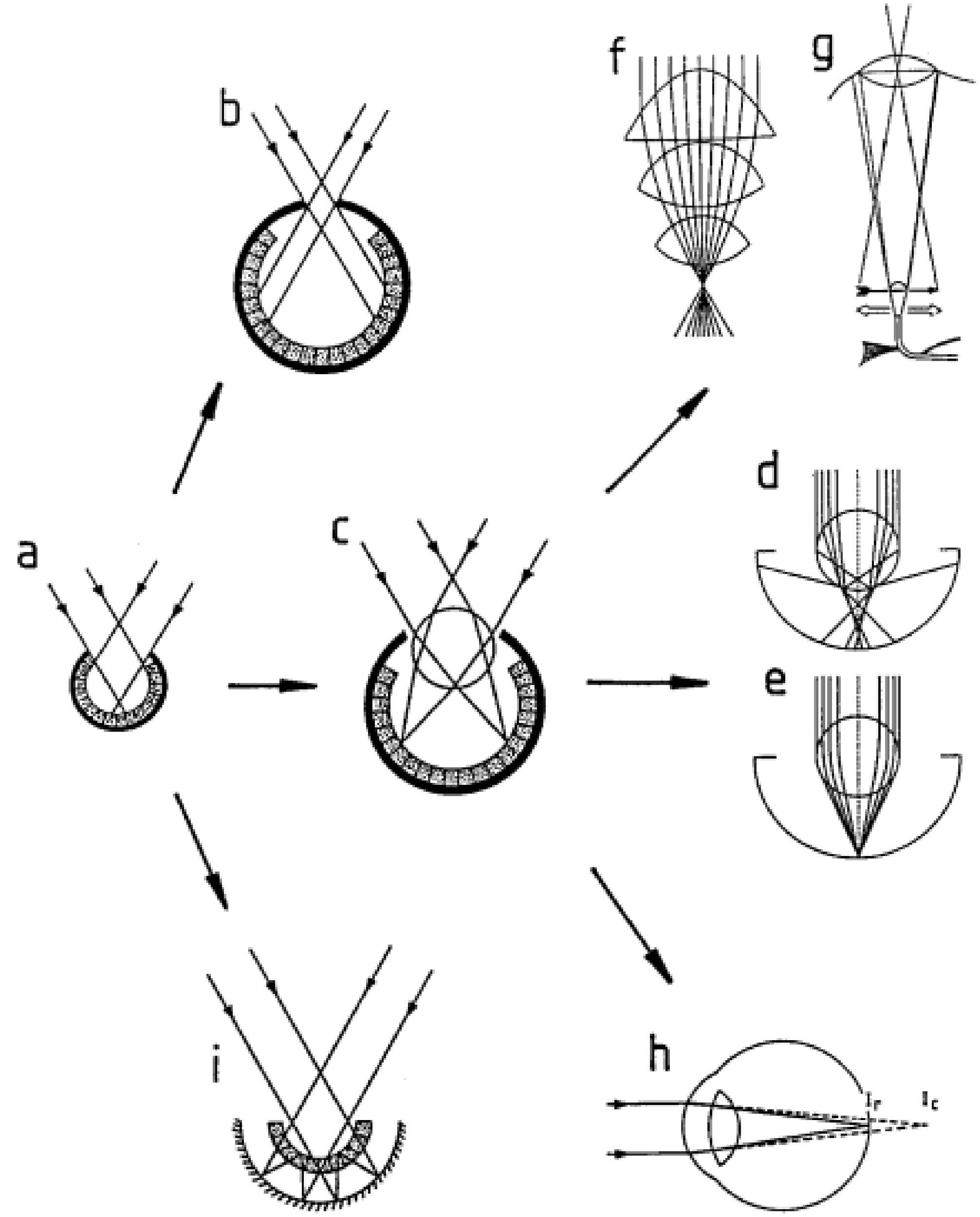
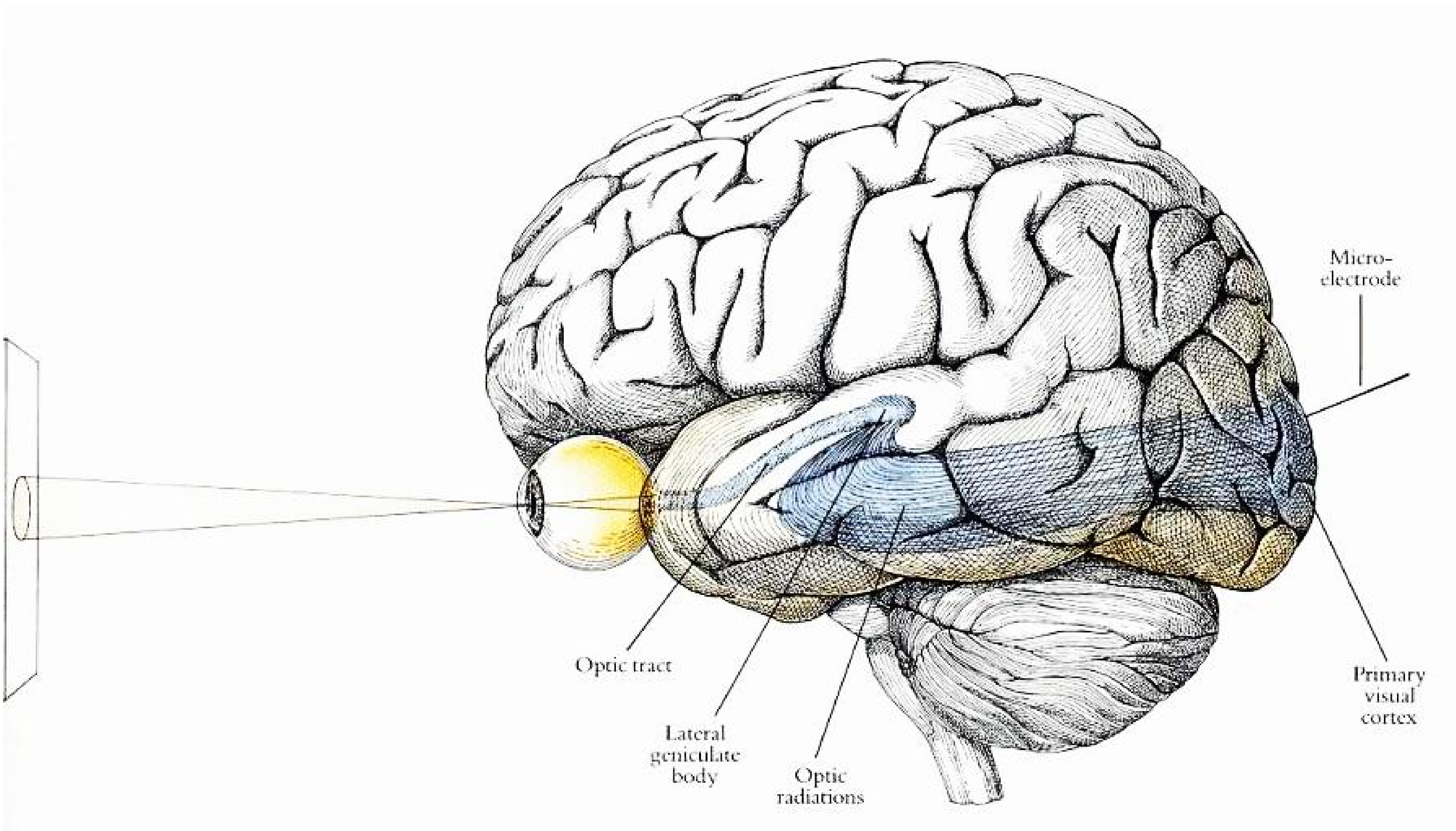
THE EVOLUTION OF EYES

Michael F. Land *Russell D. Fernald*




Micro-
electrode
Optic tract
Lateral
geniculate
body
Optic
radiations
Primary
visual
cortex

Brains and machines

Differences:

	brains	machines
matter	squishy cells	inorganic matter
power source	metabolic biochemistry	transformers and power mains
signal levels	100 mV	5 V
temporal resolution	milliseconds	nanoseconds
robustness to damage	good	poor
power consumption	10^{-12} watt/cell	10^{-5} watt/cell

Similarities:

Both systems....

- process information
- represent signals as differences in electrical potential
- convey signals on “wires”
- use active devices formed by thin energy barriers --> gain

PSYCHOLOGY

Study of behavior

Perception/cognition

Performance characteristics

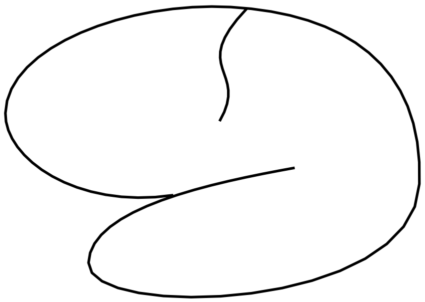
NEUROBIOLOGY

Study of neurons

Neural response properties

Signaling mechanisms

Synaptic transmission

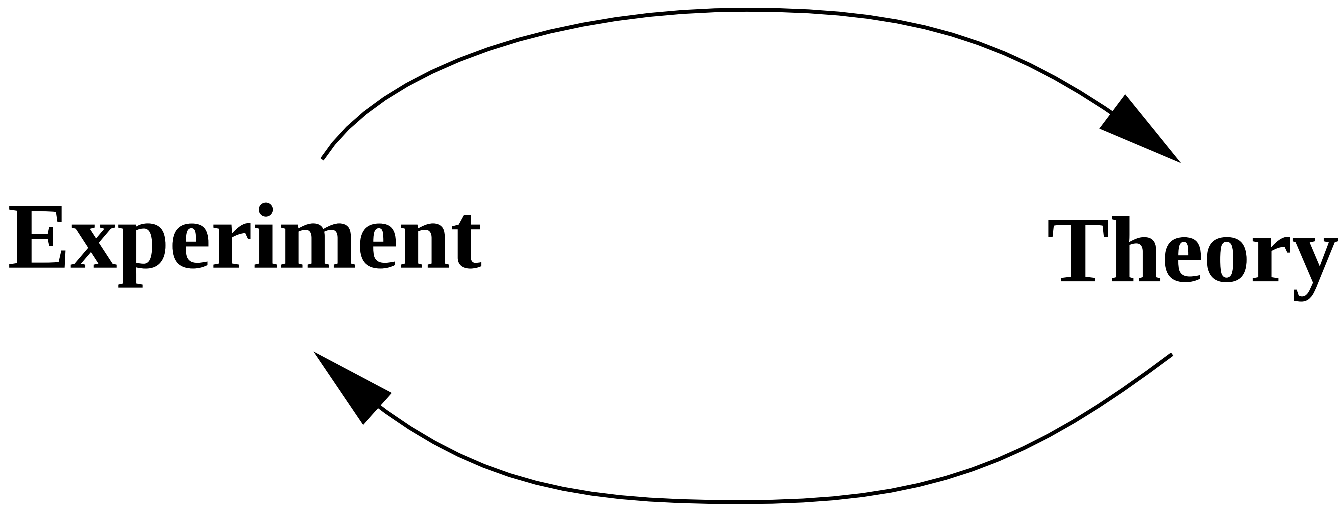


MATH/COMPUTER SCIENCE

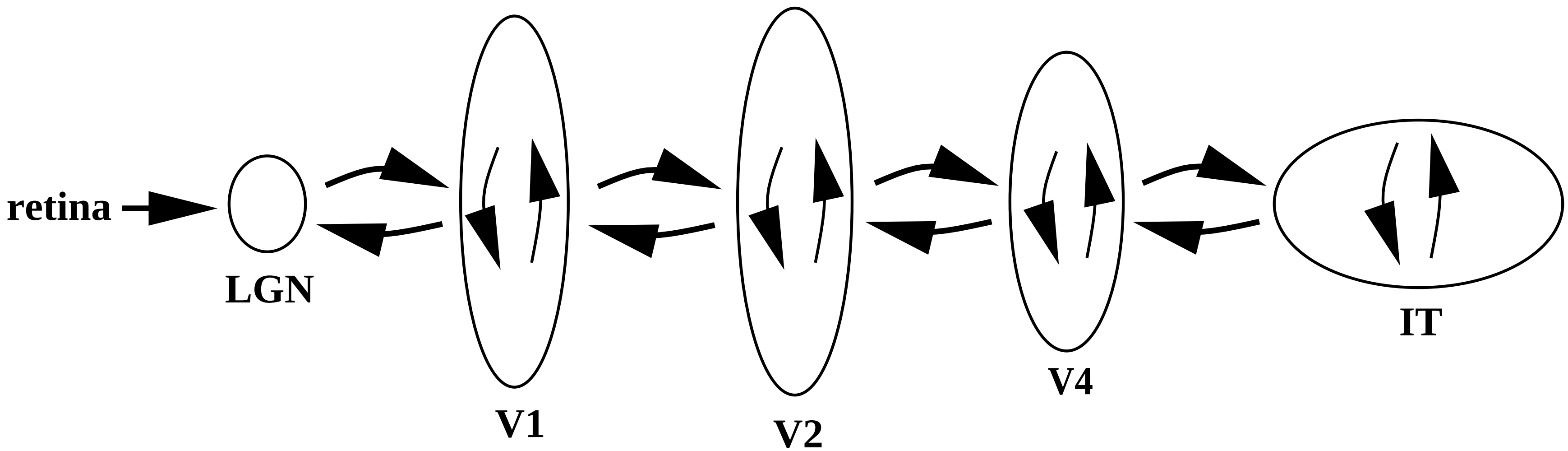
Study of information

Signal transformations

Efficient representation


Experiment
Theory

Recurrent computation is pervasive throughout cortex

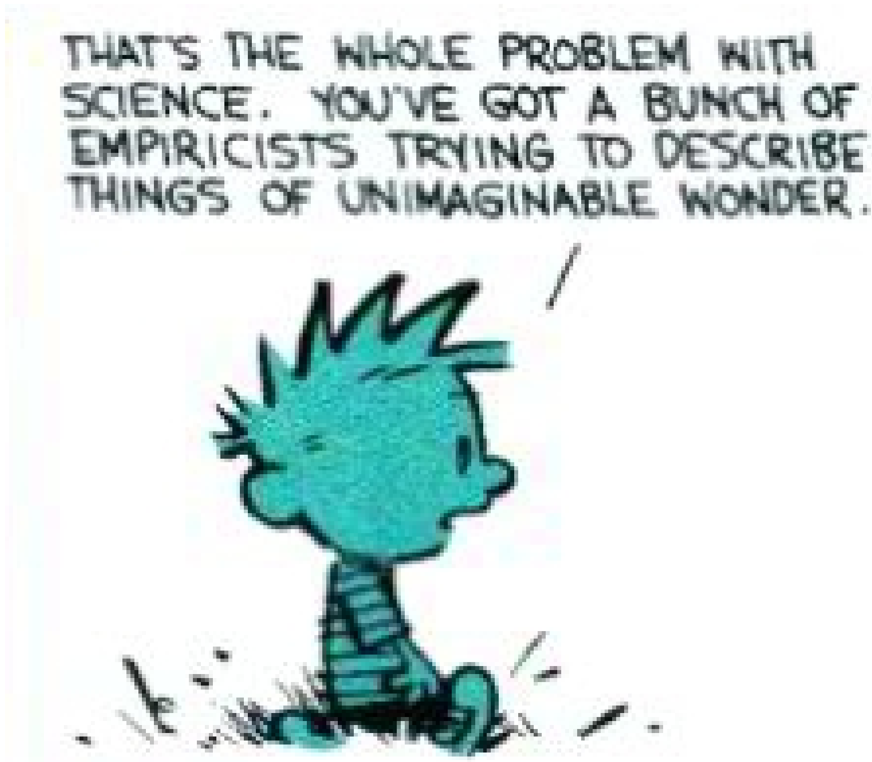


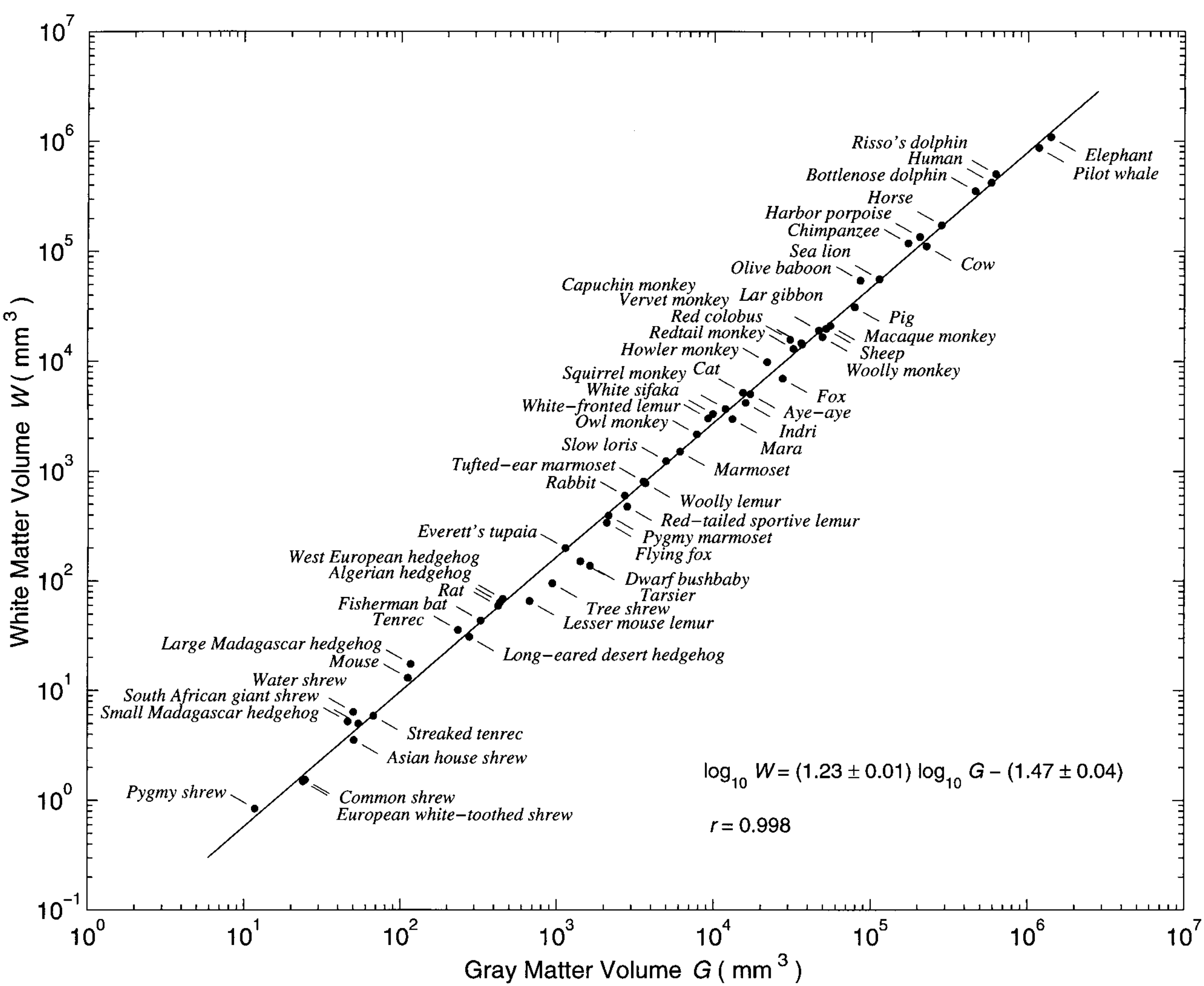
Sinewave speech

An example of *inference*.

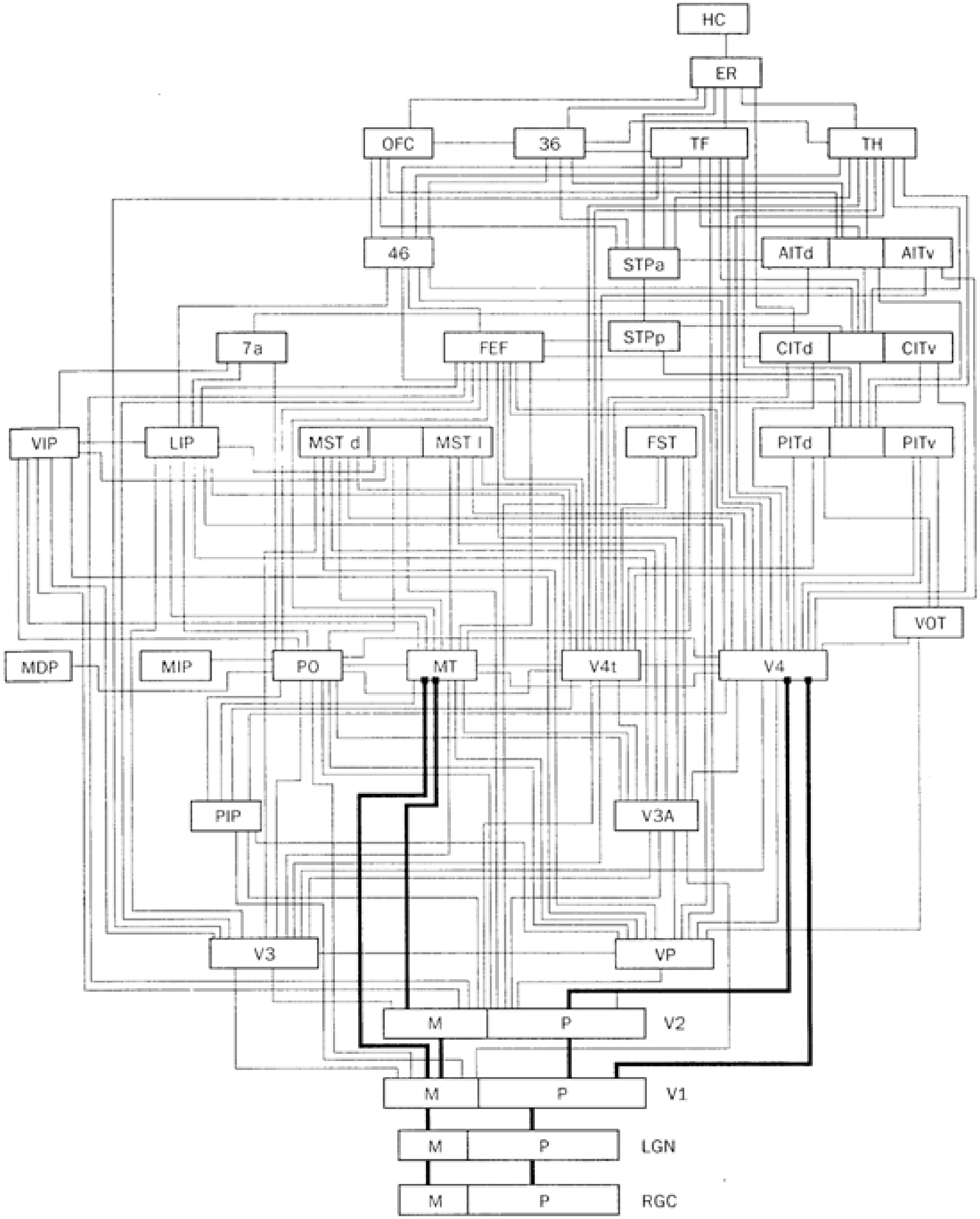
Please say what this word is.

sill shook rust wed pass lark jaw coop beak

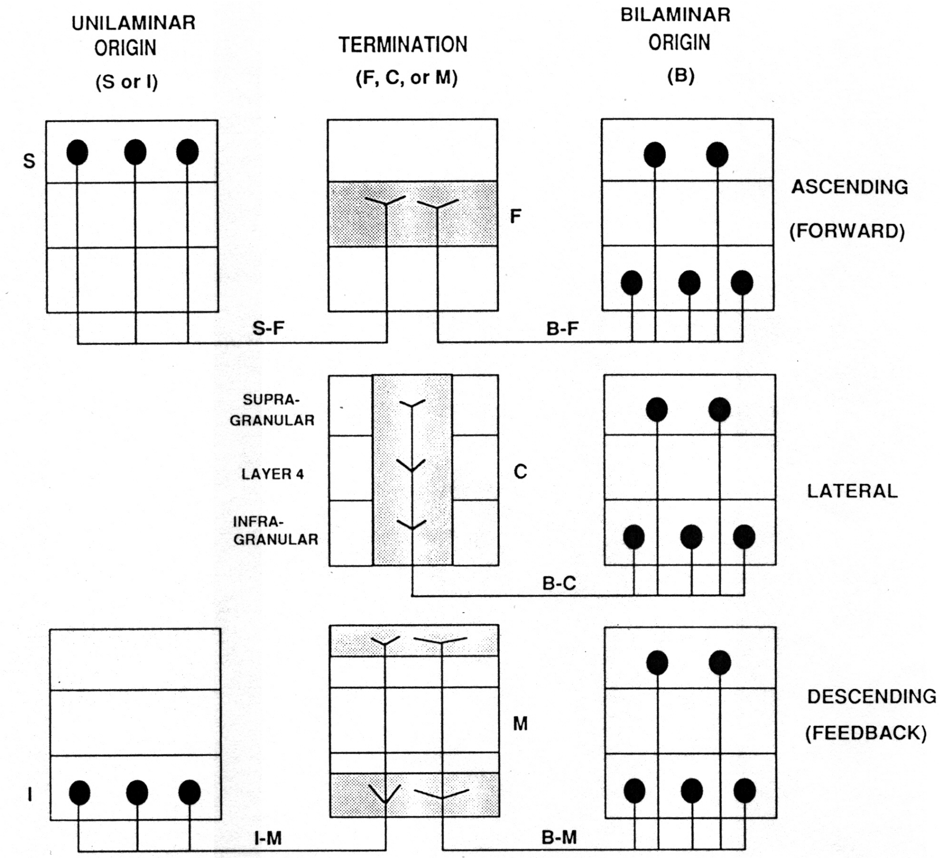

THAT'S THE WHOLE PROBLEM WITH SCIENCE. YOU'VE GOT A BUNCH OF EMPIRICISTS TRYING TO DESCRIBE THINGS OF UNIMAGINABLE WONDER.

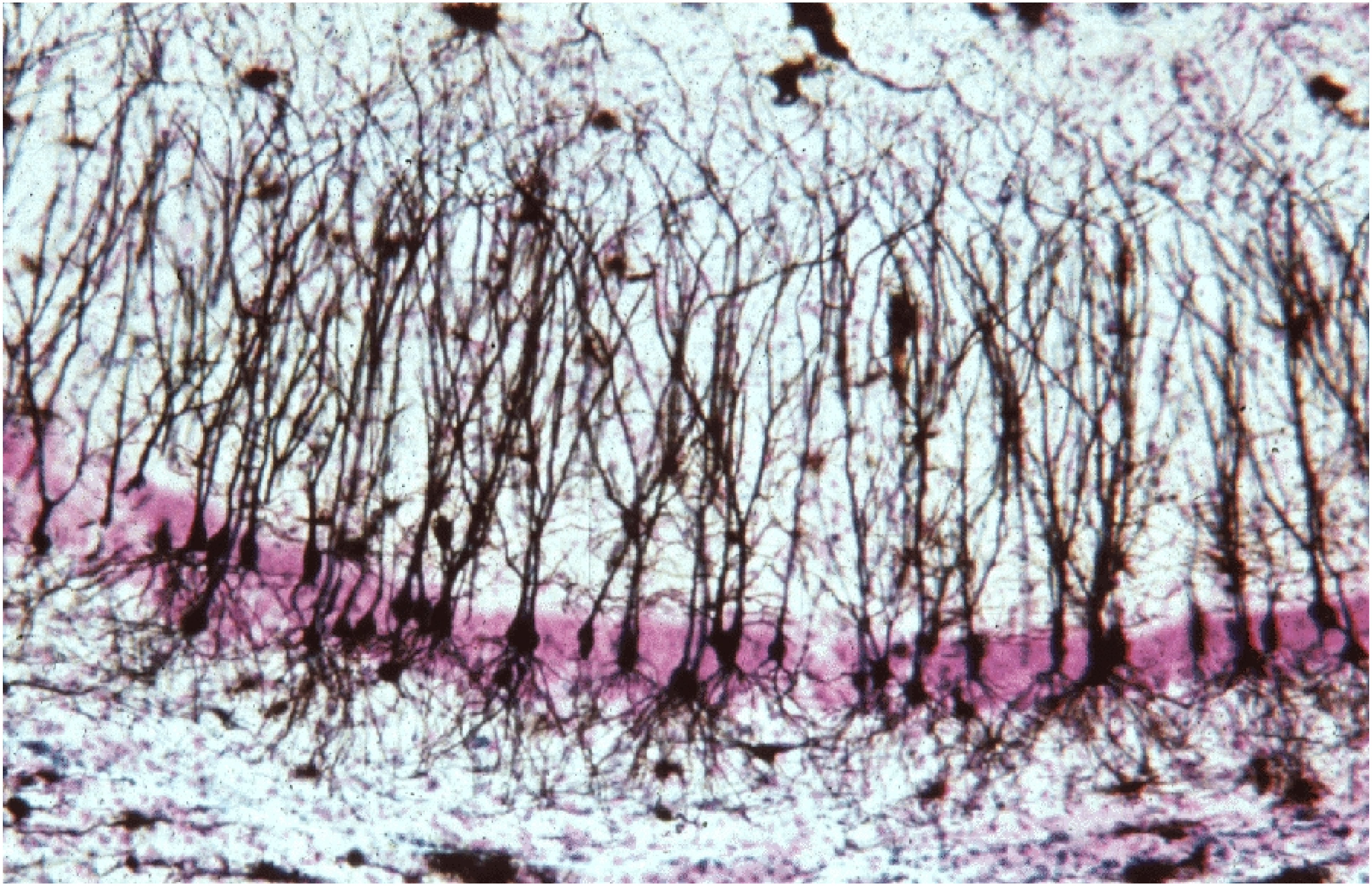


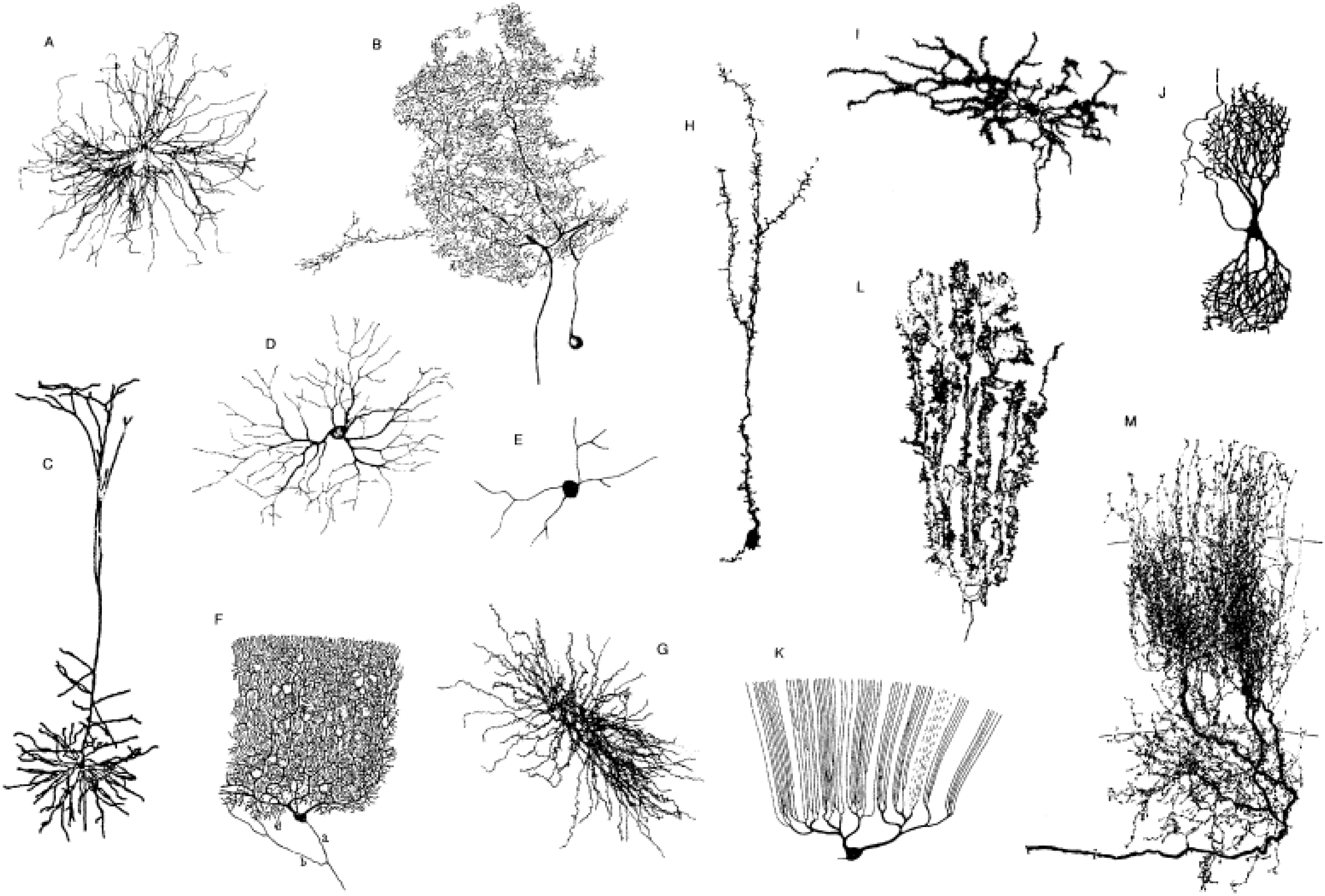
White Matter Volume W (mm^3)
Gray Matter Volume G (mm^3)
10^{-1}
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
Risso's dolphin
Human
Bottlenose dolphin
Elephant
Pilot whale
Horse
Harbor porpoise
Chimpanzee
Cow
Sea lion
Olive baboon
Capuchin monkey
Vervet monkey
Lar gibbon
Pig
Red colobus
Redtail monkey
Macaque monkey
Sheep
Woolly monkey
Howler monkey
Squirrel monkey
Cat
Fox
White sifaka
White−fronted lemur
Aye−aye
Owl monkey
Indri
Mara
Slow loris
Marmoset
Tufted−ear marmoset
Rabbit
Woolly lemur
Red−tailed sportive lemur
Pygmy marmoset
Flying fox
Everett's tupaia
West European hedgehog
Algerian hedgehog
Rat
Dwarf bushbaby
Tarsier
Tree shrew
Lesser mouse lemur
Fisherman bat
Tenrec
Long−eared desert hedgehog
Large Madagascar hedgehog
Mouse
Water shrew
South African giant shrew
Small Madagascar hedgehog
Streaked tenrec
Asian house shrew
Pygmy shrew
Common shrew
European white−toothed shrew
$\log_{10} W = (1.23 \pm 0.01) \log_{10} G - (1.47 \pm 0.04)$
$r = 0.998$

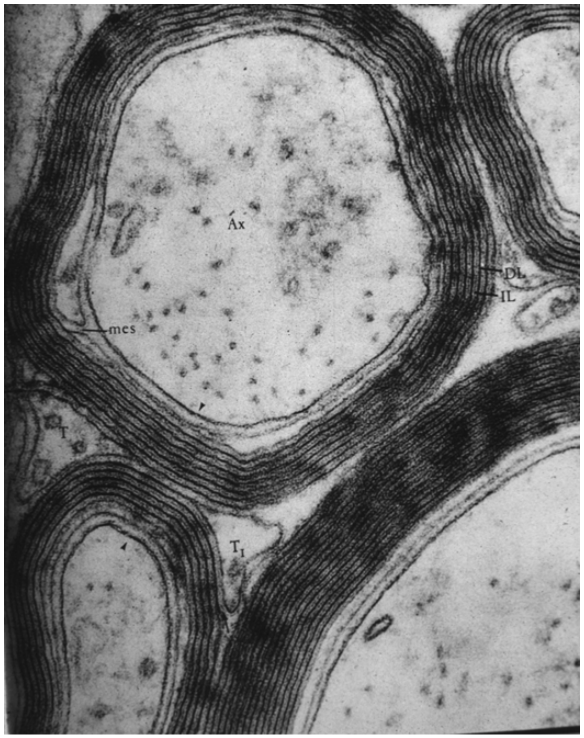

HC
ER
OFC
36
TF
TH
46
STPa
AITd
AITv
7a
FEF
STPp
CITd
CITv
VIP
LIP
MST d
MST l
FST
PITd
PITv
VOT
MDP
MIP
PO
MT
V4t
V4
PIP
V3A
V3
VP
M
P
V2
M
P
V1
M
P
LGN
M
P
RGC

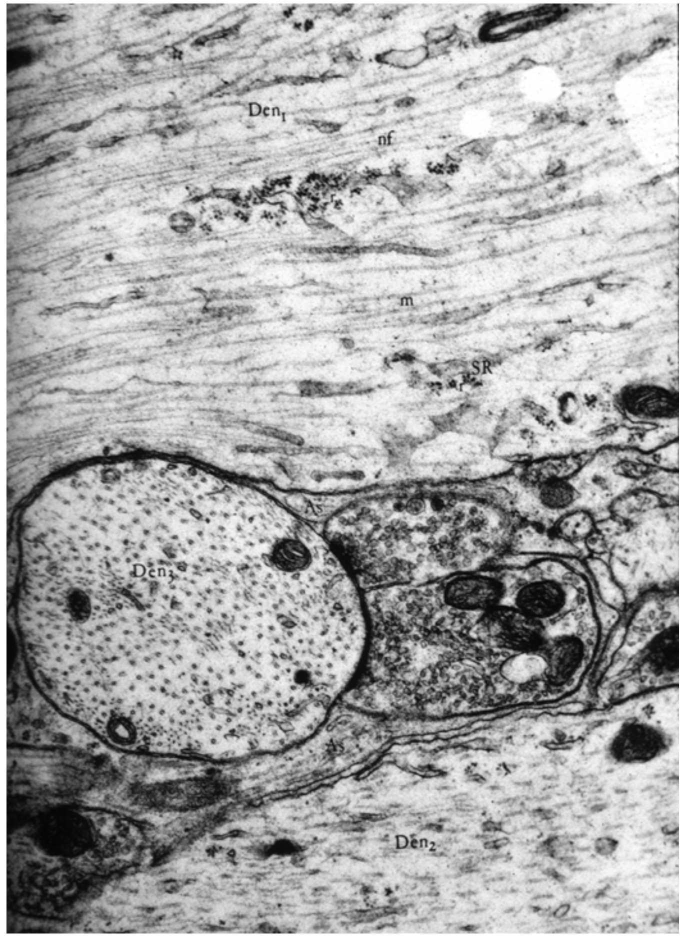
Rules of cortical connectivity



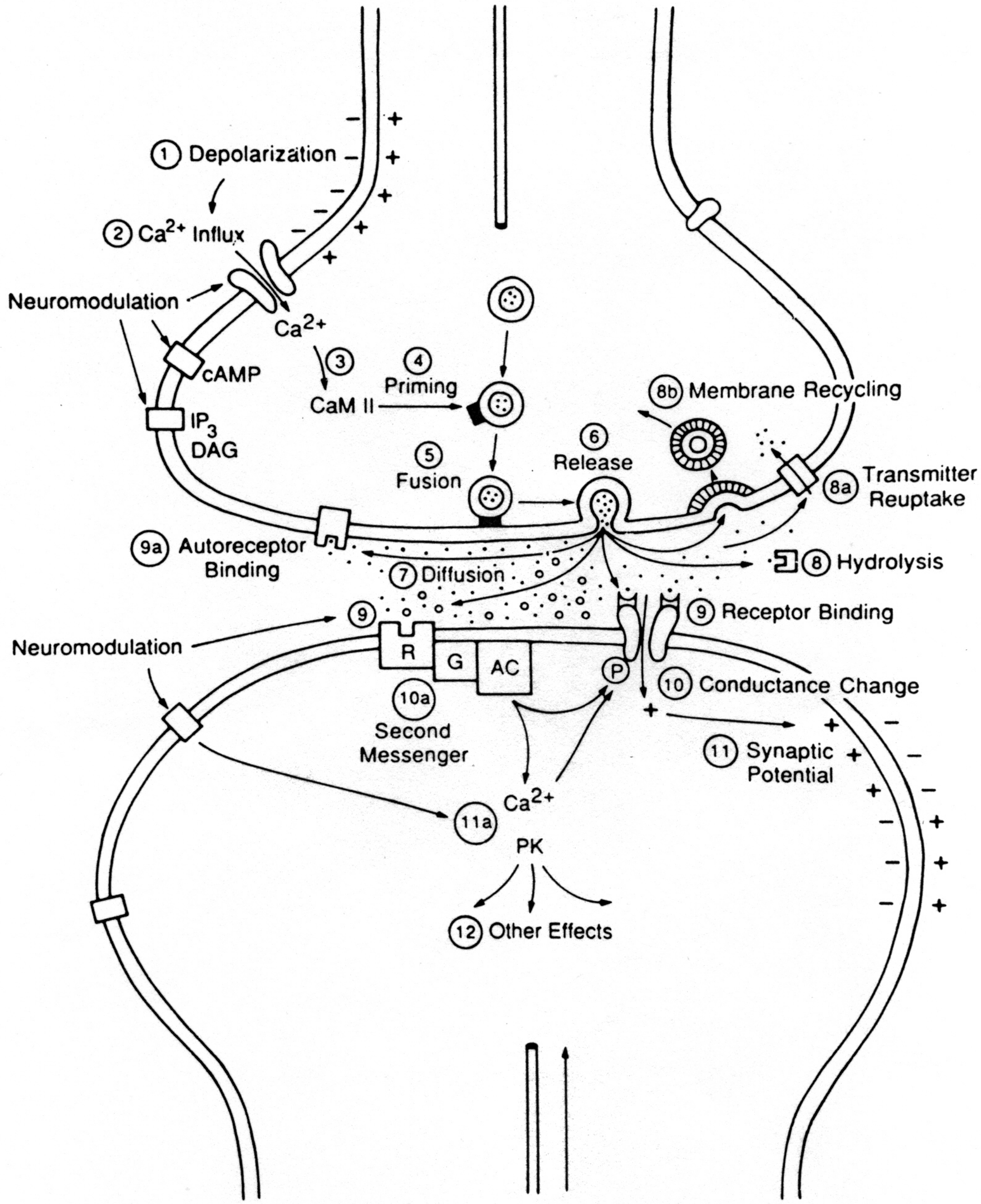



A
B
C
D
E
F
G
H
I
J
K
L
M


Ax
DL
IL
mes
T
T_1


Den_1
nf
m
SR
As
Den_3
Den_2


Sp



1 Depolarization
2 Ca^{2+} Influx
Neuromodulation
Ca^{2+}
cAMP
3
CaM II
4 Priming
IP_3
DAG
5 Fusion
6 Release
8b Membrane Recycling
8a Transmitter Reuptake
9a Autoreceptor Binding
7 Diffusion
8 Hydrolysis
9
9 Receptor Binding
Neuromodulation
R
G
AC
P
10 Conductance Change
10a Second Messenger
11 Synaptic Potential
11a
Ca^{2+}
PK
12 Other Effects

Marr's three levels

Computational theory	Representation and algorithm	Hardware implementation
What is the goal of the computation, why is it appropriate, and what is the logic of the strategy by which it can be carried out?	How can this computational theory be implemented? In particular, what is the representation for the input and output, and what is the algorithm for the transformation?	How can the representation and algorithm be realized physically?

Figure 1–4. The three levels at which any machine carrying out an information-processing task must be understood.