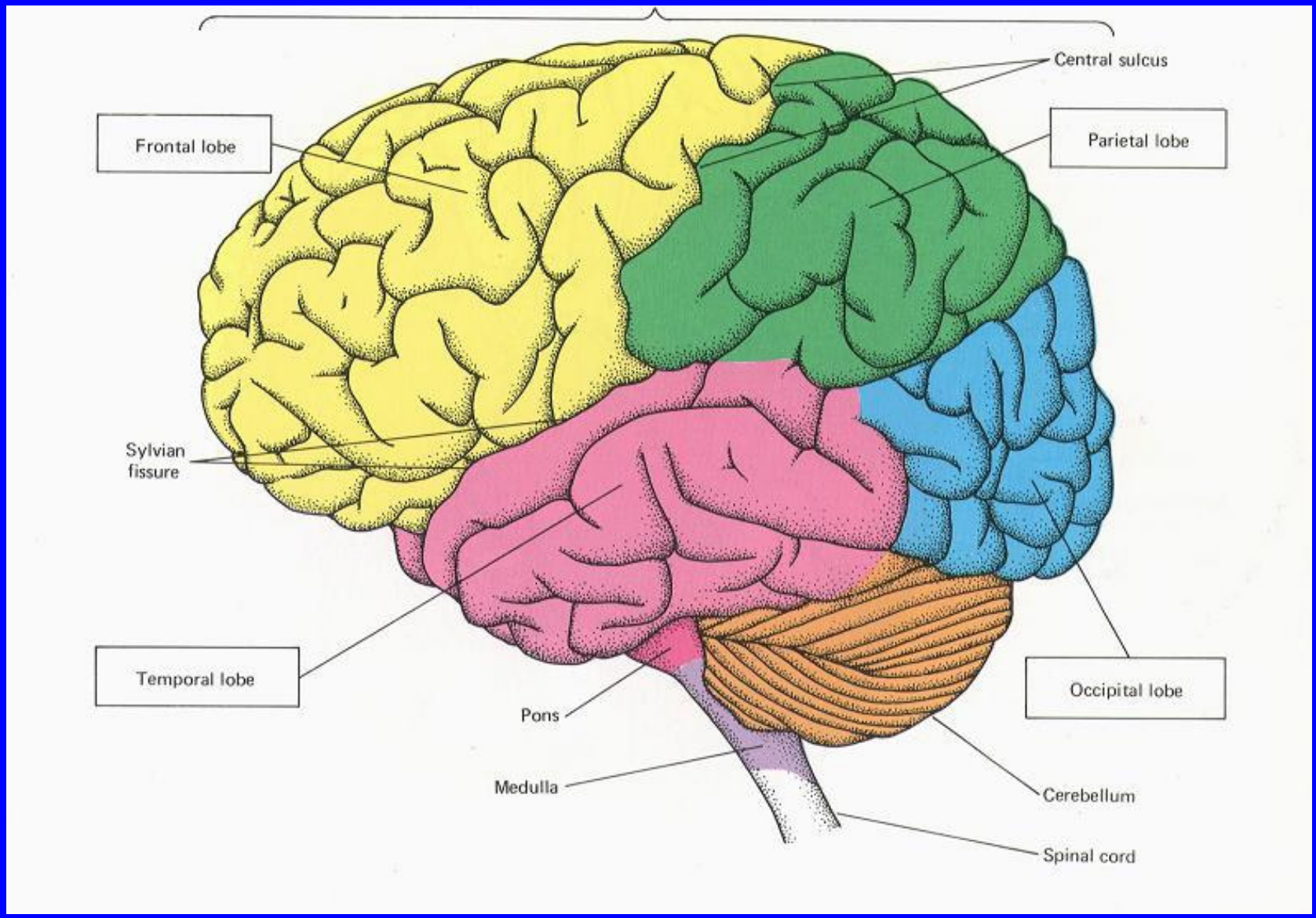
The Mind Body problem
or: the Psychophysical problem

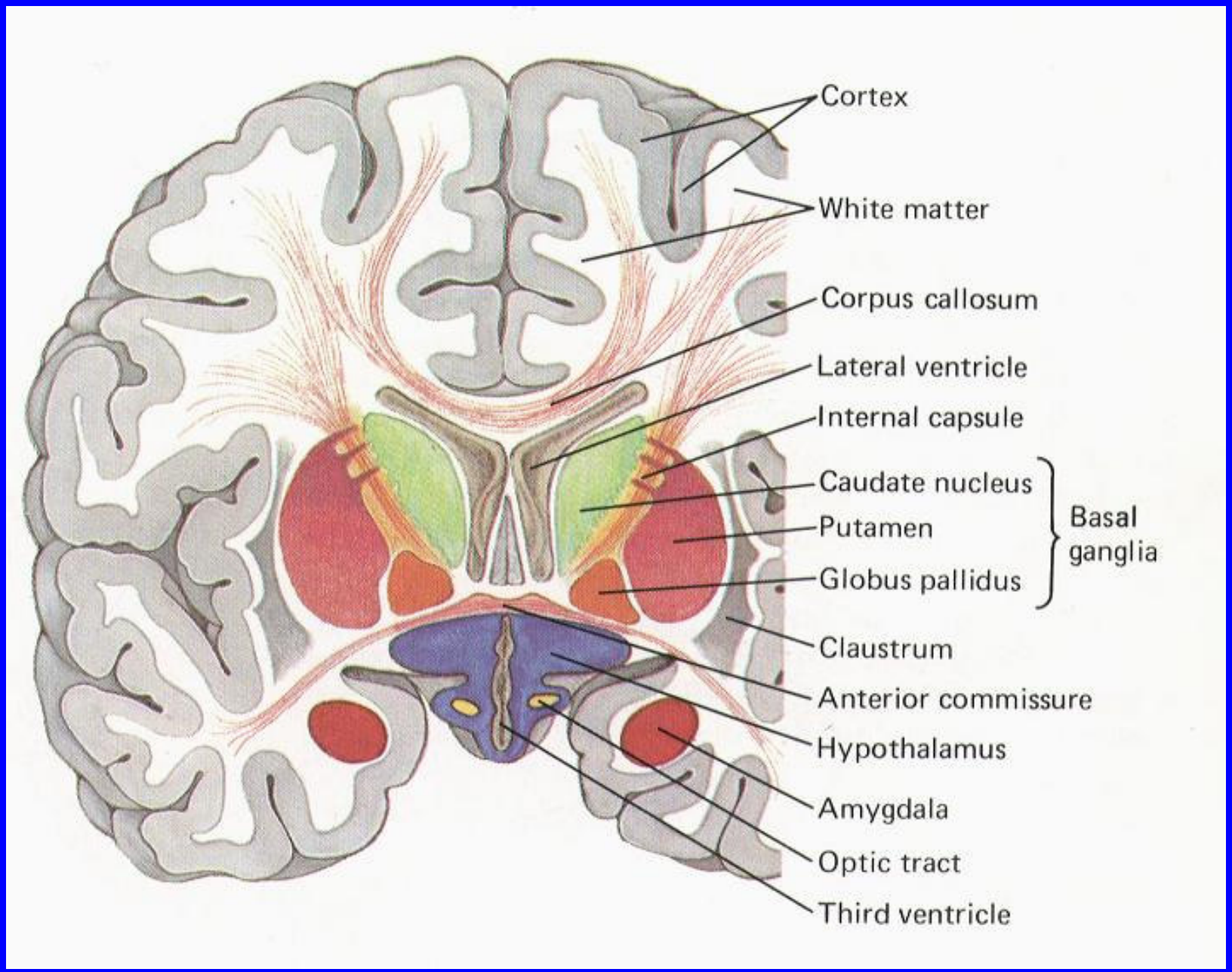
- Interactional Dualism
- Parallel Dualism
- Materialistic Monism
- Identity Monism

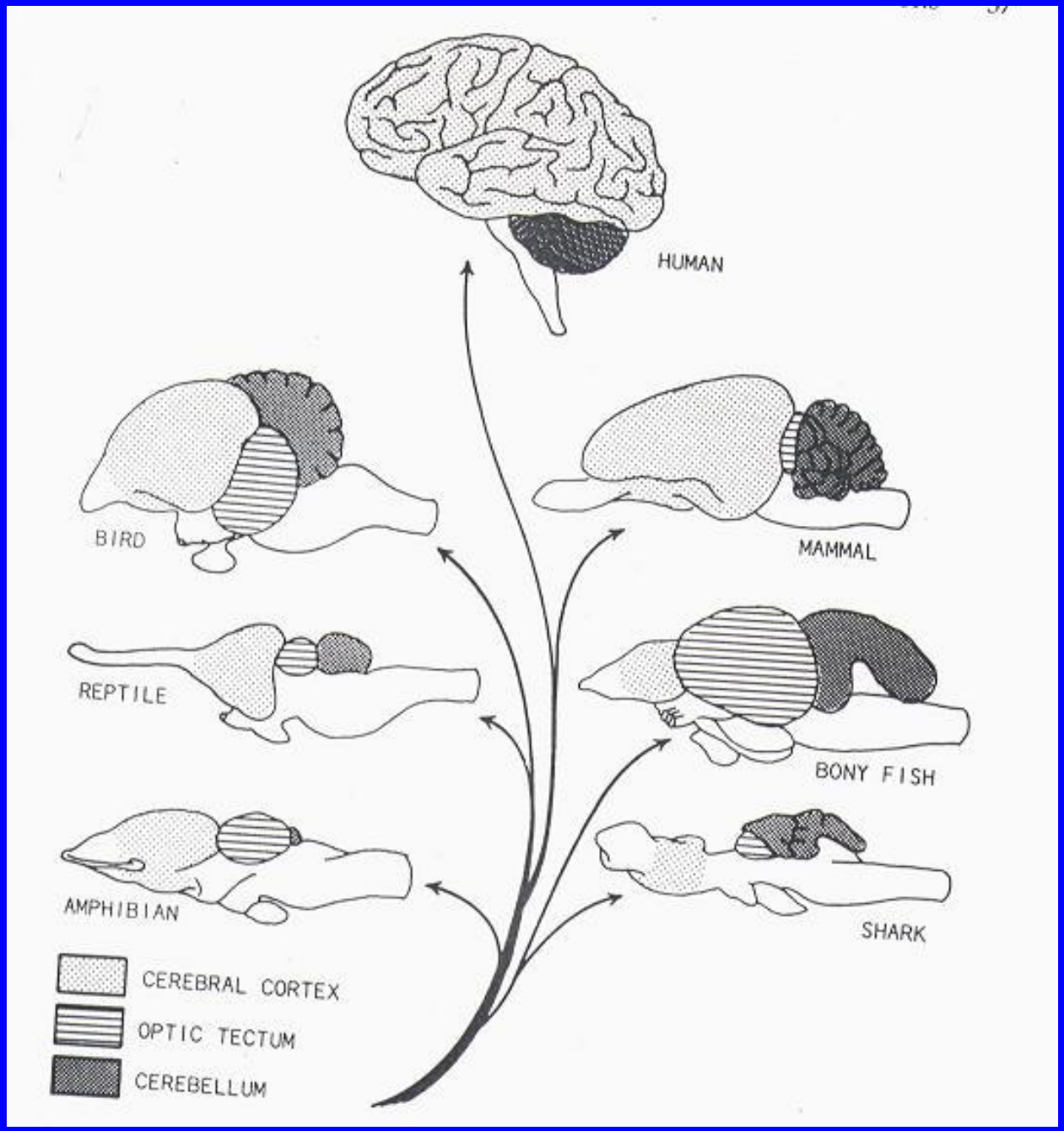
Common fallacies

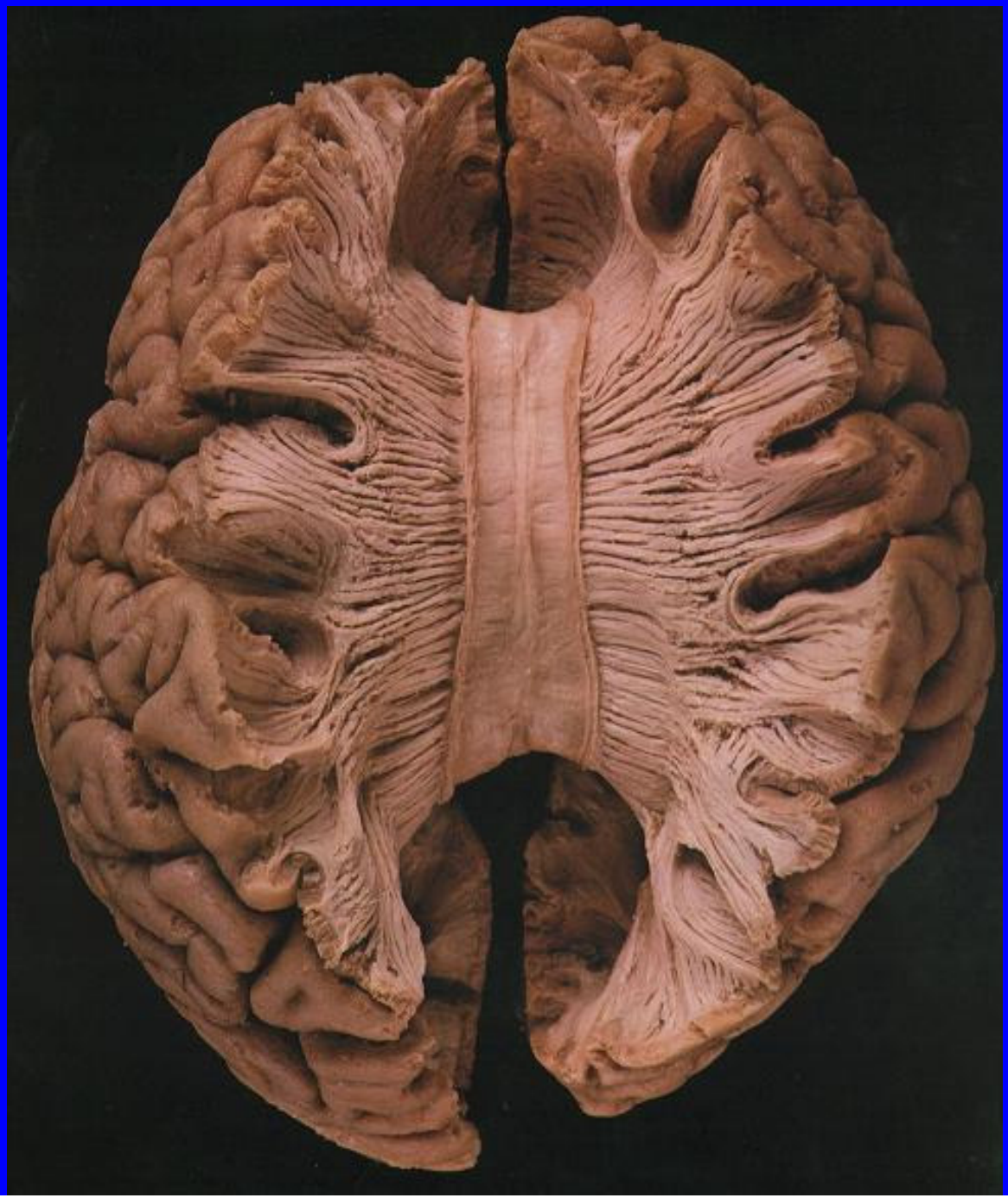
- The little green man inside
- The Chinese room
- Turing test for AI

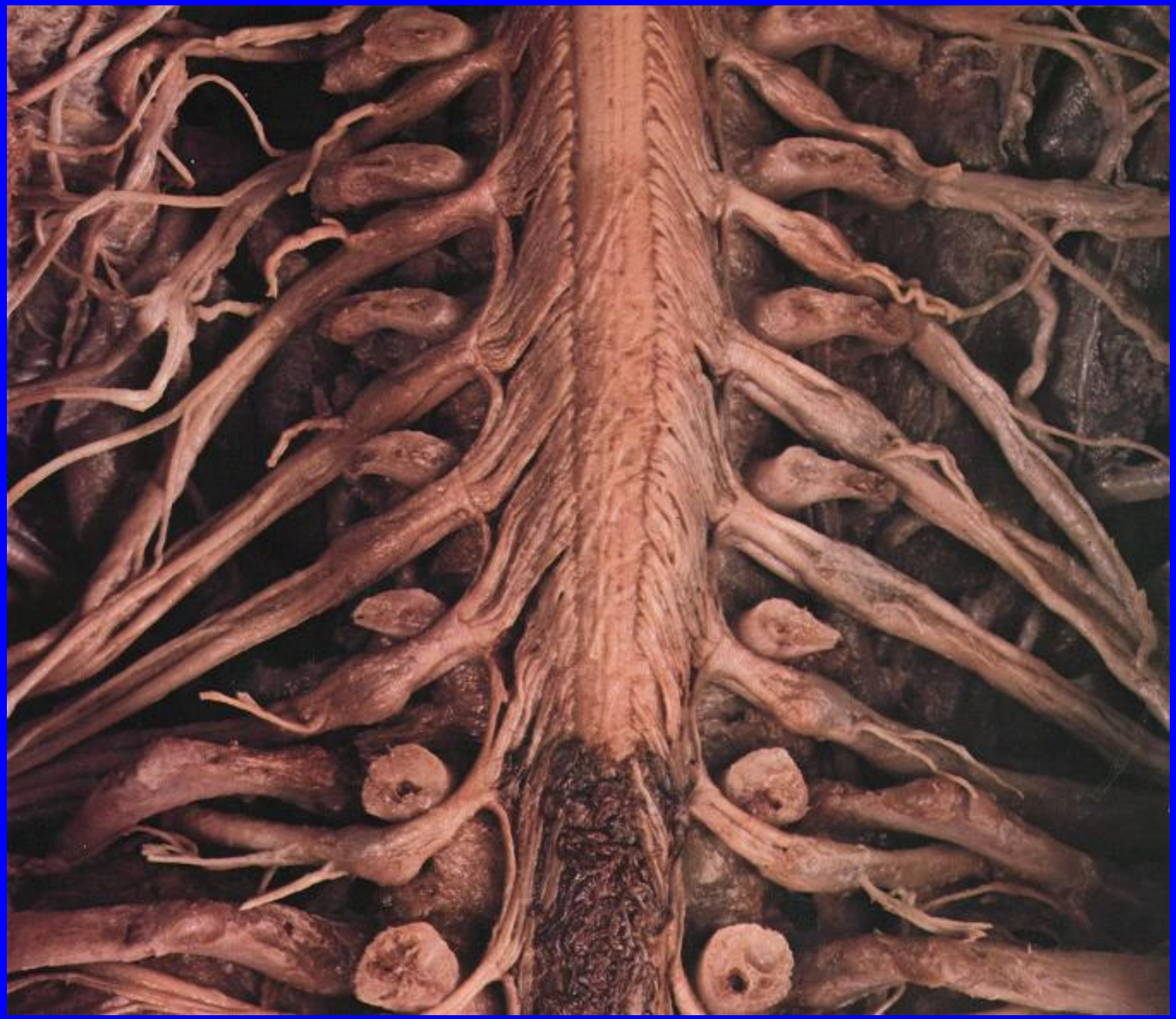

THE BRAIN
Frontal lobe
Motor area
Parietal lobe
Sensory area
Occipital lobe
Temporal lobe
Cerebellum
Frontal lobe
Medulla
Cerebrum
Cerebellum
Cervical nerves
Brachial plexus
Cervical segment
Musculo-cutaneous n.
Radial n.
Median n.
Ulnar n.
Ilioinguinal
THE SPINAL CORD
Thoracic segment
Conus medullaris
Lumbar segment
Sacral segment
Lat. femoral cutaneous n.
Sciatic n.
Femoral n.
Obturator n.
Common peroneal n.
Post. femoral cutaneous n.
Dural sac containing cauda equina and filum terminale
Tibial n.
Superf. peroneal n.
Saphenous n.
Deep peroneal n.
THE MAJOR SPINAL NERVES


Central sulcus
Frontal lobe
Parietal lobe
Sylvian fissure
Temporal lobe
Occipital lobe
Pons
Medulla
Cerebellum
Spinal cord


Cortex
White matter
Corpus callosum
Lateral ventricle
Internal capsule
Caudate nucleus
Putamen
Globus pallidus
Basal ganglia
Claustrum
Anterior commissure
Hypothalamus
Amygdala
Optic tract
Third ventricle


HUMAN
BIRD
MAMMAL
REPTILE
BONY FISH
AMPHIBIAN
SHARK
CEREBRAL CORTEX
OPTIC TECTUM
CEREBELLUM





Functional Moduls

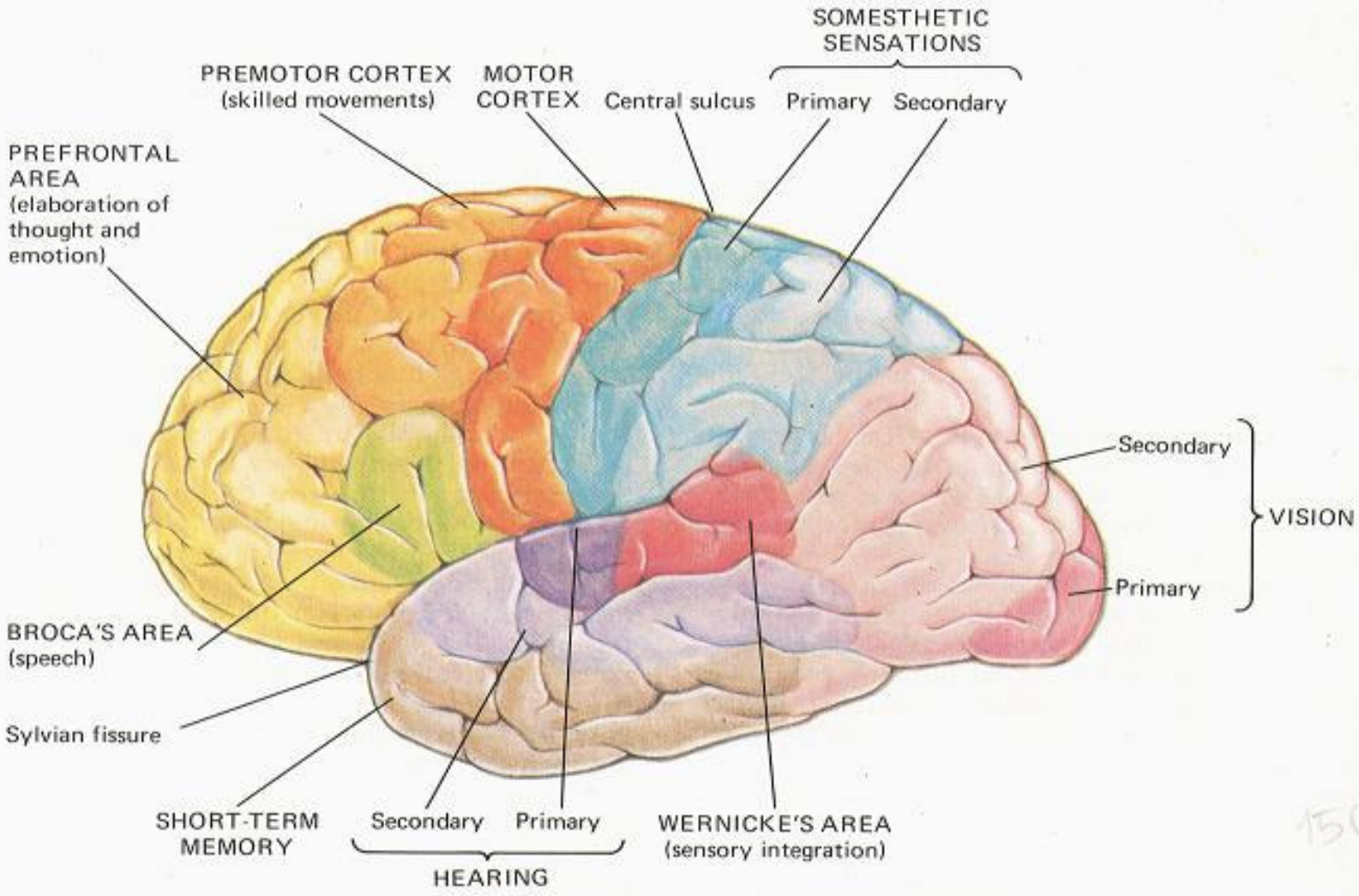
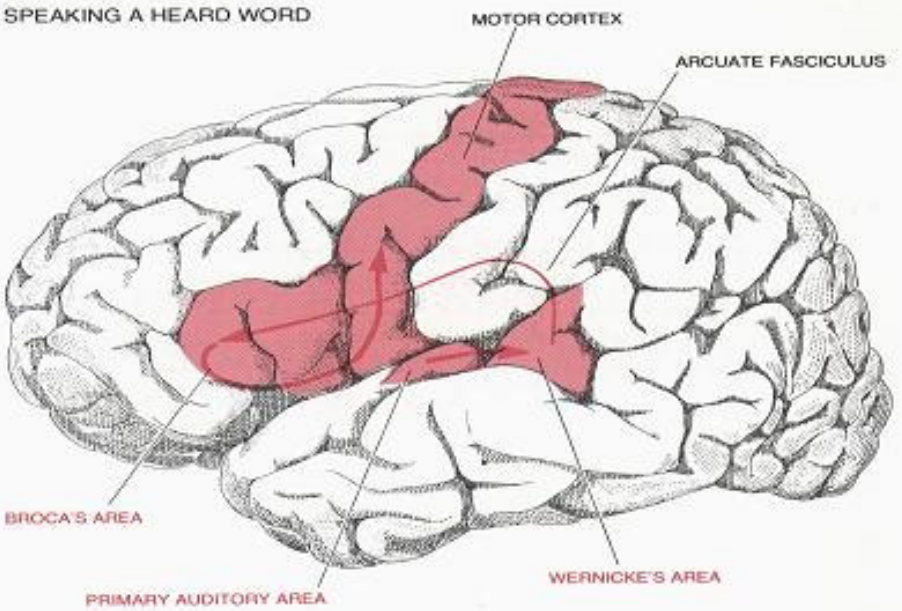
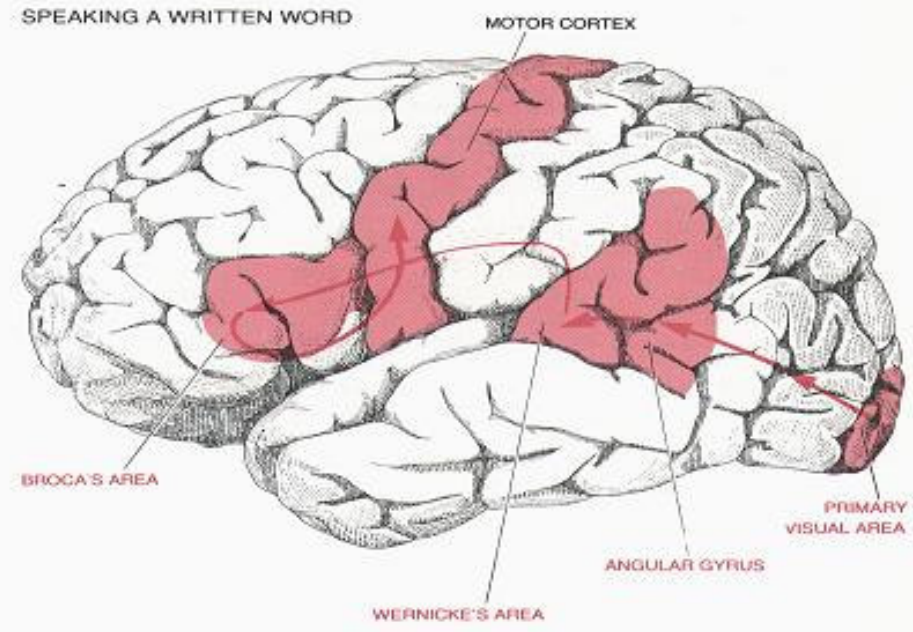
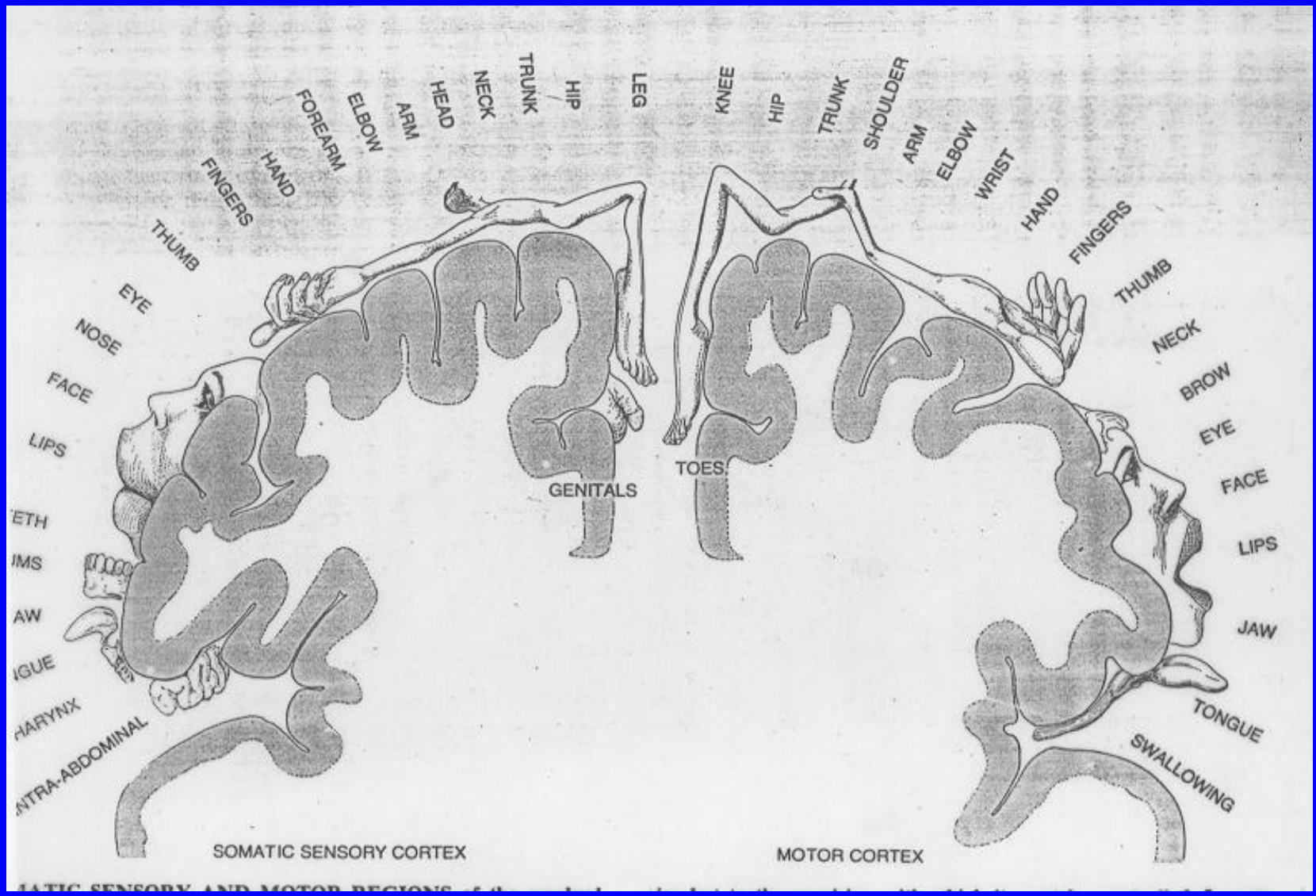


Figure 2–5. The functional areas of the cerebral cortex.


SPEAKING A HEARD WORD
MOTOR CORTEX
ARCUATE FASCICULUS
BROCA'S AREA
PRIMARY AUDITORY AREA
WERNICKE'S AREA


SPEAKING A WRITTEN WORD
MOTOR CORTEX
BROCA'S AREA
PRIMARY
VISUAL AREA
ANGULAR GYRUS
WERNICKE'S AREA

Somatosensory Mapping



Functional Moduls

- Motor: high resolution control (lips,thumb)
- Premotor: Spatio-temporal procedures
- Broca: Speech control

- Primary Somesthetic: spatial mapping
- Secondary Somesthetic: Object recognition?

Functional Moduls

- Visual: V1 - IT
- Continuous representation
- Space variant representation
- Hierarchical
- Grandmother cell

Functional moduls

- Primary Auditory: pure tones, loudness
- Secondary Auditory: speech, music

- Stimulating primary cortex: tones/noise/flickers/lines/colours
- Lesions in primary cortex: loss in complex objects recognition

Functional moduls

- Wernicke: Sensory data integration (meaning? Language?)
- Stimulating: complex pattern retrieval
- lesions: word meaning loss
- Wernicke - Auditory link ?
- Lateralization: right hemisphere handles music, spatial relations

Functional moduls

- Prefrontal: thrash can, planning, lesions

Functional moduls

- Diencephalon = (Thalamus, Hypothalamus)
- Thalamus: linking lower input to cortex
- MGB/LGN
- Cortical feedback

Functional moduls

- Diencephalon = (Thalamus, Hypothalamus)
- Hypothalamus: regulation, auton. System
- Hunger
- Joy/fear/punishment
- Blood pressure
- Sex drive

Functional moduls

- Diencephalon = (Thalamus, Hypothalamus)
- Hypothalamus: regulation, auton. System
- Weak stimulus:”positive”, Strong stimulus: “negative”
- “negative” overrides “positive”
- Less than 1% of the brain’s mass

Functional moduls

- Limbic system: between the Hypothalamus and the Cortex
- Amygdala: fear/stress/social behaviour
- Hypocampus: short to long term memory
- lesion: anterograde amnesia
- Filtering ?
- Link to Olfactory system ?

Functional moduls

- Cerebellum: motor control (classical)
- Muscle timing for complex sequences
- Activity predicts further motion
- Damping overshooting motion
- Motion planning/ TTC