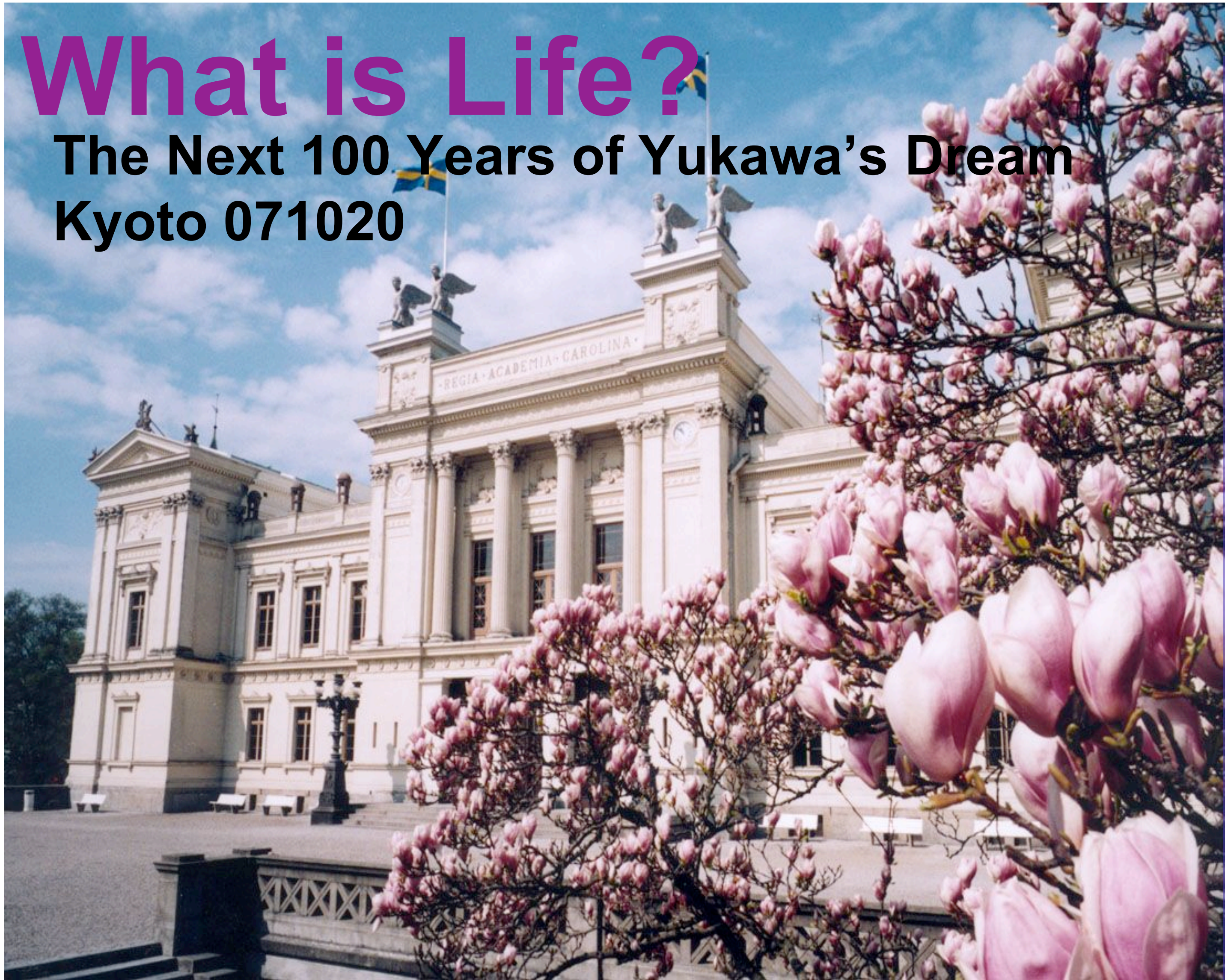
What is Life?

The Next 100 Years of Yukawa's Dream
Kyoto 071020



The mammalian brain in the electromagnetic fields designed by man.

Leif G. Salford MD, PhD
and the EMF research group, Lund University, Lund, Sweden

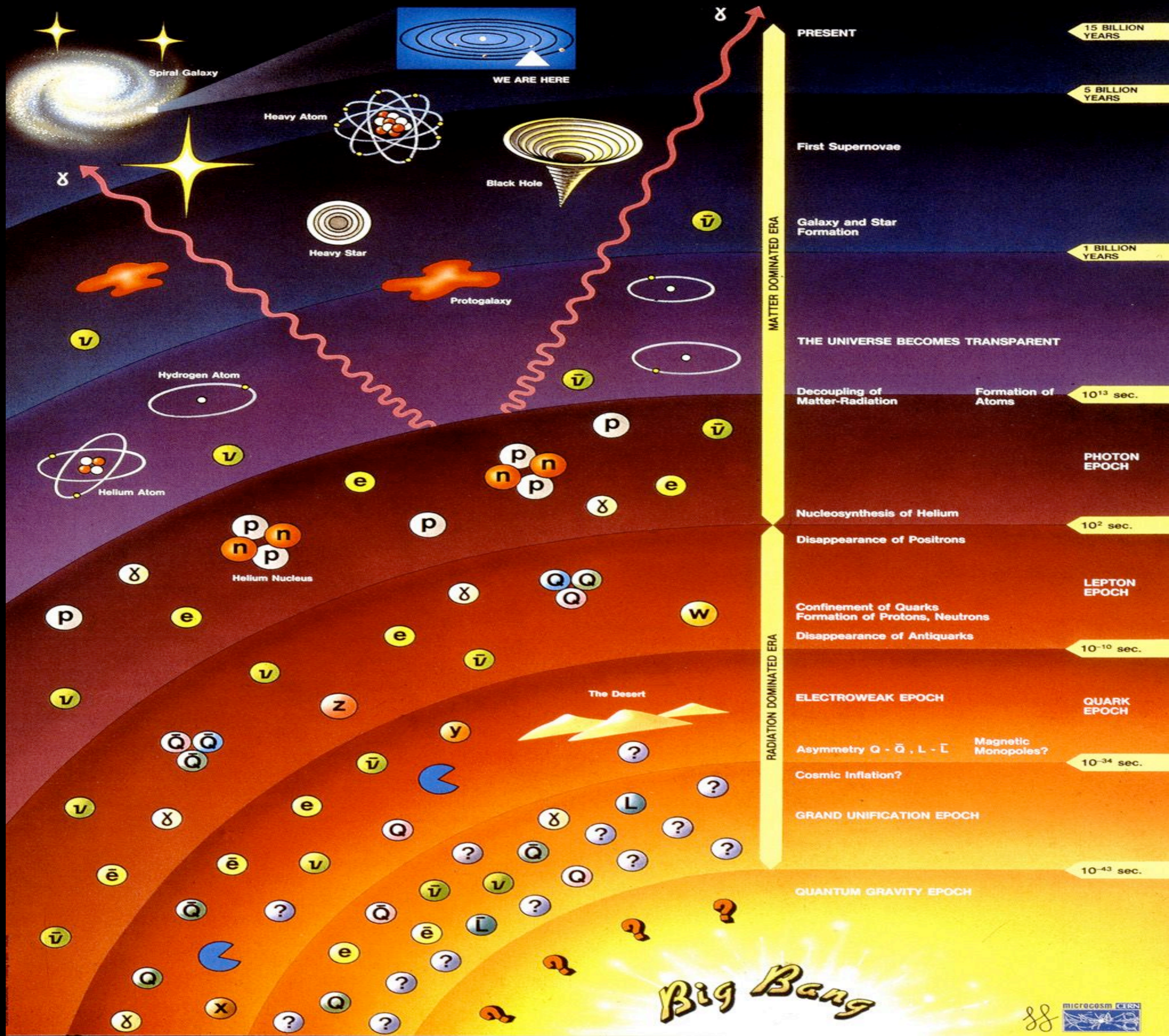
CV Leif G. Salford

MD 1969
Spec. neurosurg. 1975
Neurosurgery 1967 –
PhD studies Lund and New York, Cornell: Ischemia in rat model
PhD 1974
Prof of Neurosurgery
-Kuwait Univ 1981-83
-Gothenburg Univ. 1993-97
-Lund Univ. 1996 –

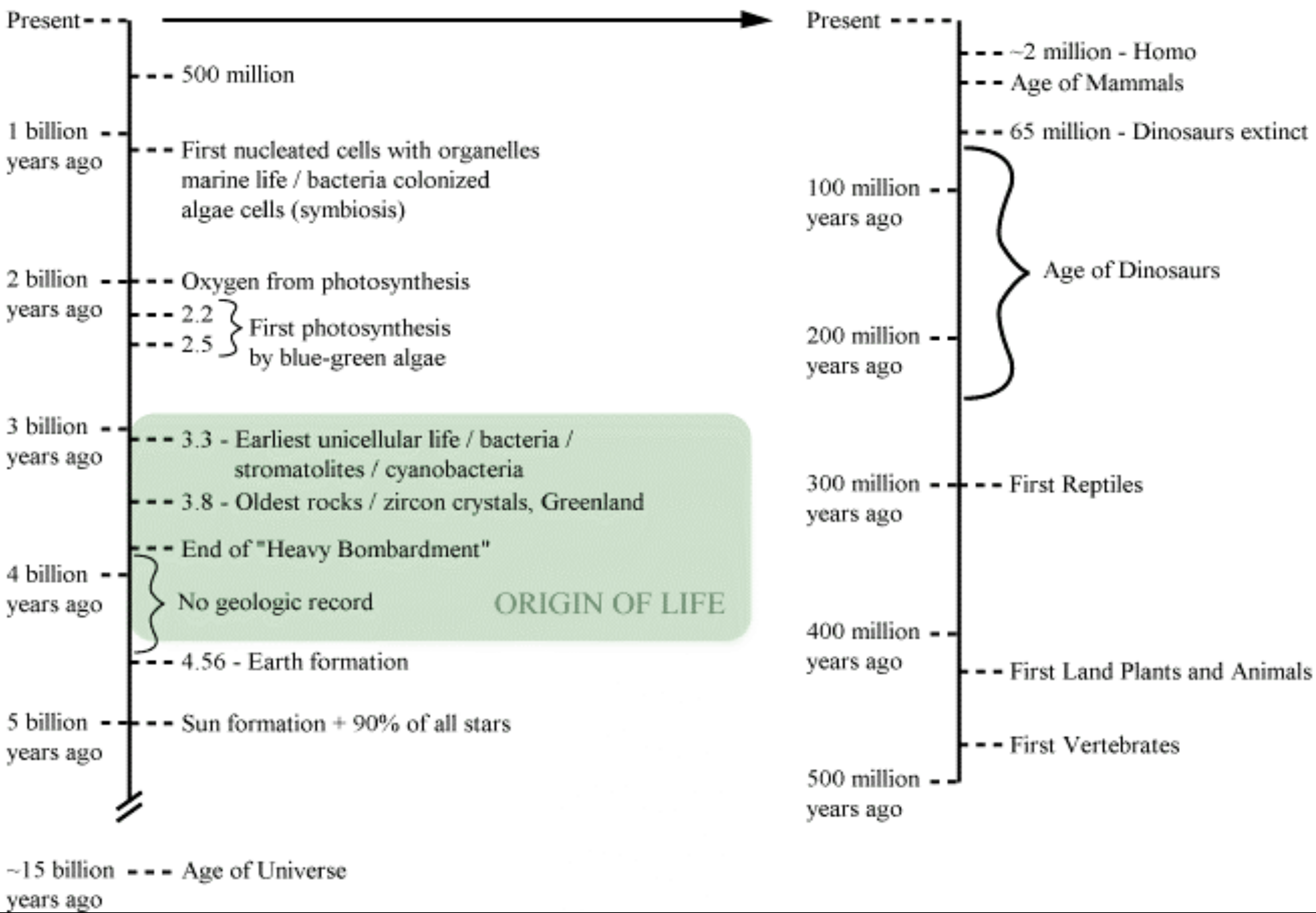
Studies on
Brain pato-physiol. and SAH in rats and baboons 1970-78
Brain tumours in rats and humans 1978 -

EMF and brain 1988 -

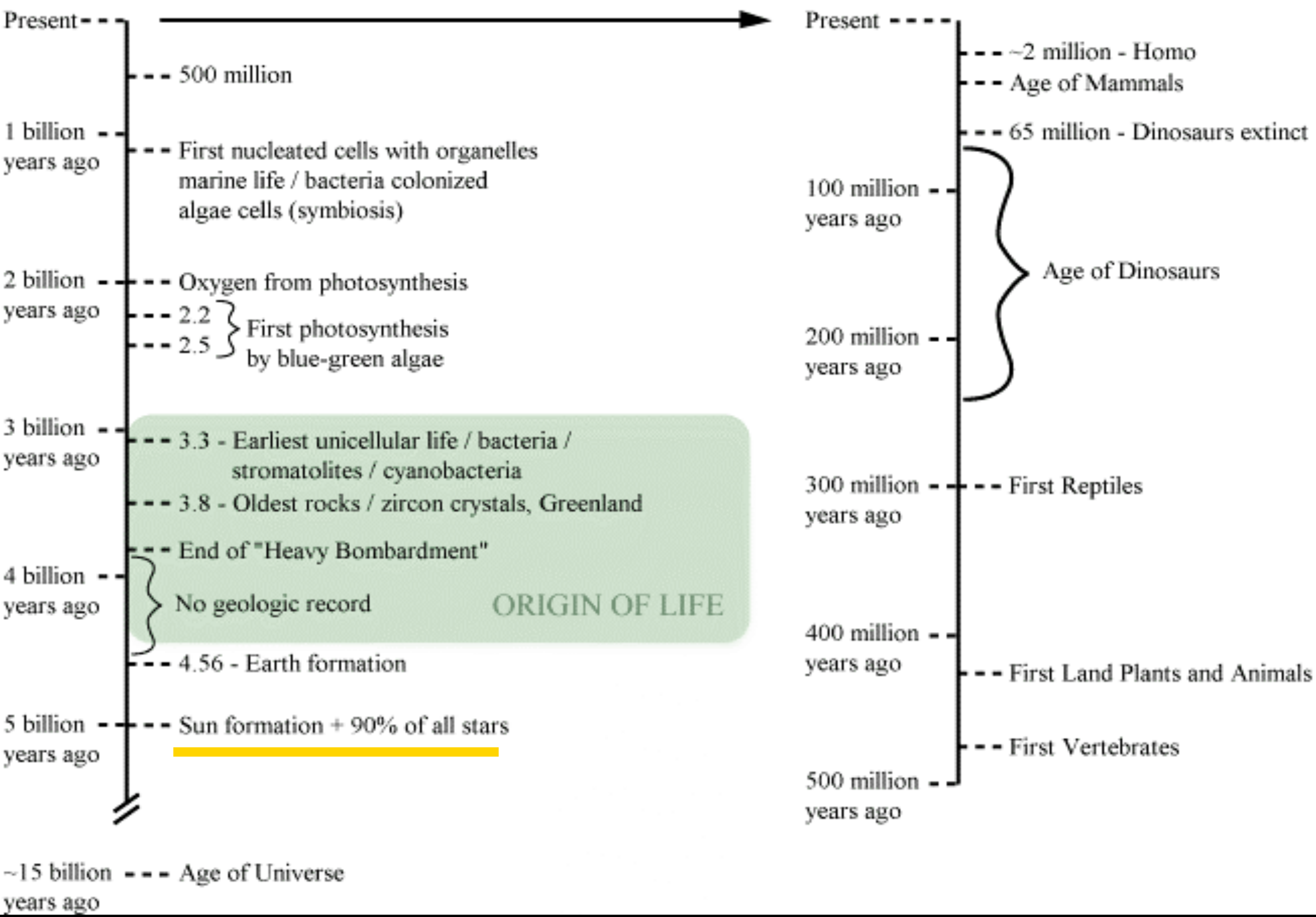
History of the Universe



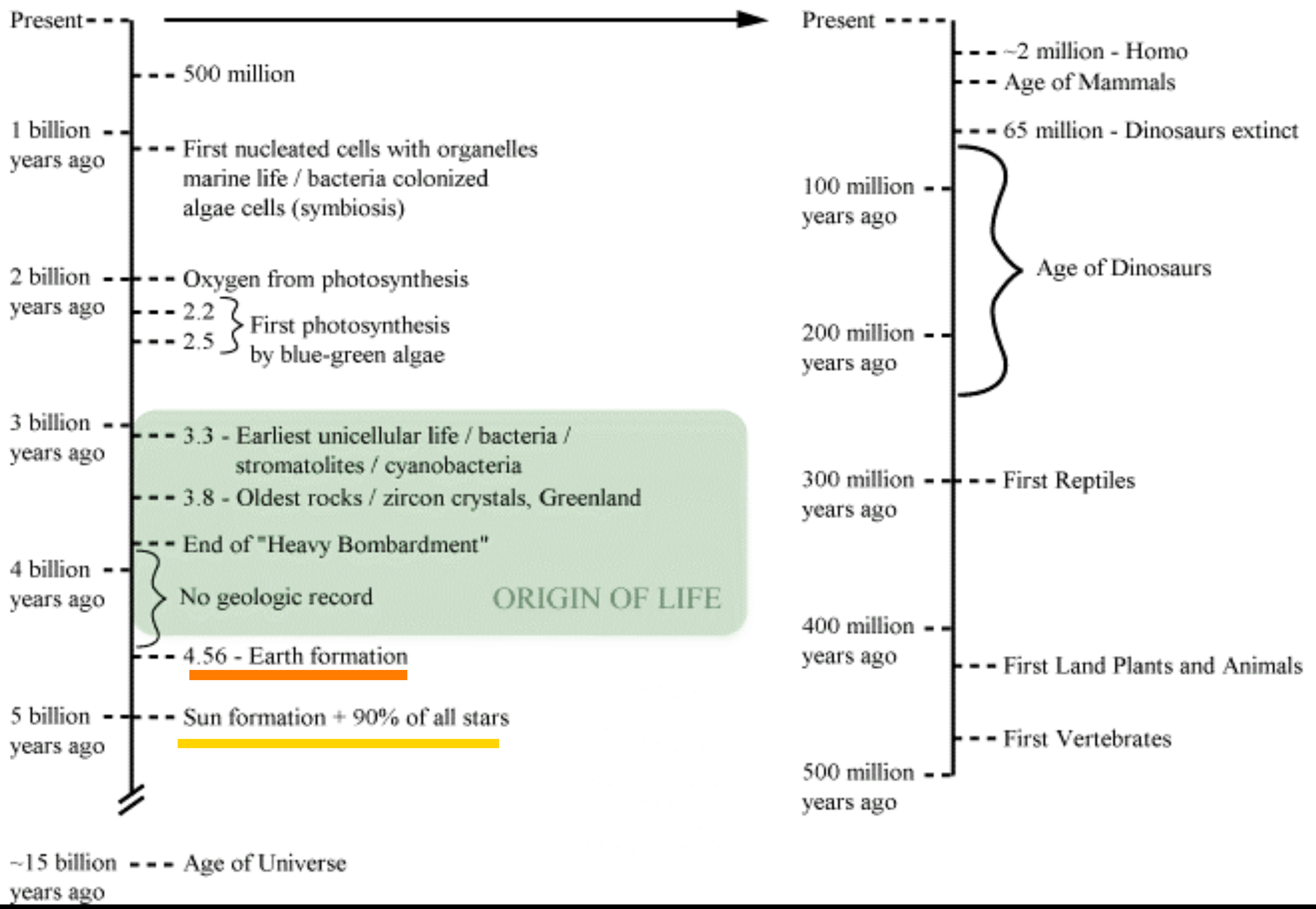
"Time - Line" For The Origin of Life



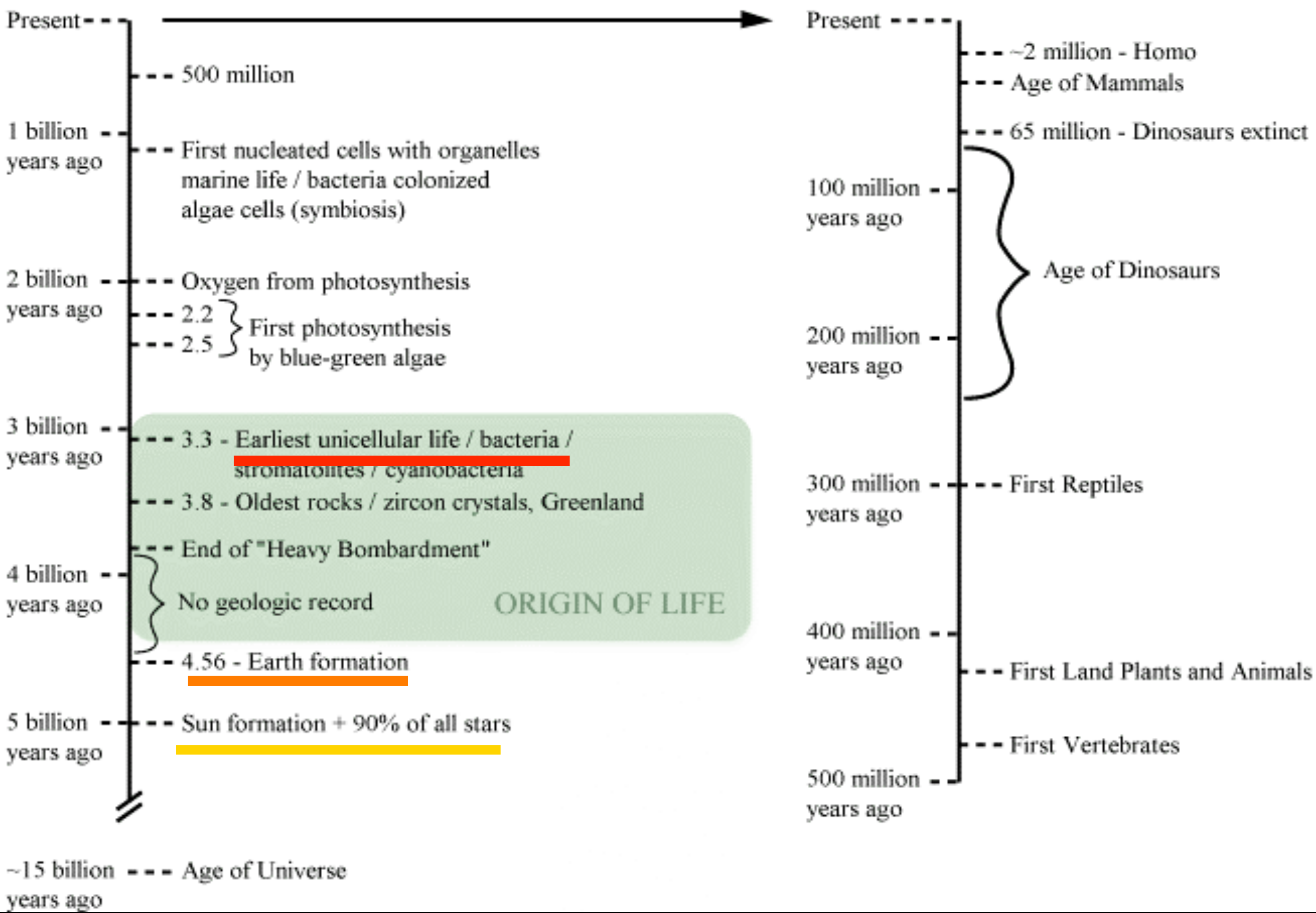
"Time - Line" For The Origin of Life



"Time - Line" For The Origin of Life



"Time - Line" For The Origin of Life

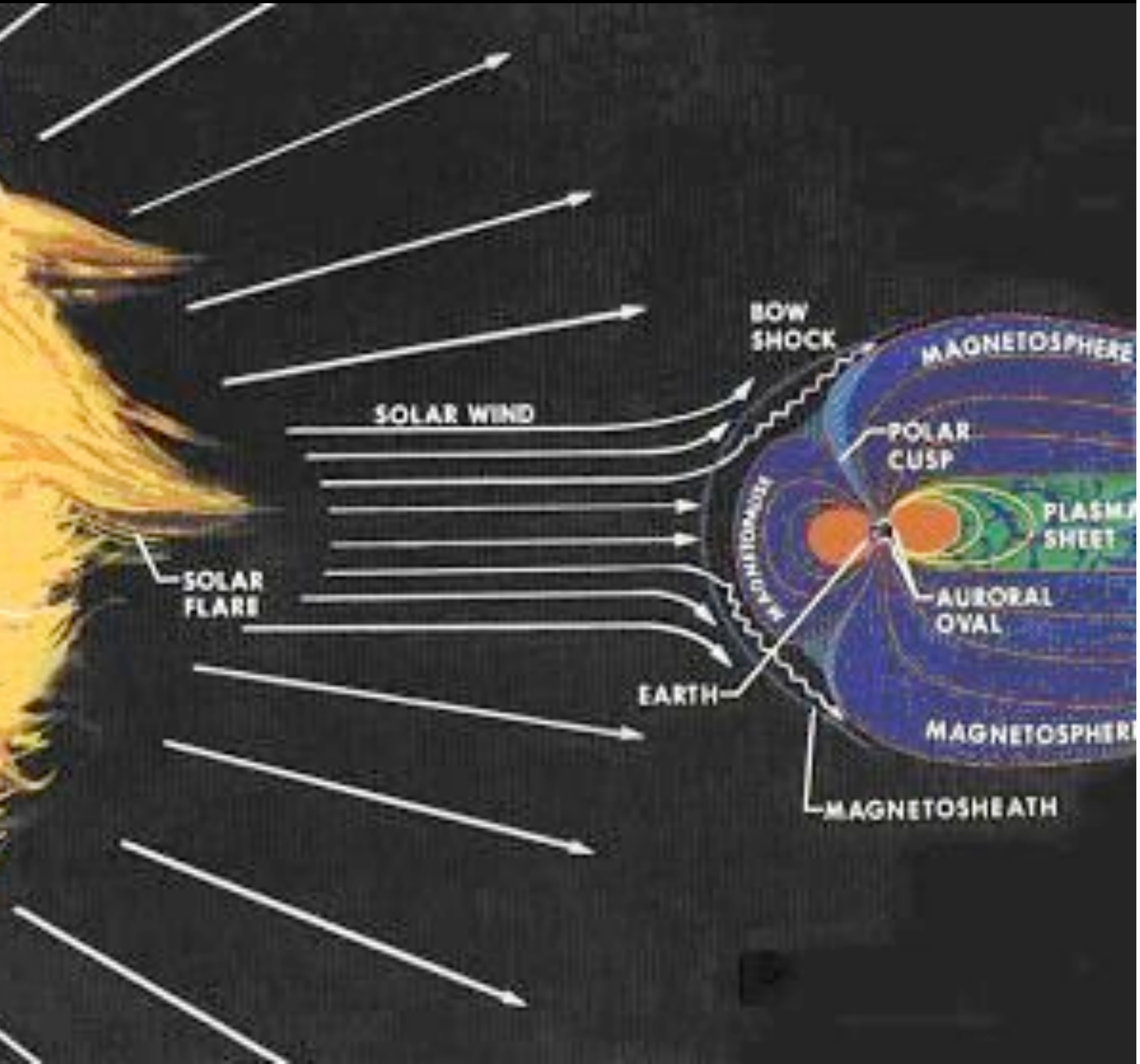


The geomagnetic field (GMF) and the magnetic storms (MS)

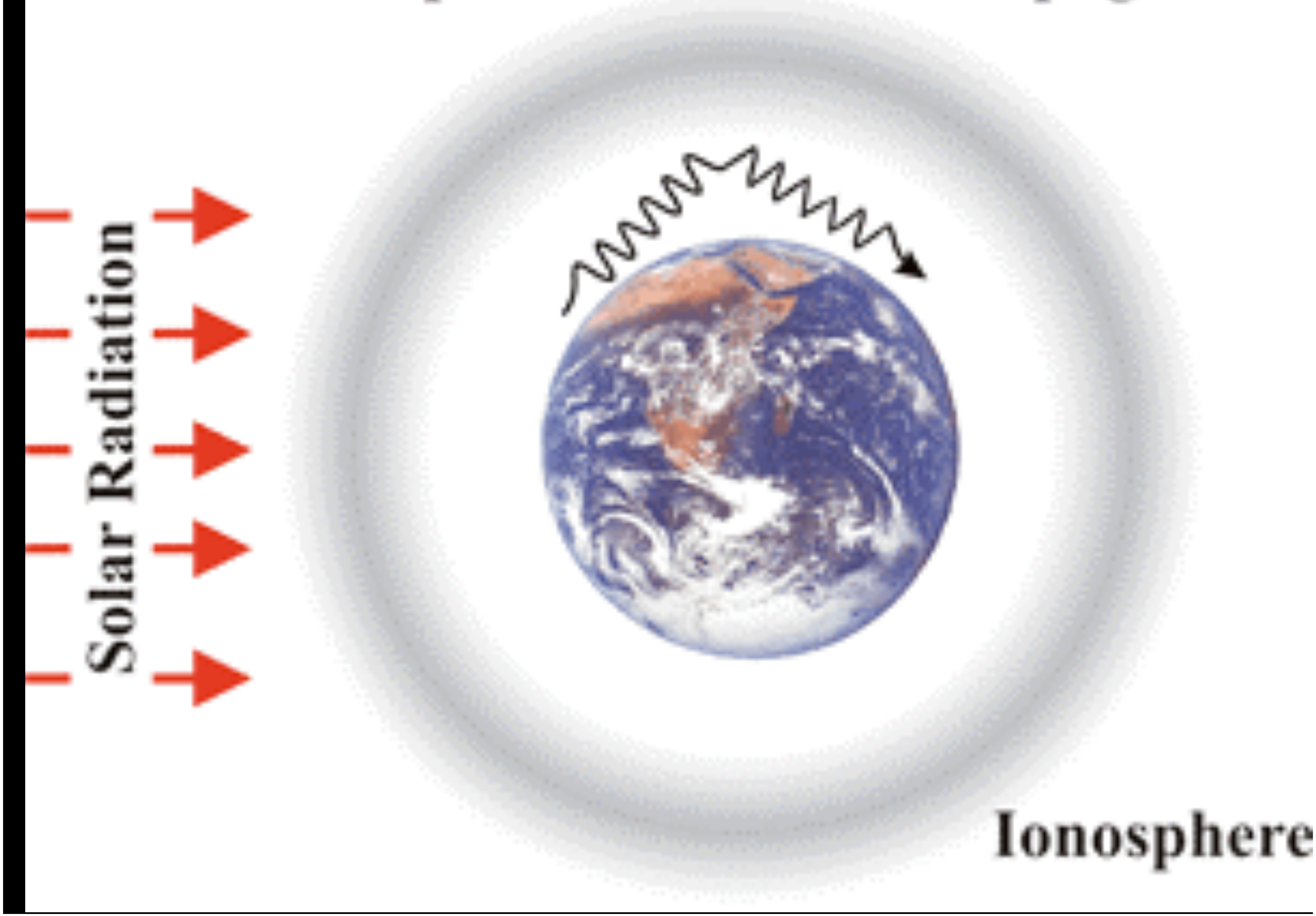
MS generated by the sun's plasma flows
10 times in a month
with a 11 year periodicity.
They produce alterations of the GMF lasting from hours to days all around the Earth.

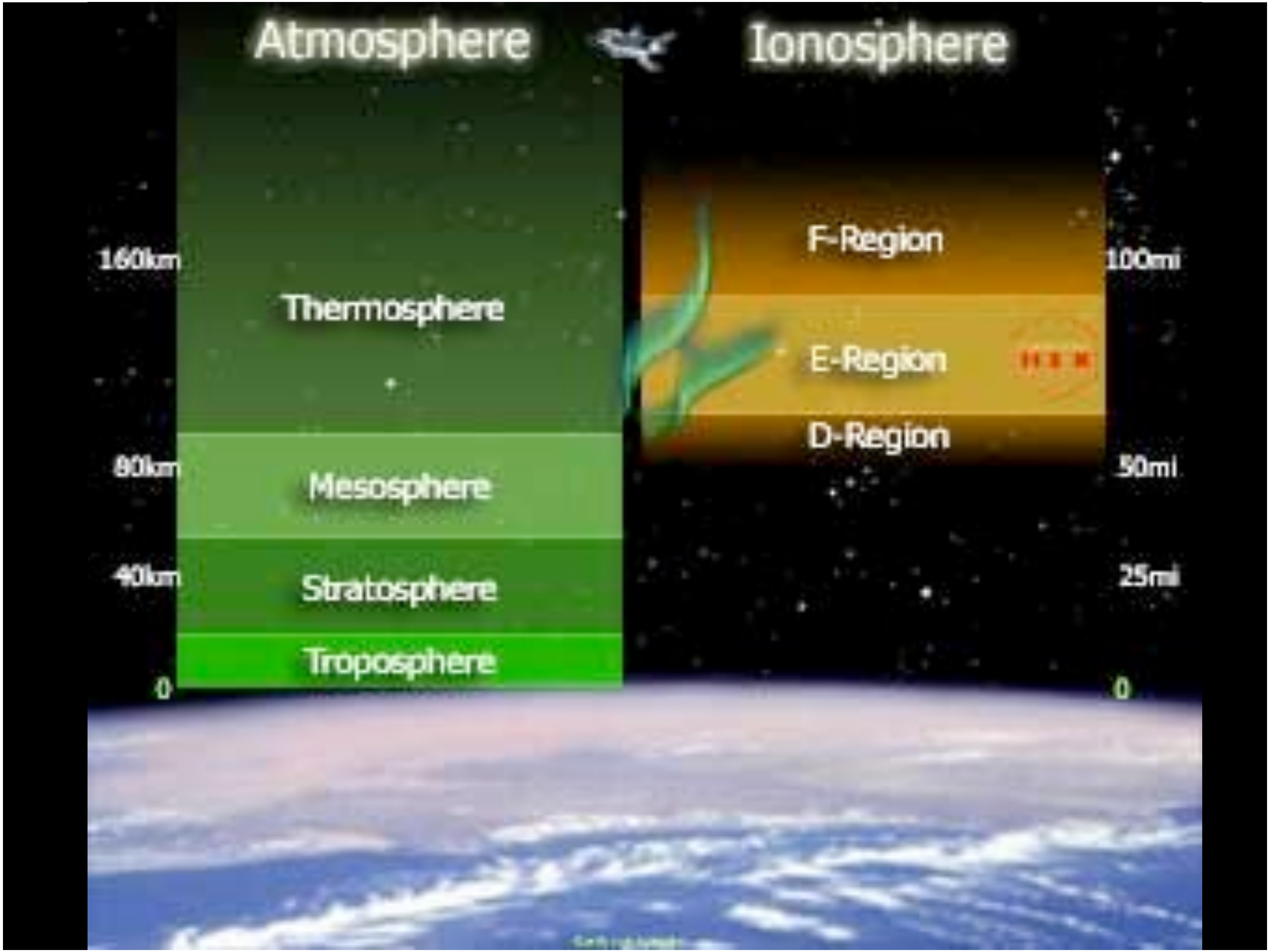
Other cycles:
1 day - Earth's rotation;
6–7 day and 13 -14 days corresponding to the solar winds;
27 days- the Sun's rotation around its own axis.

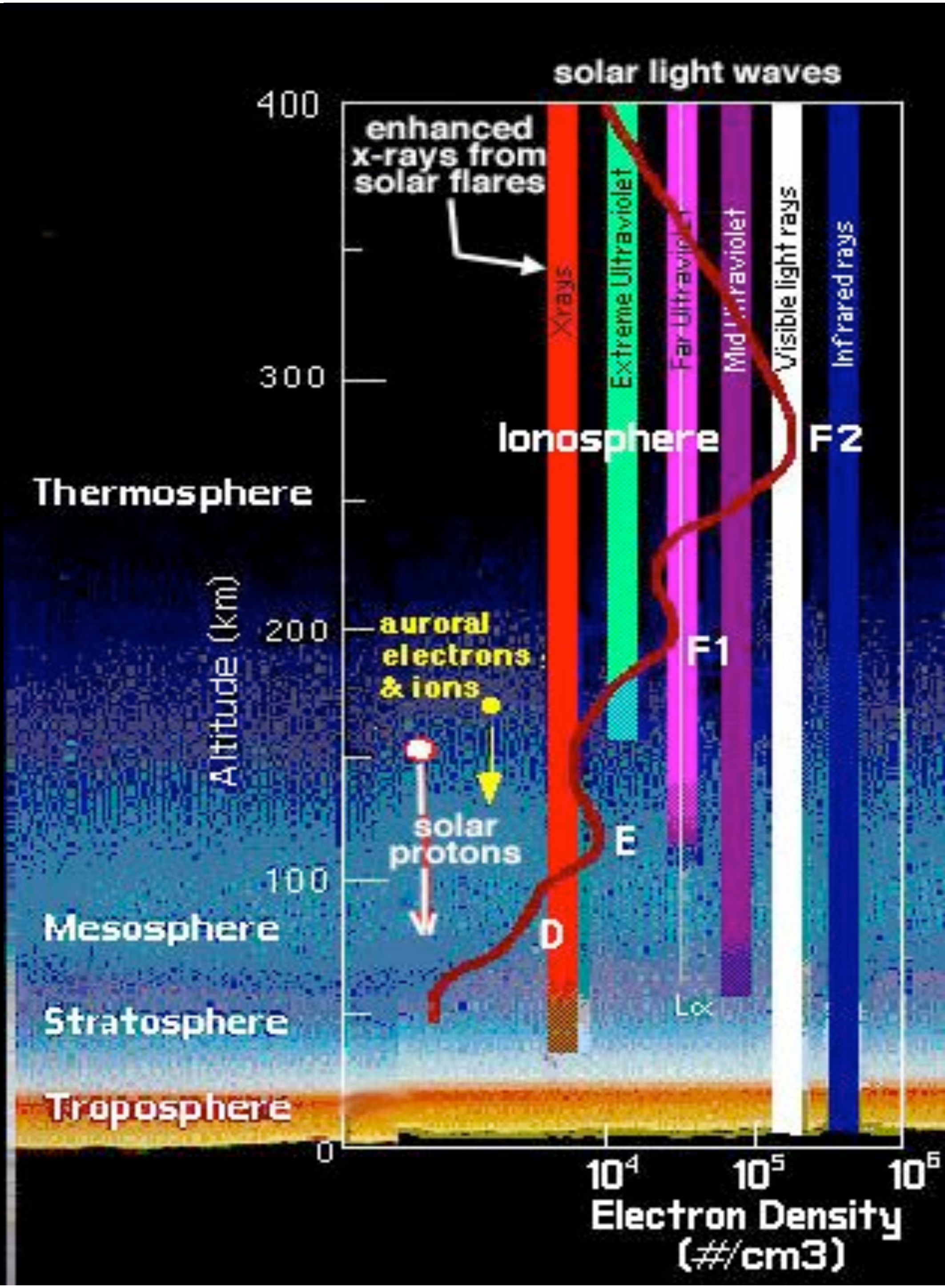
29.5 days - the synodic period of the Moon;
1 year – the Earth's revolution;



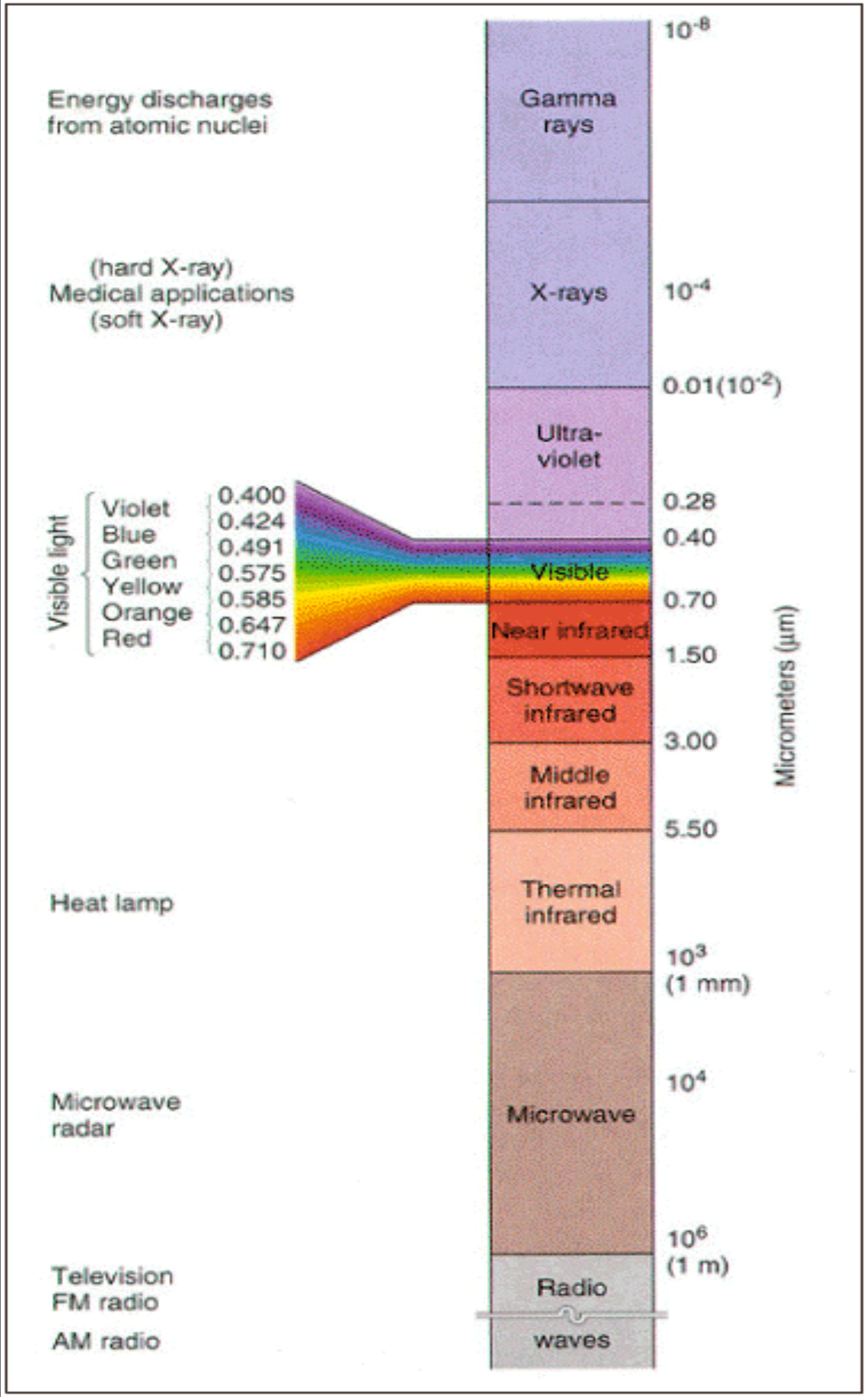
Ionospheric EM Wave Propagation



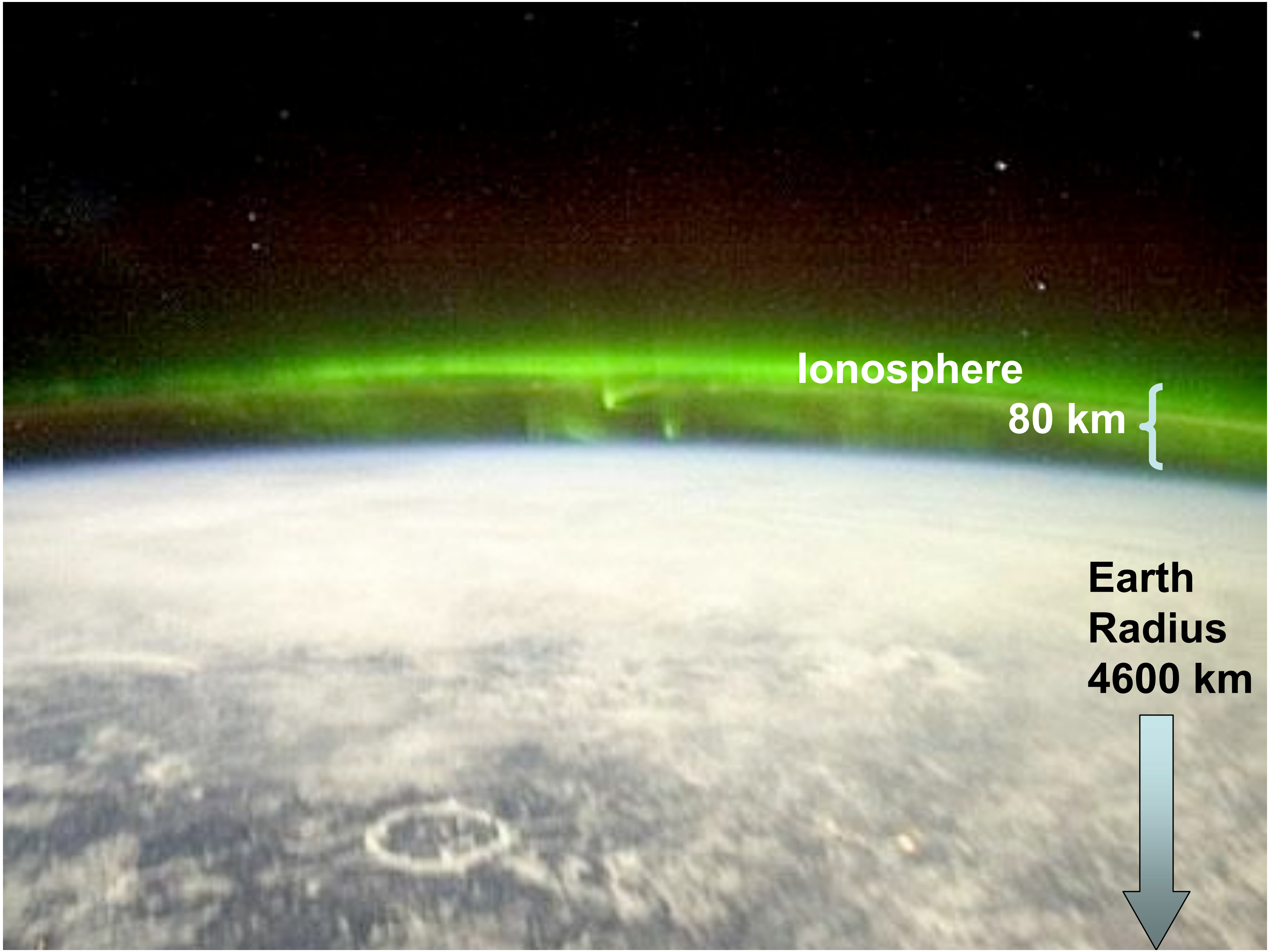

Atmosphere
Ionosphere
160km
Thermosphere
80km
Mesosphere
40km
Stratosphere
Troposphere
0
F-Region
E-Region
D-Region
100mi
50mi
25mi
0

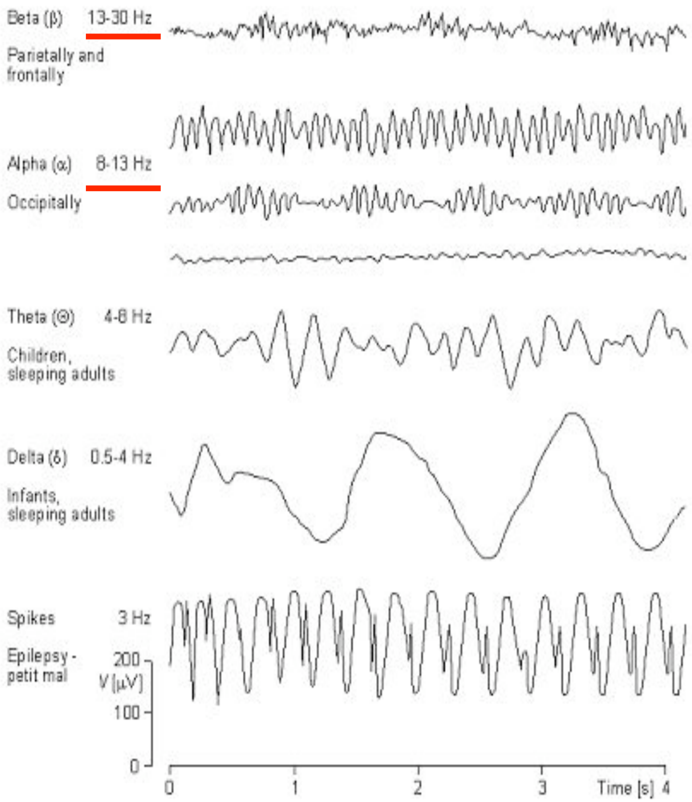


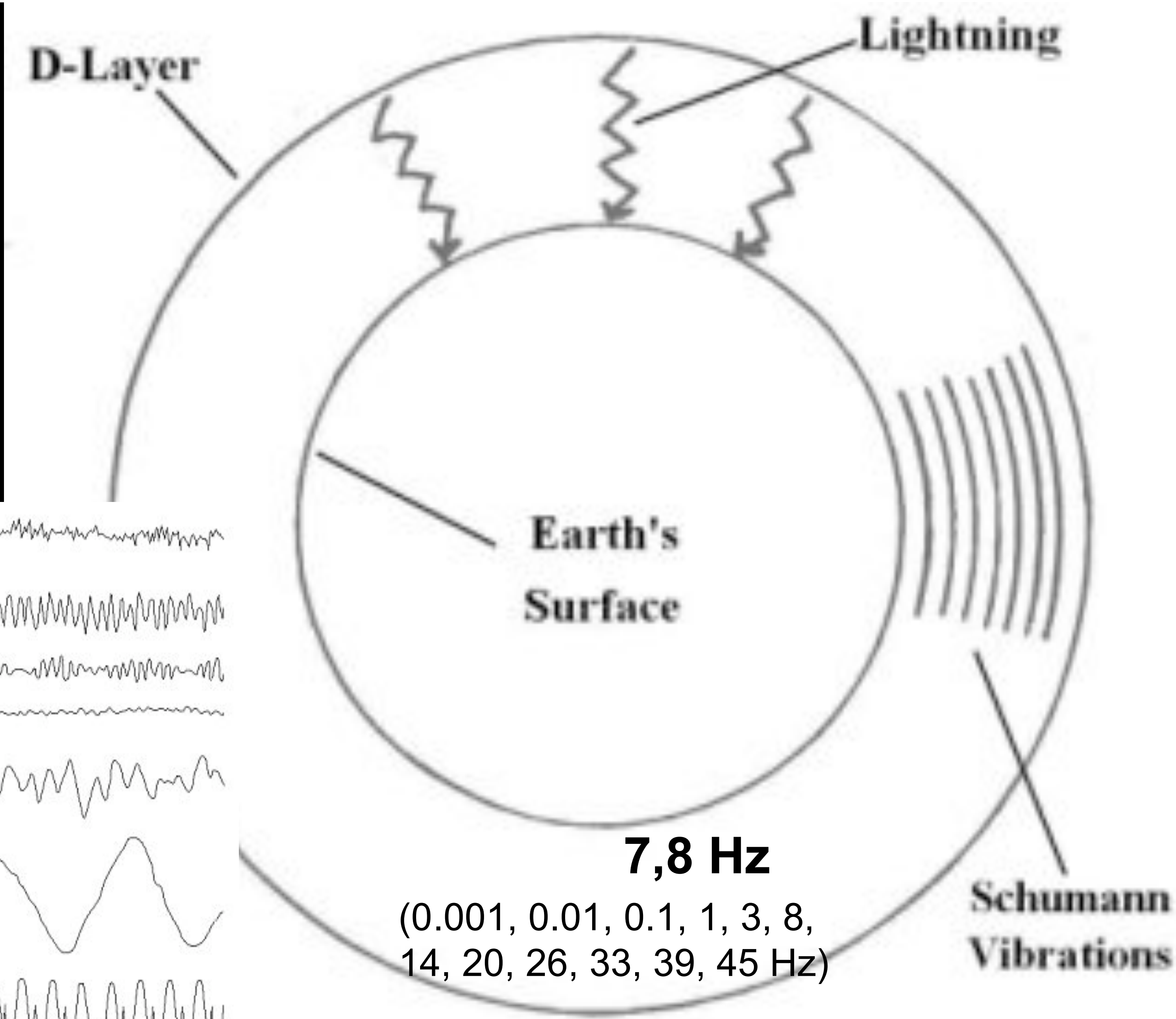
solar light waves
400
300
200
100
0
enhanced x-rays from solar flares
Xrays
Extreme Ultraviolet
Far Ultraviolet
Mid Ultraviolet
Visible light rays
Infrared rays
Ionosphere
F2
F1
E
D
Lα
Thermosphere
Mesosphere
Stratosphere
Troposphere
Altitude (km)
auroral electrons & ions
solar protons
10^4
10^5
10^6
Electron Density (#/cm3)



Energy discharges from atomic nuclei
(hard X-ray) Medical applications (soft X-ray)
Visible light
Violet
Blue
Green
Yellow
Orange
Red
0.400
0.424
0.491
0.575
0.585
0.647
0.710
Heat lamp
Microwave radar
Television
FM radio
AM radio
Gamma rays
X-rays
Ultra-violet
Visible
Near infrared
Shortwave infrared
Middle infrared
Thermal infrared
Microwave
Radio waves
10-8
10-4
0.01(10-2)
0.28
0.40
0.70
1.50
3.00
5.50
10^3 (1 mm)
10^4
10^6 (1 m)
Micrometers (µm)


Ionosphere
80 km
Earth
Radius
4600 km





7,8 Hz

(0.001, 0.01, 0.1, 1, 3, 8, 14, 20, 26, 33, 39, 45 Hz)

GMF-dependence on the Earth (Volpe 2003)
orientation of sea gulls and pigeons, plant branching, orientation of root branches, metabolism and proliferation of root cells; protein synthesis in a number of vegetal cells

Shielding of the geomagnetic field causes biological alterations

- decrease of the vital functions in bacteria

- in meristem (cf stemcells in animals) of seedling roots of pea, flax and lentil, electron microscopy reveals changes in the mitochondrial structure,

-a 68–75% reduction of cell proliferation, variation of RNA and protein biosynthetic rates

- change in timing of fibroblast division and increase in sensitivity of *in vitro* cell cultures to poisons

-decrease in erythrocyte sedimentation in rats

- decrease of learning *vs*. an increase of hippocampus catecholamines

- increase of the epinephrine and histamine levels and a decrease of the serotonin level in the blood of guinea-pigs.

Magnetic storms cause additional biological dysfunctions

(Volpe 2003)

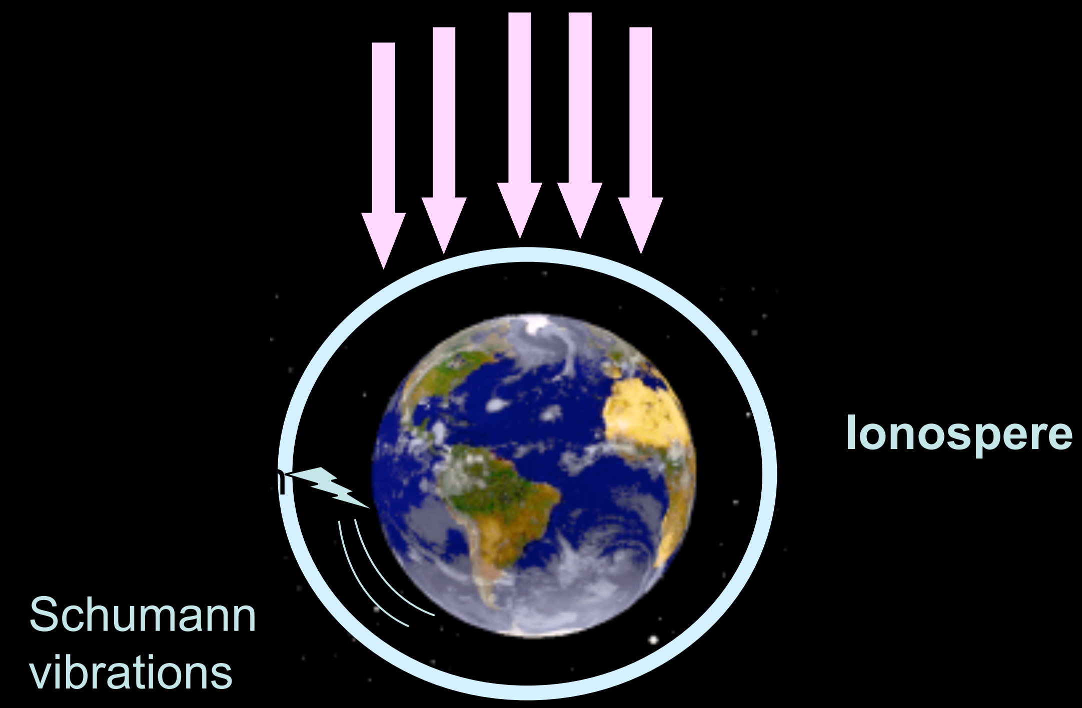
Bacterial bioluminescent intensity varies according to the amplitude and duration of the MSs,

M,edical studies correlate MSs with anxiety and irritability and lower attention and accuracy, with an increment of the probability of road accidents.

Acute attacks of cardiovascular diseases become more frequent

During the strong planetary MS of September 21–23, 1984, investigations in rabbits showed that the normal circadian structure in each cardiovascular parameter was lost; desynchronization increased, and abrupt drop of cardiac activity was observed;
as well as degradation of mitochondria in cardiomyocytes.

Since birth of Earth: Extremely Low Frequency EMF



Extremely Low Frequency EMF from the late 19th century

Volta: the electric battery 1800

Edison: Commercial electrical networks

Tesla: the induction motor

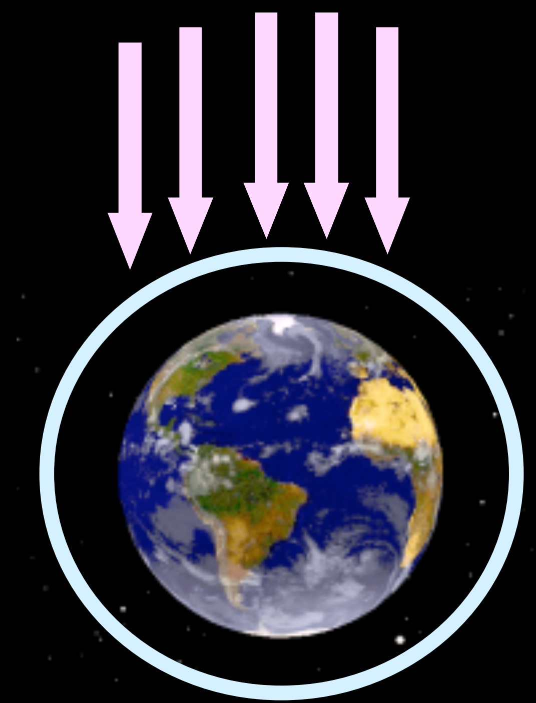
Bell: the telephone

Morse: the long-range telegraph

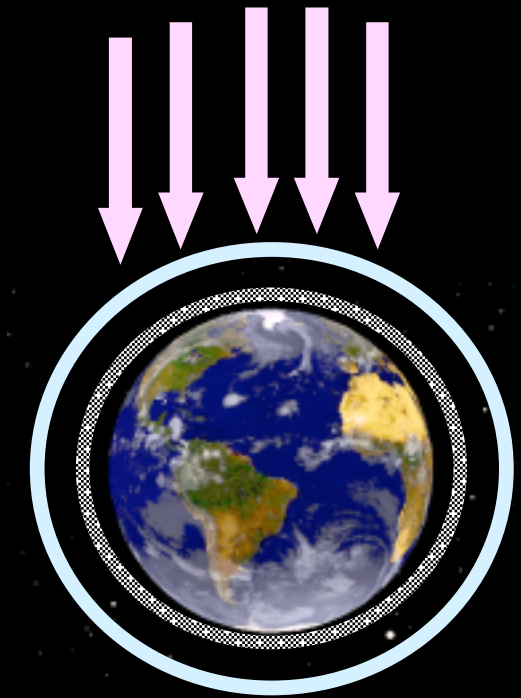
Hertz demonstrated radiowaves, "Hertzian, aetherial" waves 1888

Marconi: the wireless receiver 1896

Microwaves
5 biljon years until 1940

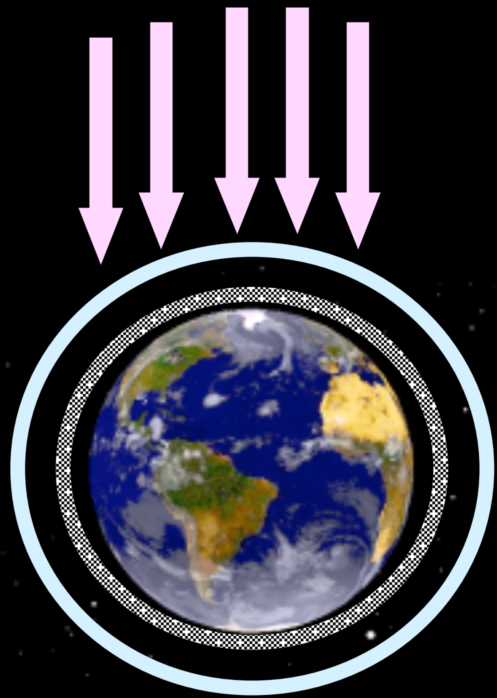


Microwaves
Since 60 years



Sir Robert Watson-Watt, descendant of James Watt, created the first workable radar system after searching for a way to predict thunder and lightning to warn aviators.
Sir Robert, an unsung hero of World War II, was knighted 1942

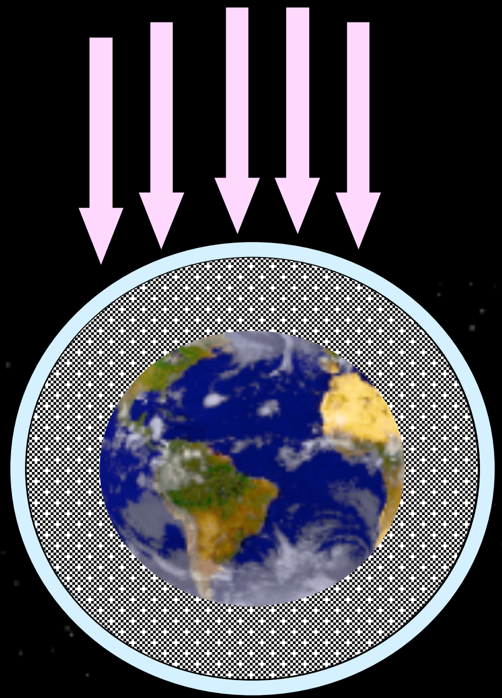
Microwaves
Since 60 years



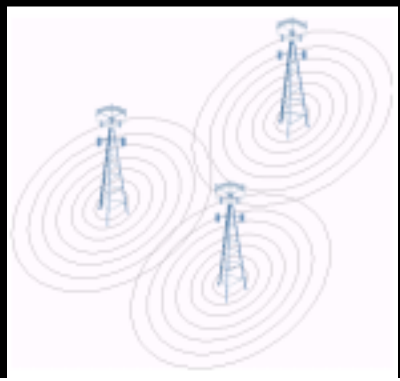
Sir Robert Watson-Watt, descendant of James Watt, created the first workable radar system after searching for a way to predict thunder and lightning to warn aviators.
Sir Robert, an unsung hero of World War II, was knighted 1942

It was during a radar-related research project around 1946 that Dr. Percy Spencer, noticed something very unusual. He was testing vacuum tube called a magnetron, when he discovered that the candy bar in his pocket had melted. The Microwave oven was born

Microwaves
Today



The original mobile phone from SRA, Ericsson, 1956

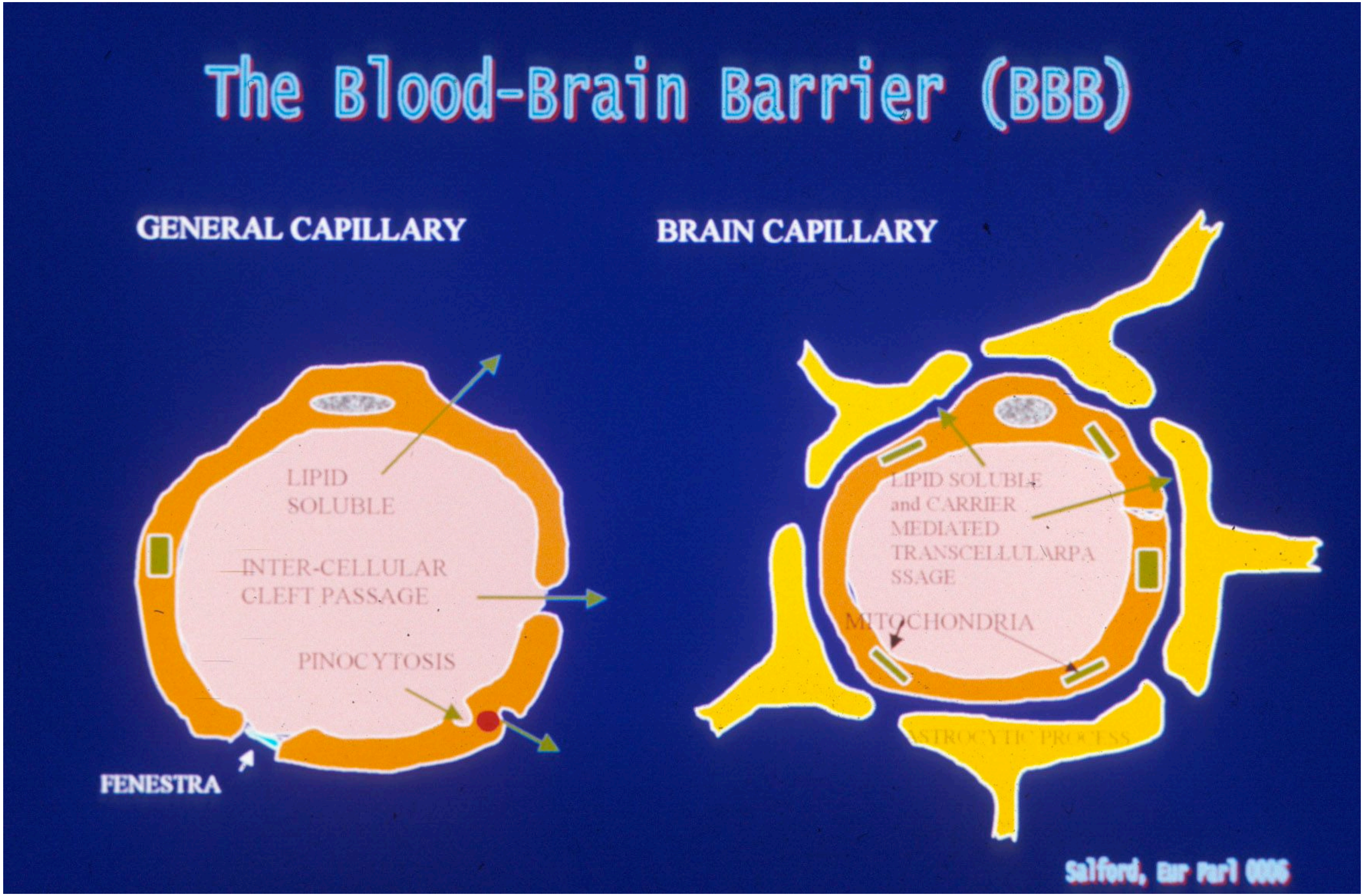


Mobile Phones 1980 -

One third of the world´s population now volunteer as guinea-pigs in theWorld´s largest biological experiment

Nineteen years of EMF - BBB studies in Lund

- **Shivers R et al., 1987 London Ontario   Visited 1988**
- **1988 - blood-brain barrier (BBB) albumin leakage using Evans Blue after exposure for NMR imaging magnetic and RF fields.**
- **1989 – BBB leakage studies with immunostaining for albumin and fibrinogene using pulse modulated 915 MHz microwaves.**
- **1998 – BBB leakage of albumin, neuronal damage, gene expression, cognitive functions using real GSM-900 and GSM-1800 exposure**



All mammals have a Blood-Brain Barrier. There are good reasons to believe that the BBB of a rat functions as the human BBB – But there might be differences which make results from animal experiments not directly translatable to the human situation! Enzymatic?

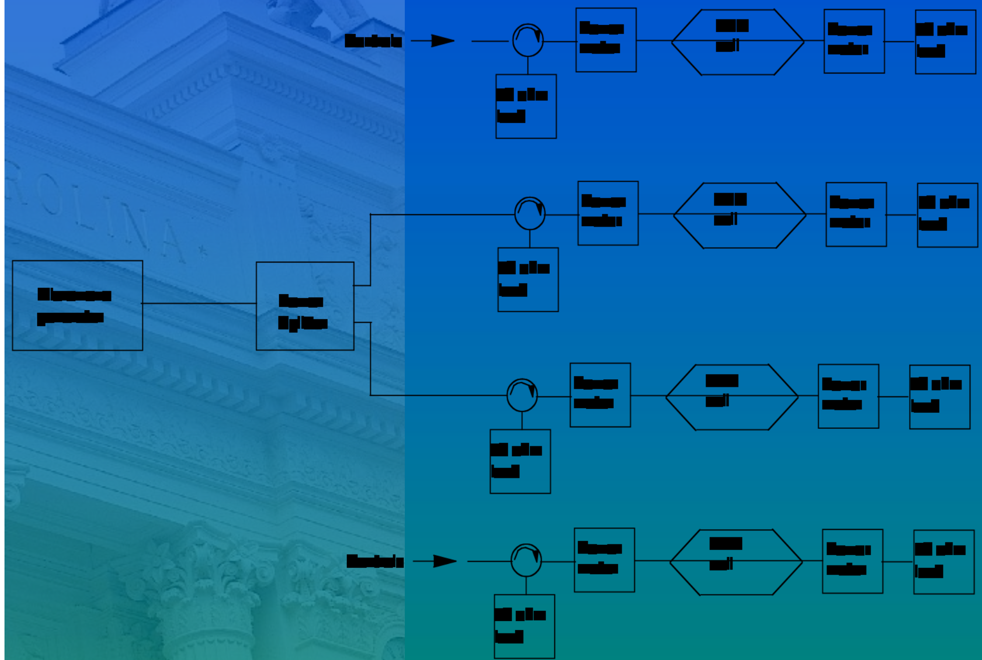
The TEM-cell

The TEM-cell is enclosed in a wooden box. The outer conductor is made of a brass net and is attached to the inner walls of the box.

The central plate, or septum, is constructed of aluminium and is held up by teflon braces, which are attached at the inner side-walls.

To allow access to the inside of the cell both ends can be removed. The inside of the cell is ventilated through 18 holes (diam. 18 mm) in the side-walls and top of the box, and the brass net allows air to circulate.

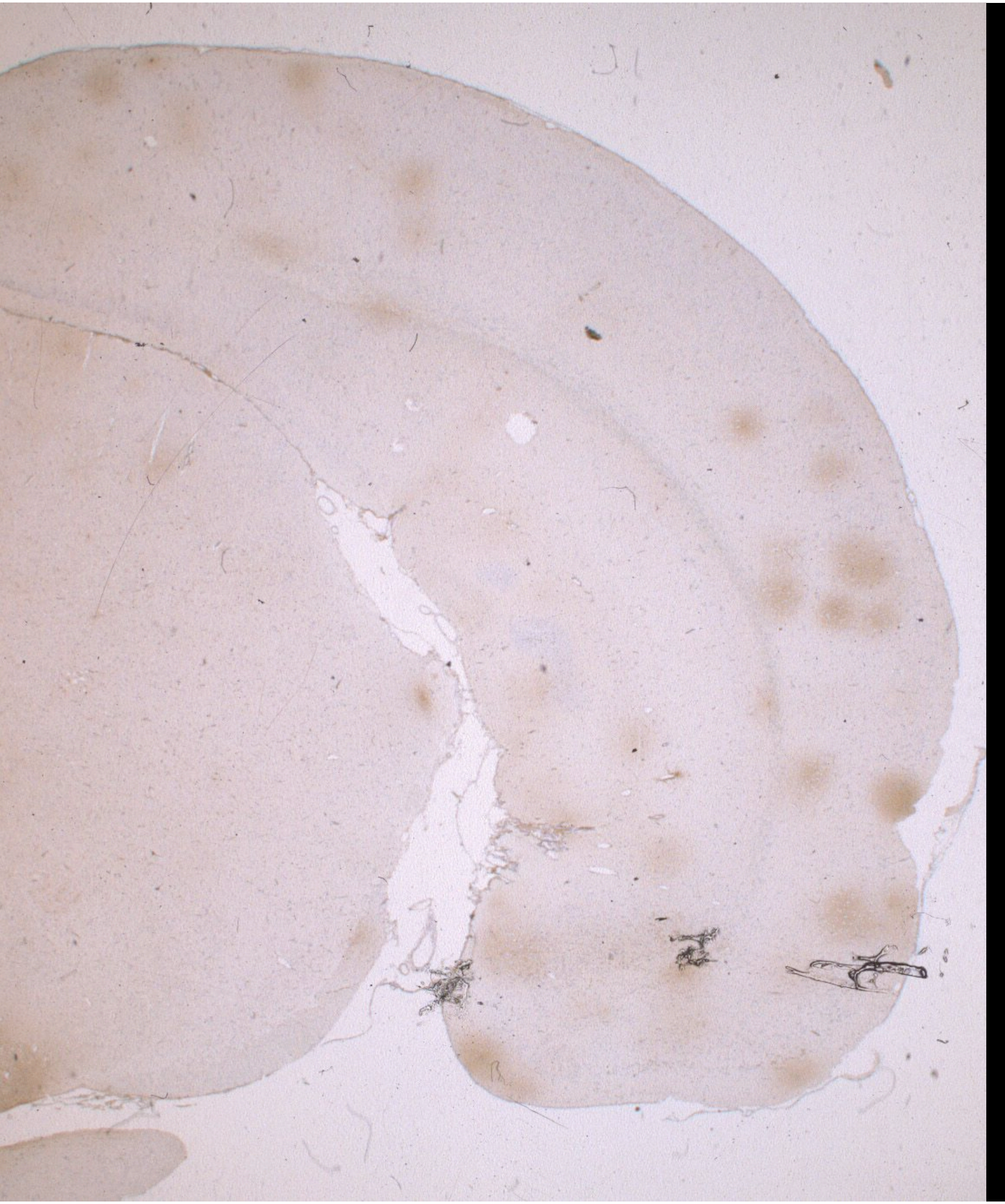
Fibre optic probes for monitoring the temperature inside the cell or in the test objects are inserted through these holes.

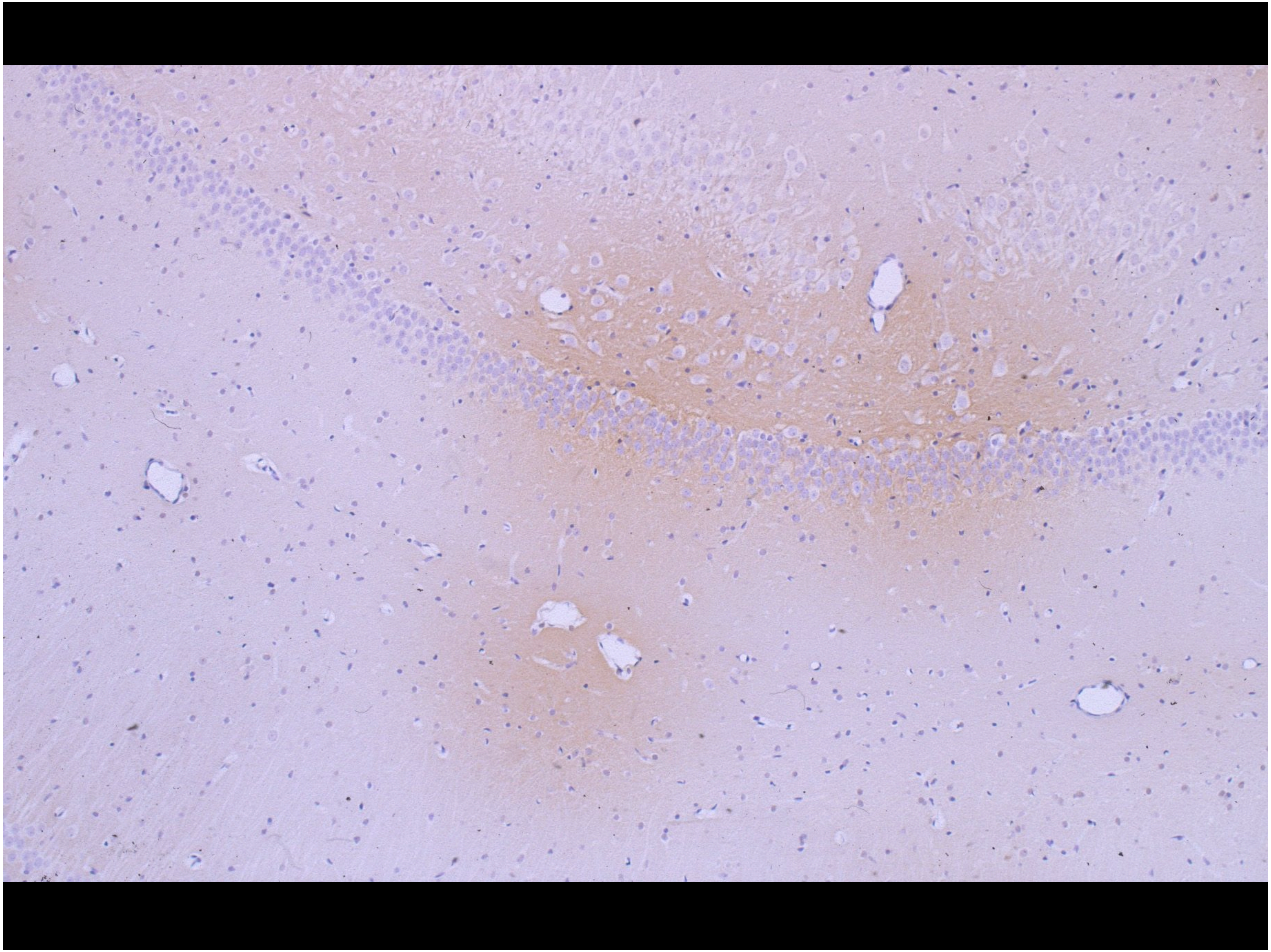


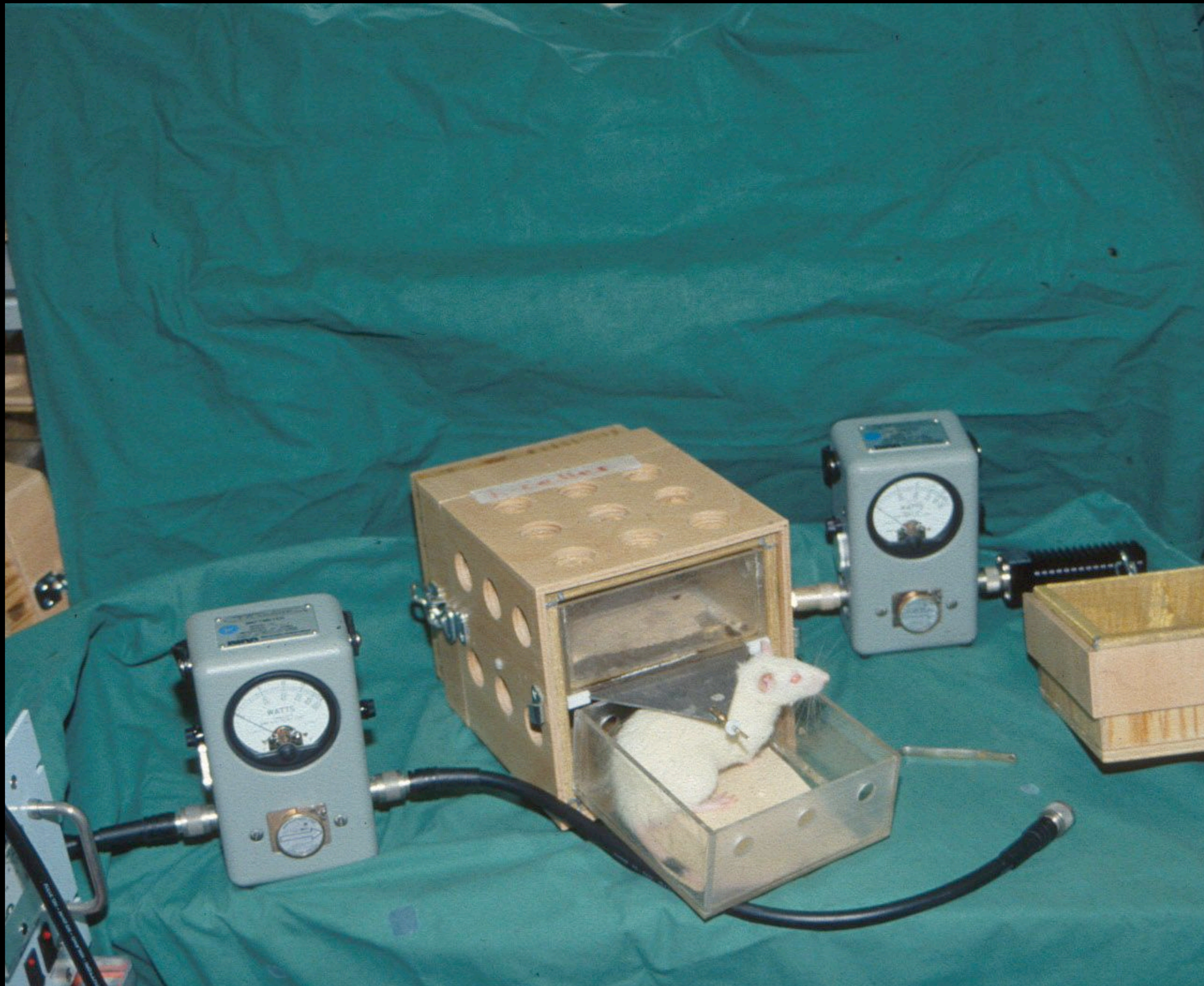
Block diagram and the four TEM cells used in our investigations of non-thermal biological effects of electromagnetic fields.

Earlier experiments in The Rausing lab:

Albumin leakage through the BBB: Fischer rats (>1600) exposed to EMF for 2 min - 16 hours (majority for 2 hours). Examined within 30 minutes to 16 hours after exposure.






WATTS

All our experiments: Non-thermal energy

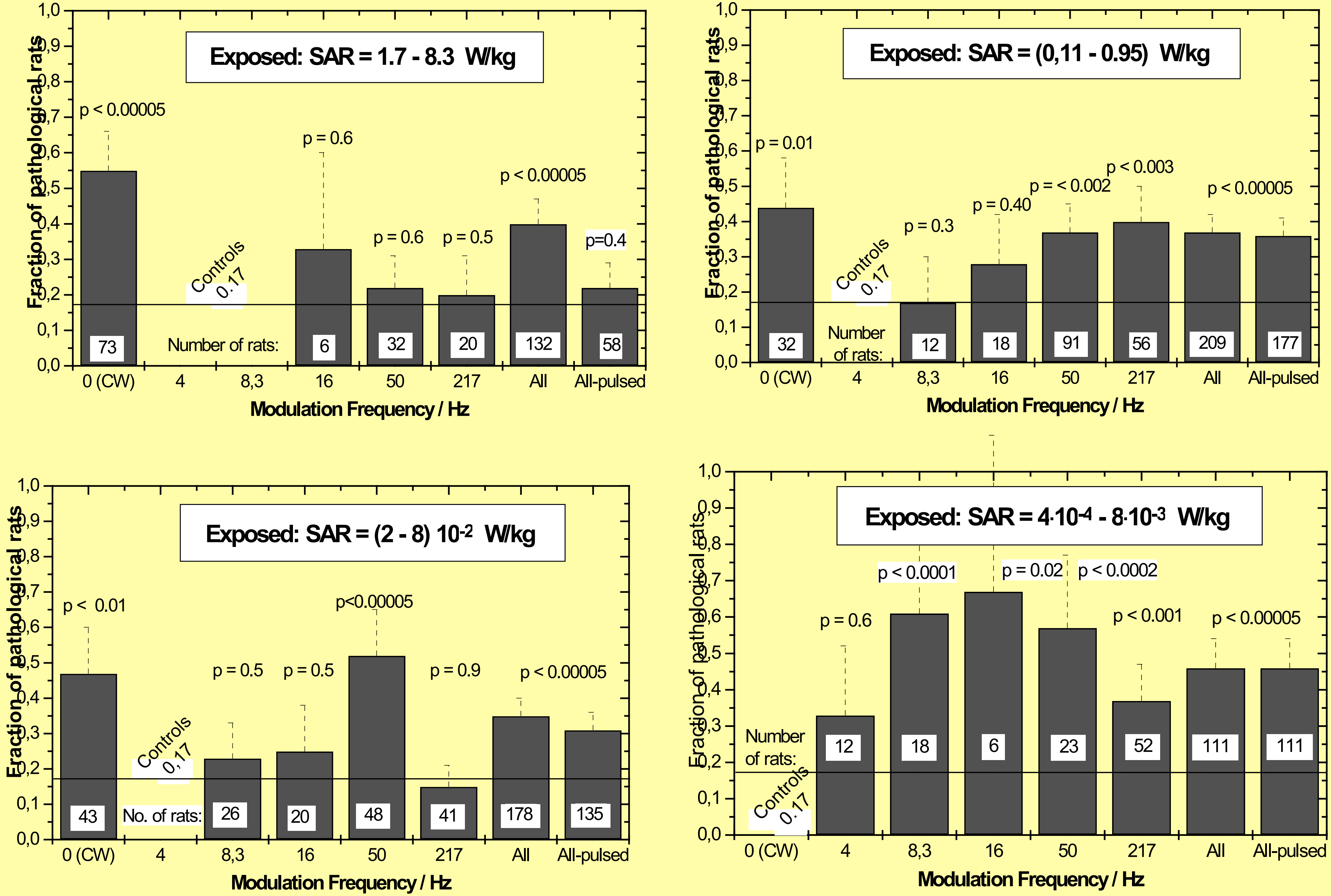
Specific Absorbed Ratio (SAR) = energy absorbed by the tissue.

SAR $>$ 2W/kg can increase the temperature of the tissue an cause thermal effects.

Regulations for mobile phones allow only SAR $<$ 2W/kg

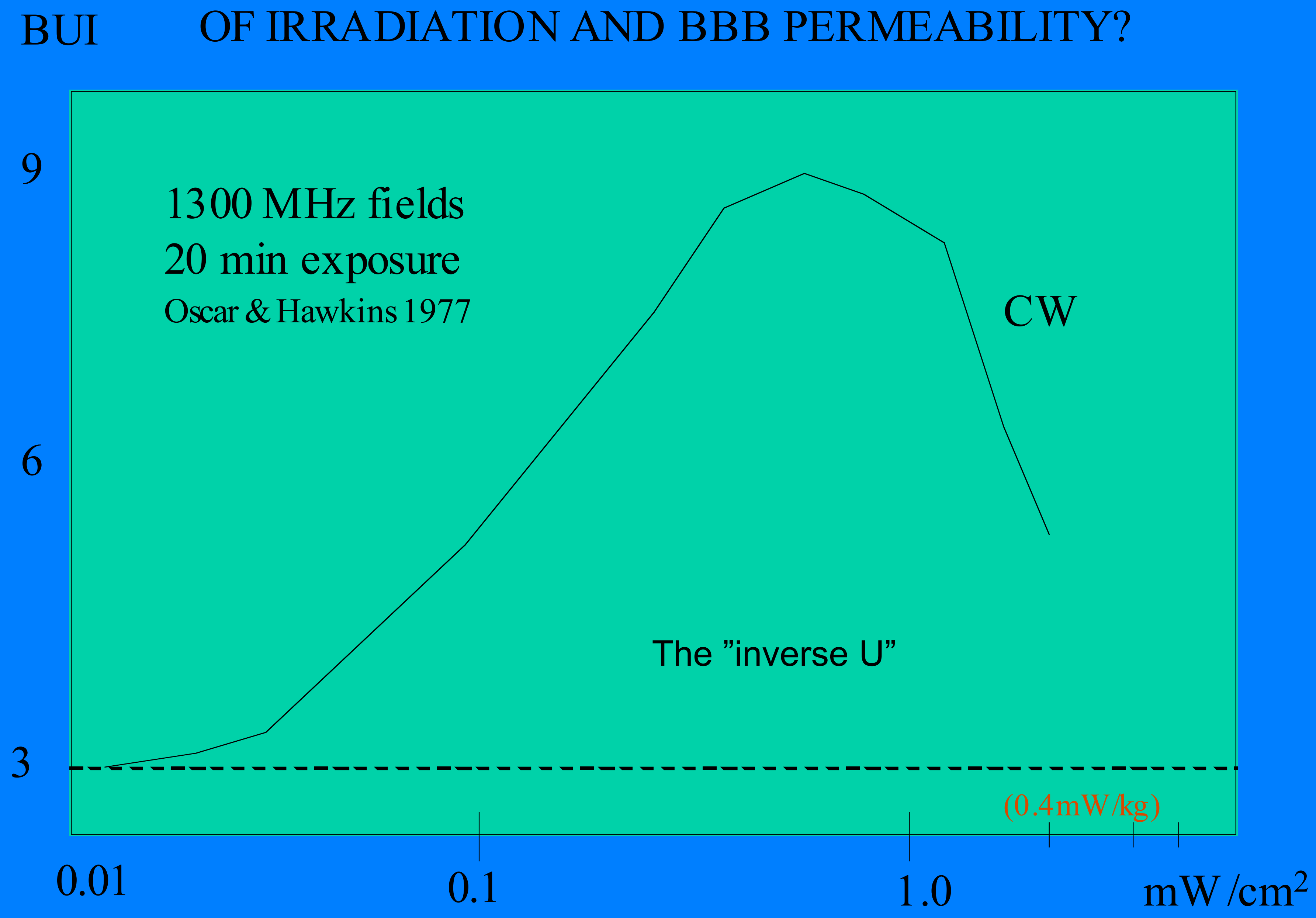
”Biological window”

1/1000 and 1/10000
of the energy at the antenna
=SAR value 0,5 – 1 W/kg
(Specific Absorbed Ratio)
of the mobile phone opens the
BBB more efficiently than the
energy at the antenna



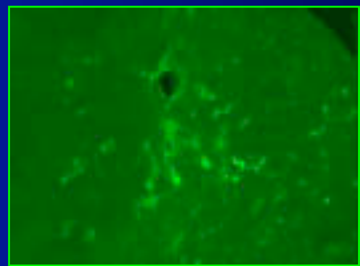
Exposed: SAR = 1.7 - 8.3 W/kg
Fraction of pathological rats
Modulation Frequency / Hz
0 (CW) 4 8,3 16 50 217 All All-pulsed
p < 0.00005
p = 0.6
p = 0.6
p = 0.5
p < 0.00005
p=0.4
Controls 0.17
Number of rats:
73 6 32 20 132 58
Exposed: SAR = (0,11 - 0.95) W/kg
Fraction of pathological rats
Modulation Frequency / Hz
0 (CW) 4 8,3 16 50 217 All All-pulsed
p = 0.01
p = 0.3
p = 0.40
p = < 0.002
p < 0.003
p < 0.00005
Controls 0.17
Number of rats:
32 12 18 91 56 209 177
Exposed: SAR = (2 - 8) 10-2 W/kg
Fraction of pathological rats
Modulation Frequency / Hz
0 (CW) 4 8,3 16 50 217 All All-pulsed
p < 0.01
p = 0.5
p = 0.5
p<0.00005
p = 0.9
p < 0.00005
Controls 0,17
No. of rats:
43 26 20 48 41 178 135
Exposed: SAR = 4·10-4 - 8·10-3 W/kg
Fraction of pathological rats
Modulation Frequency / Hz
0 (CW) 4 8,3 16 50 217 All All-pulsed
p = 0.6
p < 0.0001
p = 0.02
p < 0.0002
p < 0.001
p < 0.00005
Number of rats:
Controls 0.17
12 18 6 23 52 111 111

“WINDOWED” RELATION BETWEEN INTENSITY OF IRRADIATION AND BBB PERMEABILITY?



Dr. David Begley, Kings College, London, chairman at the FGF/COST 281, Reisensburg, 2-6 Nov 2003:

statement based upon the presented results of the Lund and the Bordeaux (Aubineau, Töre) groups.



”It seems clear that RF fields can have some effects on tissues”

Albumin in the Brain Parenchyma: Neuronal degeneration is seen in areas with BBB disruption:

*** Intracarotid infusion of hyperosmolar solutions in rats (Salahuddin et al. 1988)**

*** In the stroke-prone hypertensive rat (Fredriksson et al. 1988)**

*** In acute hypertension by aortic compression in rats (Sokrab et al. 1988)**

*** And epileptic seizures cause extravasation of plasma into brain parenchyma. The cerebellar Purkinje cells are heavily exposed to plasma constituents and degenerate in epileptic patients (Sokrab et al., 1990)**

Albumin is the most likely neurotoxin in serum (Eimerl et al. 1991)

Albumin in the brain

25 microlitres rat albumin infused into rat neostriatum.

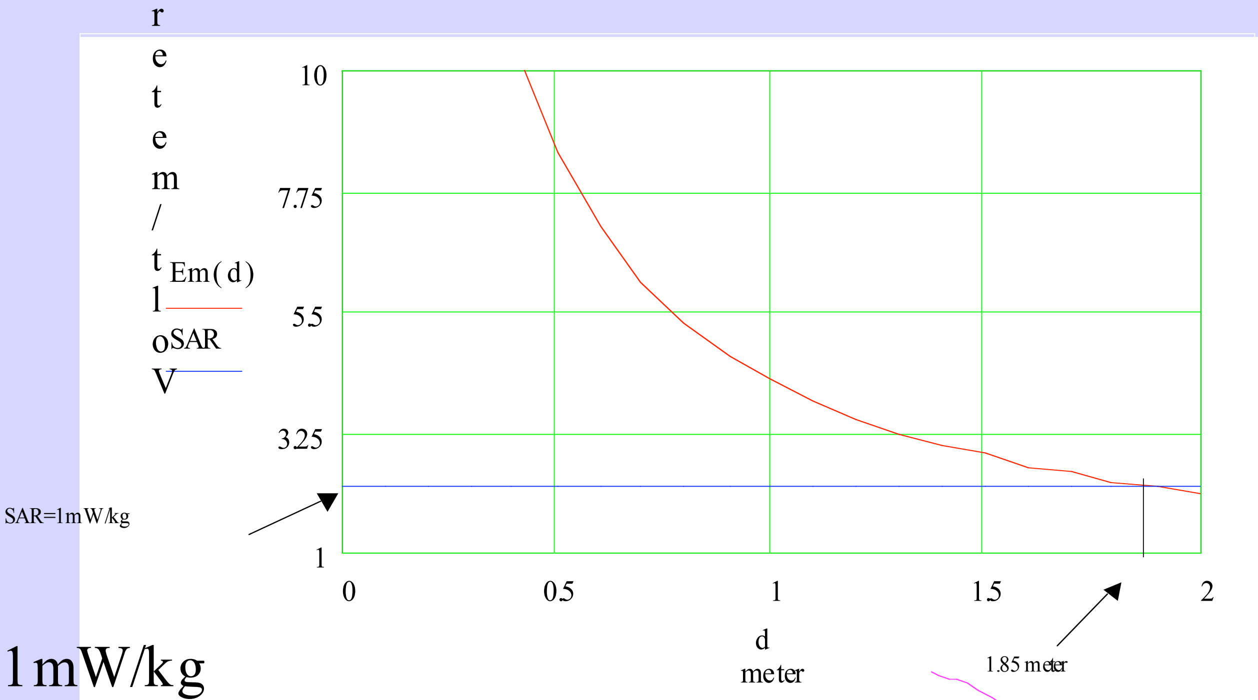
10 and 30, but not 3 mg/ml albumin causes neuronal cell death and axonal severe damage.

It also causes leakage of endogenous albumin in and around the area of neuronal damage.

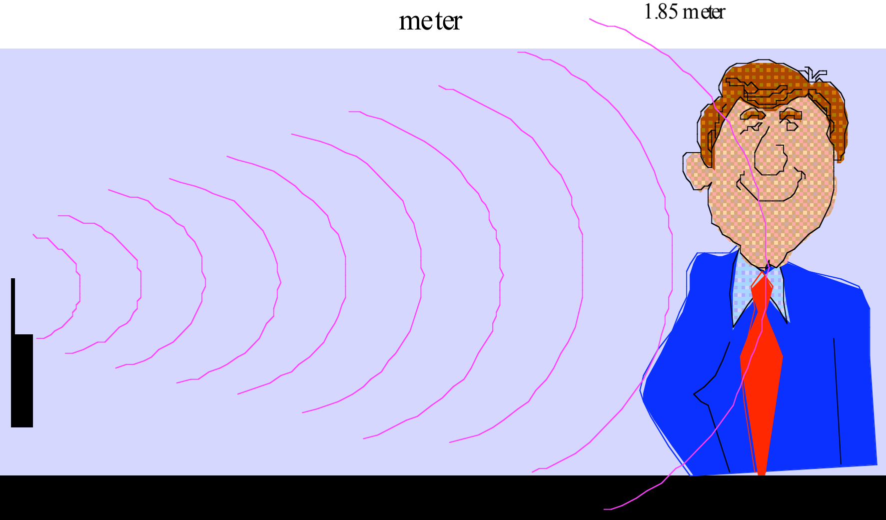
10 mg/ml is approx. 25% of the serum concentration

Hassel B et al. Neuroscience Letters 167:29-32, 1994

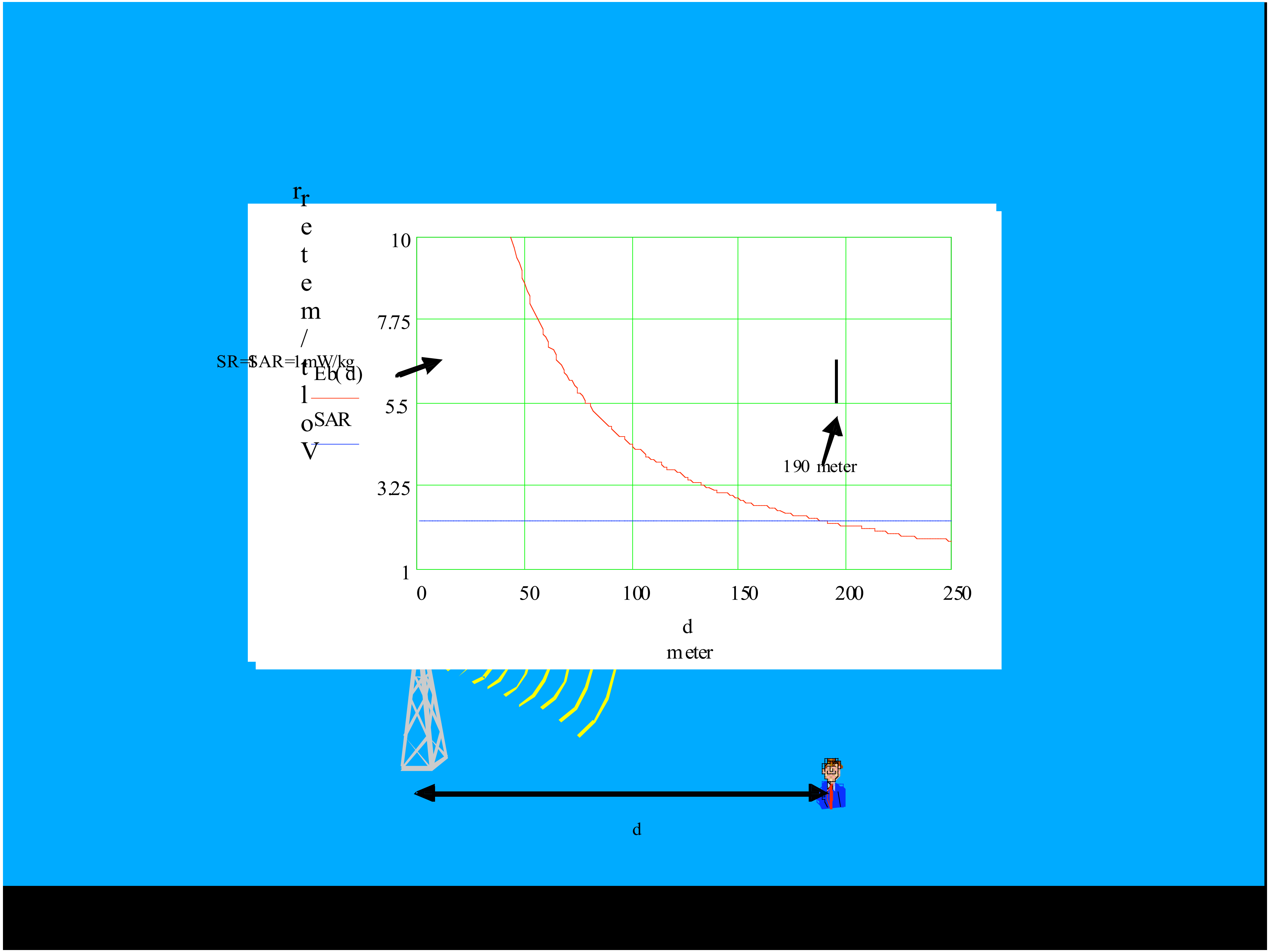
”Passive” mobile exposure ?



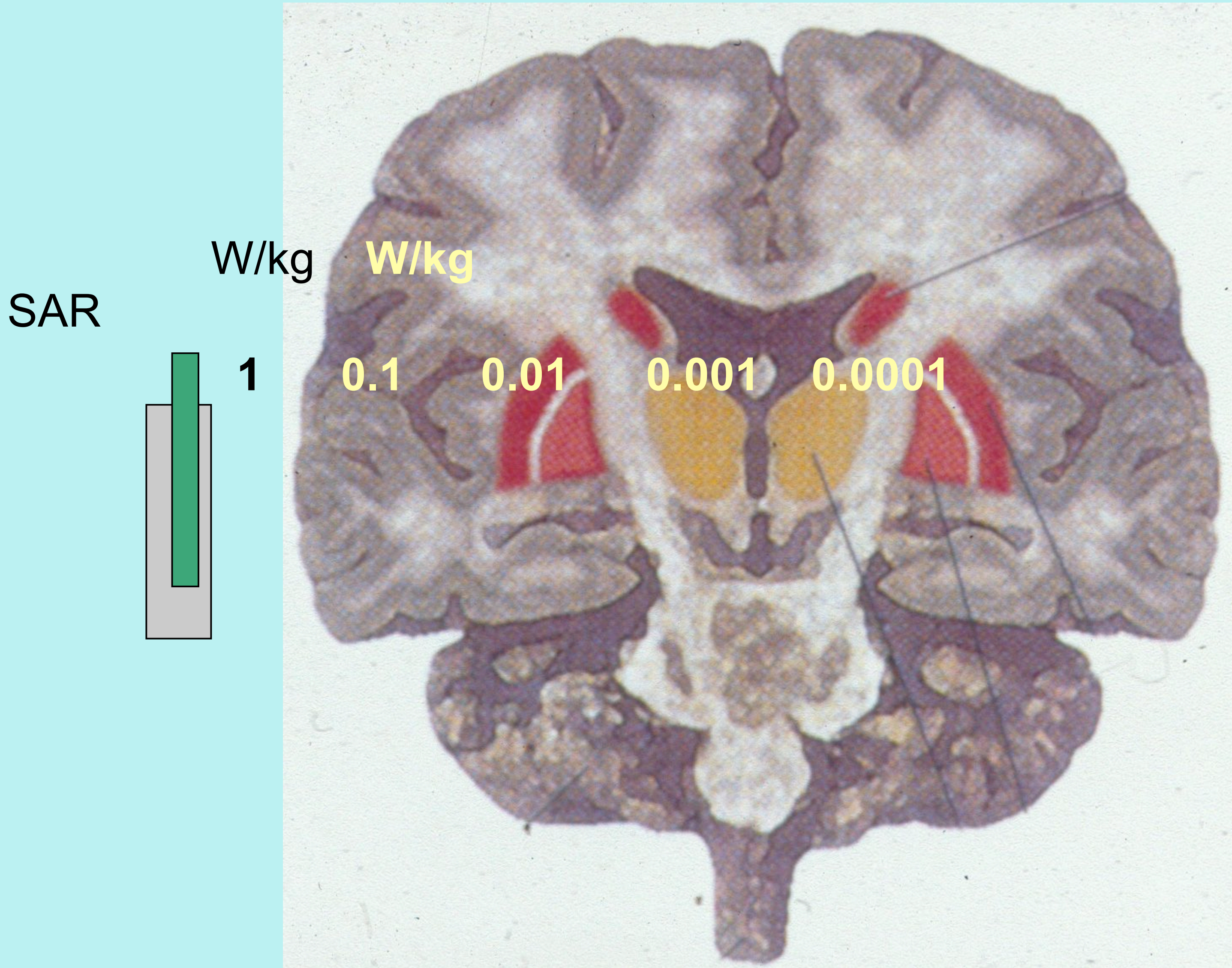
SAR = 1mW/kg
1.85 metres away
from the mobile
phone



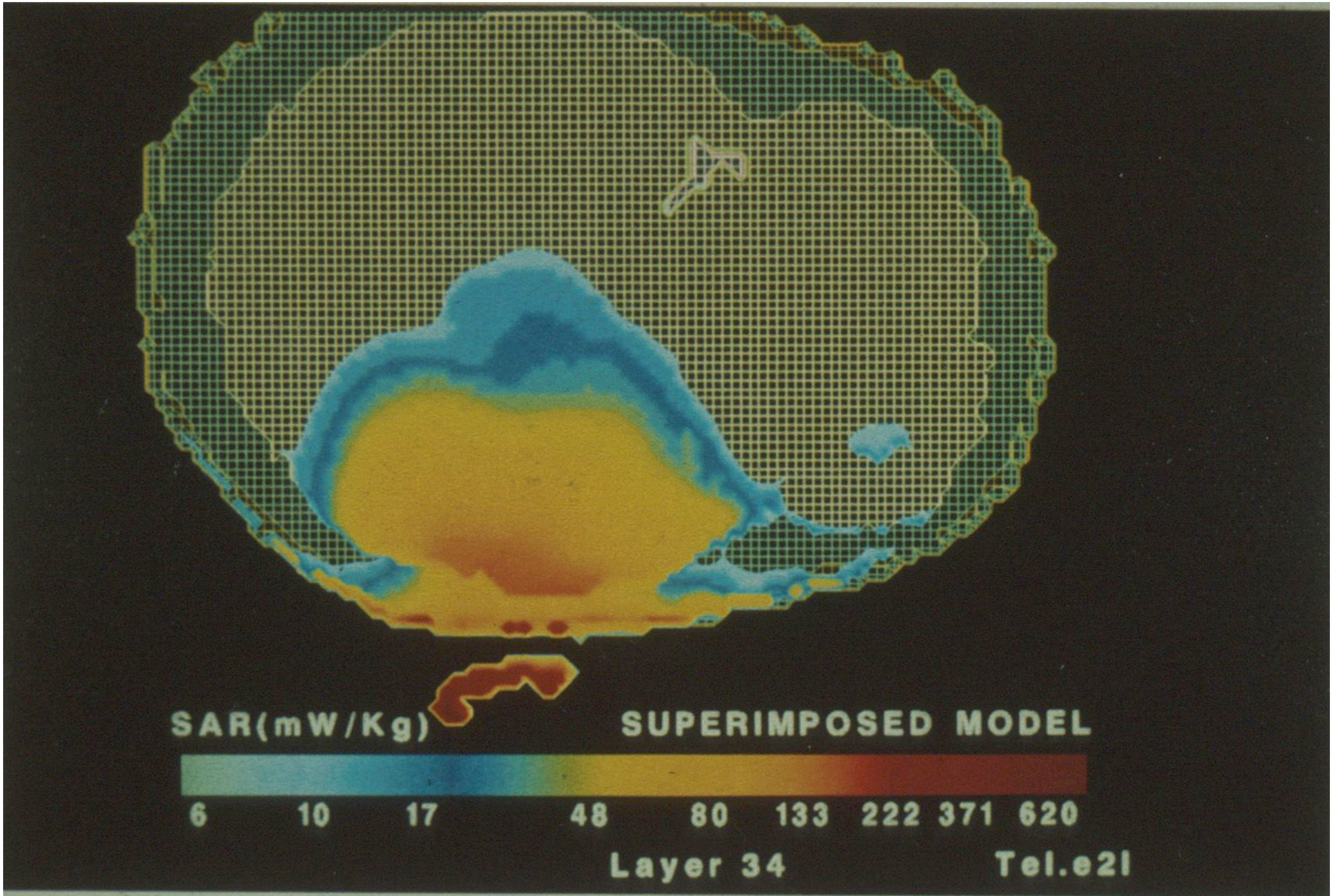
Effect from base stations ?


r
r
e
t
e
m
/
t
l
o
V
SR=SAR=1 mW/kg
Eb(d)
SAR
10
7.75
5.5
3.25
1
0
50
100
150
200
250
d
meter
190 meter
d

Antenna 1,4 cm from human head, 915 MHz, SAR values derived from Anderson and Joyer 1995 and Dimylow 1994



Salford and Persson



From Gandhi

10.2 cm from the top of the head

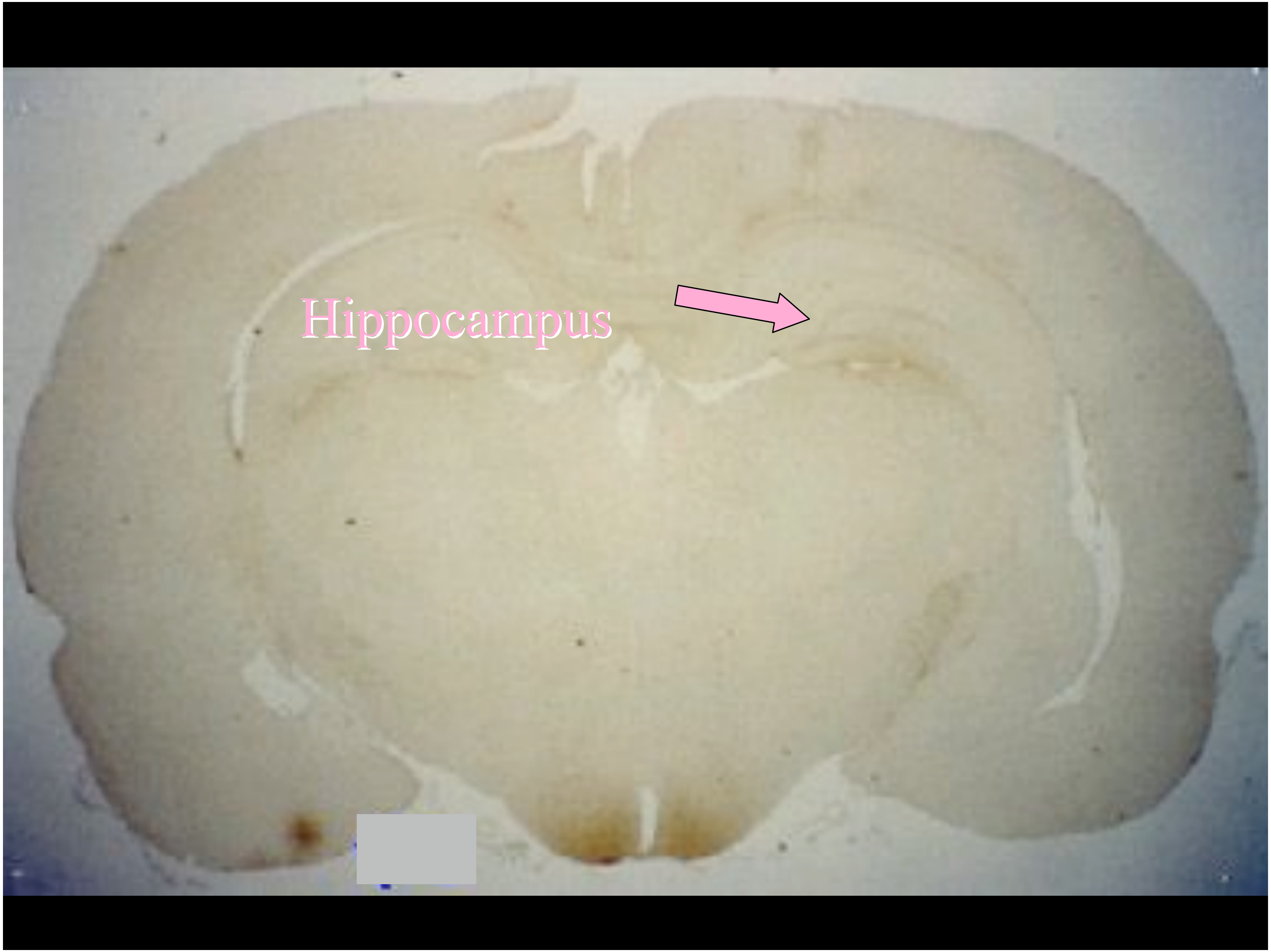
DAMAGE TO BRAIN CELLS LONG TIME AFTER ONE EXPOSURE FOR 2 HOURS TO MICROWAVES FROM A GSM MOBILE PHONE???

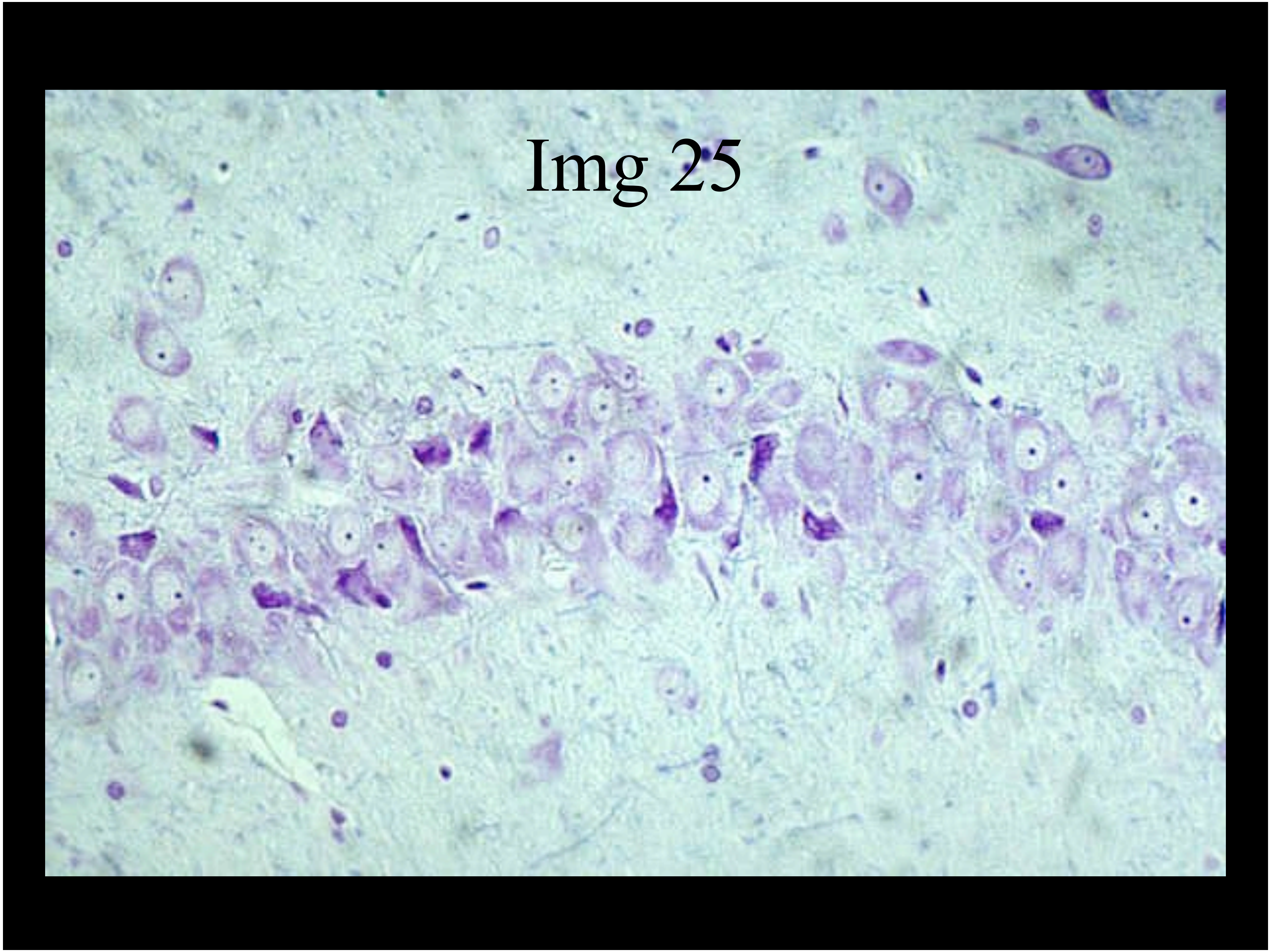
One exposure for 2 hours. Each exposure group: 8 rats (12-26 weeks old – comparable to human teenagers)

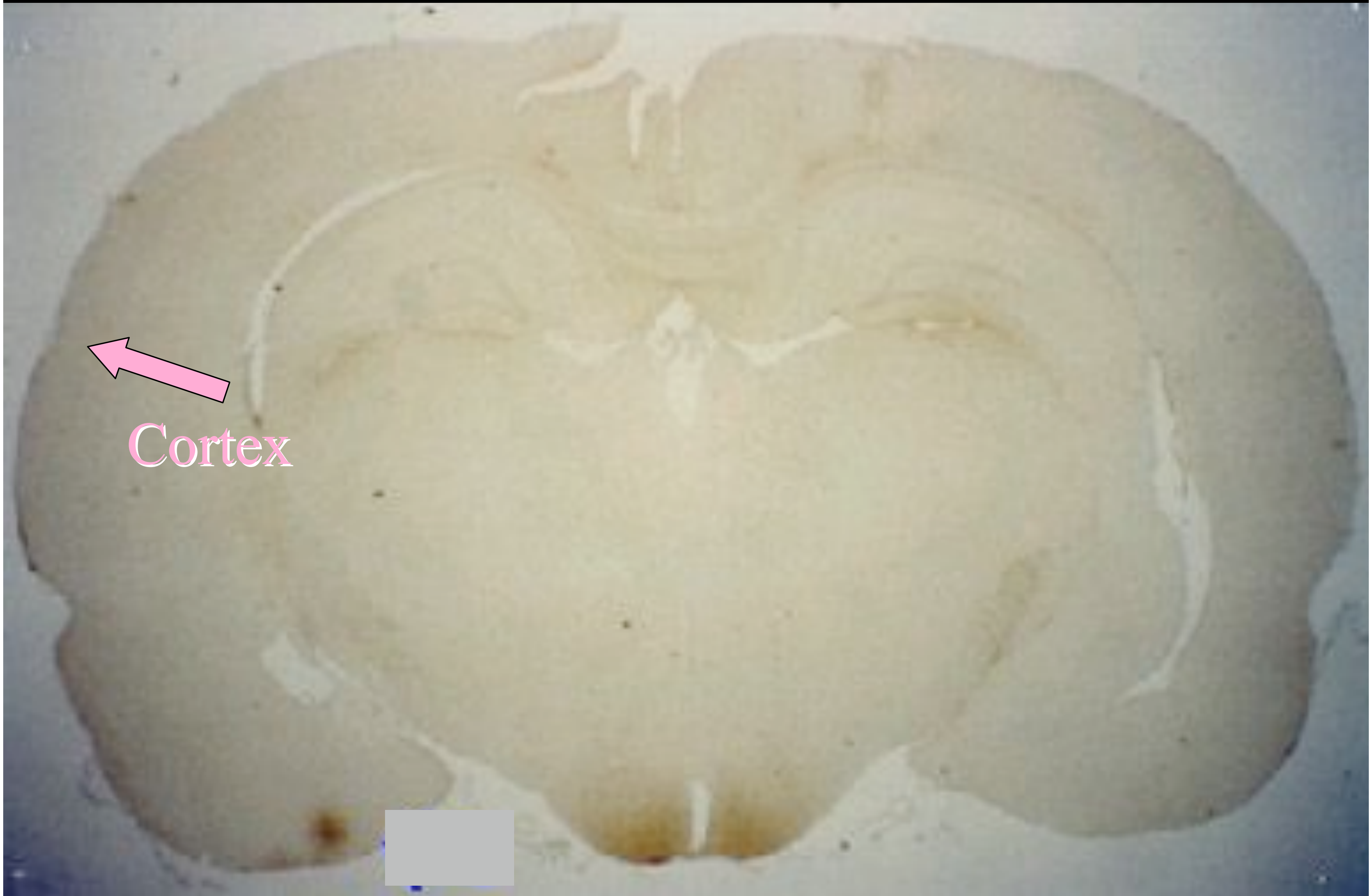
Exposure groups:
0,002 W/kg (1/1000 of the energy at the antenna)
0.02 W/kg (1/100 of the energy at the antenna)
0,2 W/kg (1/10 of the energy at the antenna
Control rats (8 animals in TEM-cell for 2 hours without GSM irradiation)

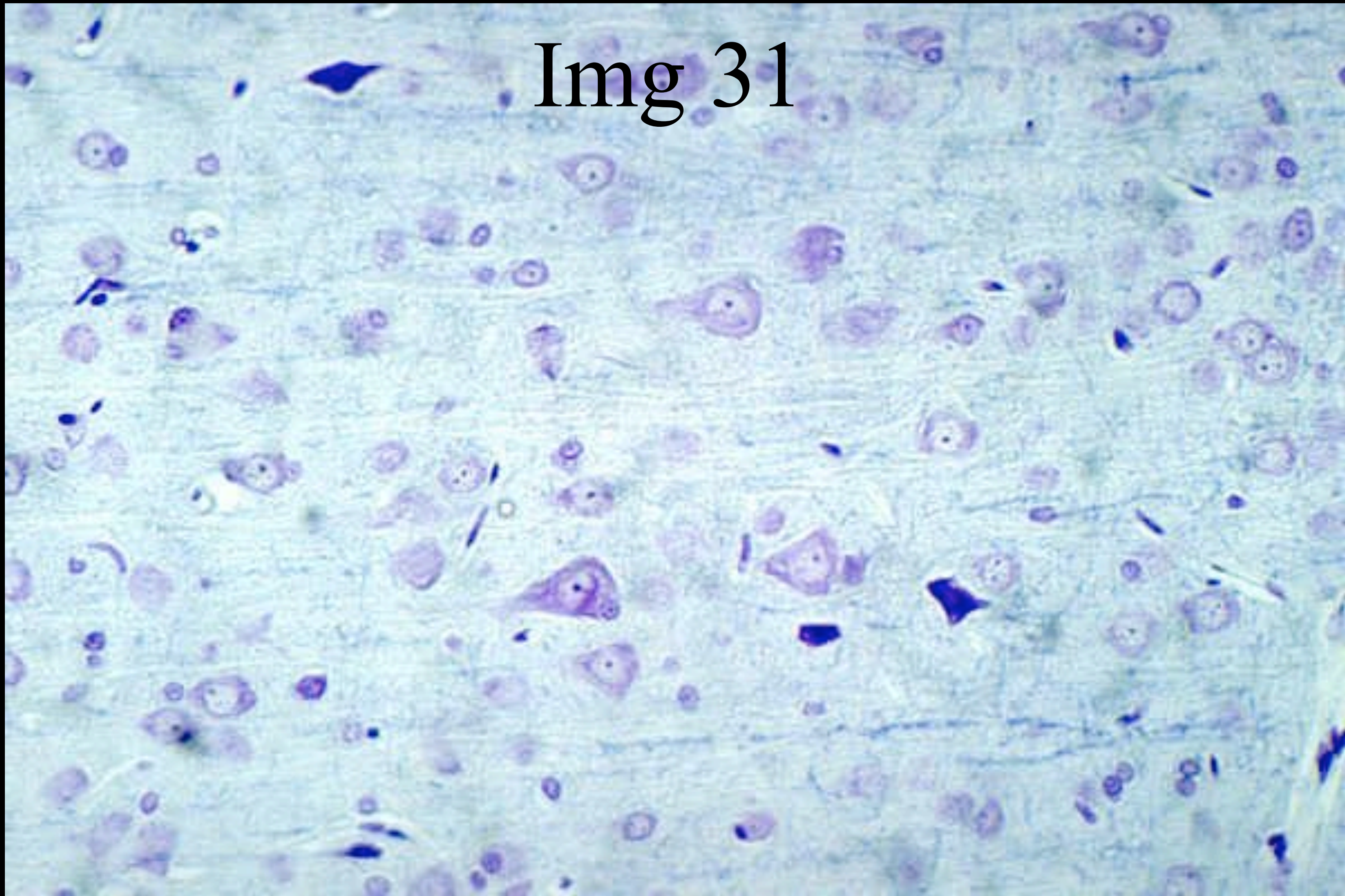
The animals were then allowed to survive for 50 days in standard cages. They were then anesthetised and sacrifized by perfusion-fixation followed by histopathological examination for neuronal damage and albumin leakage.

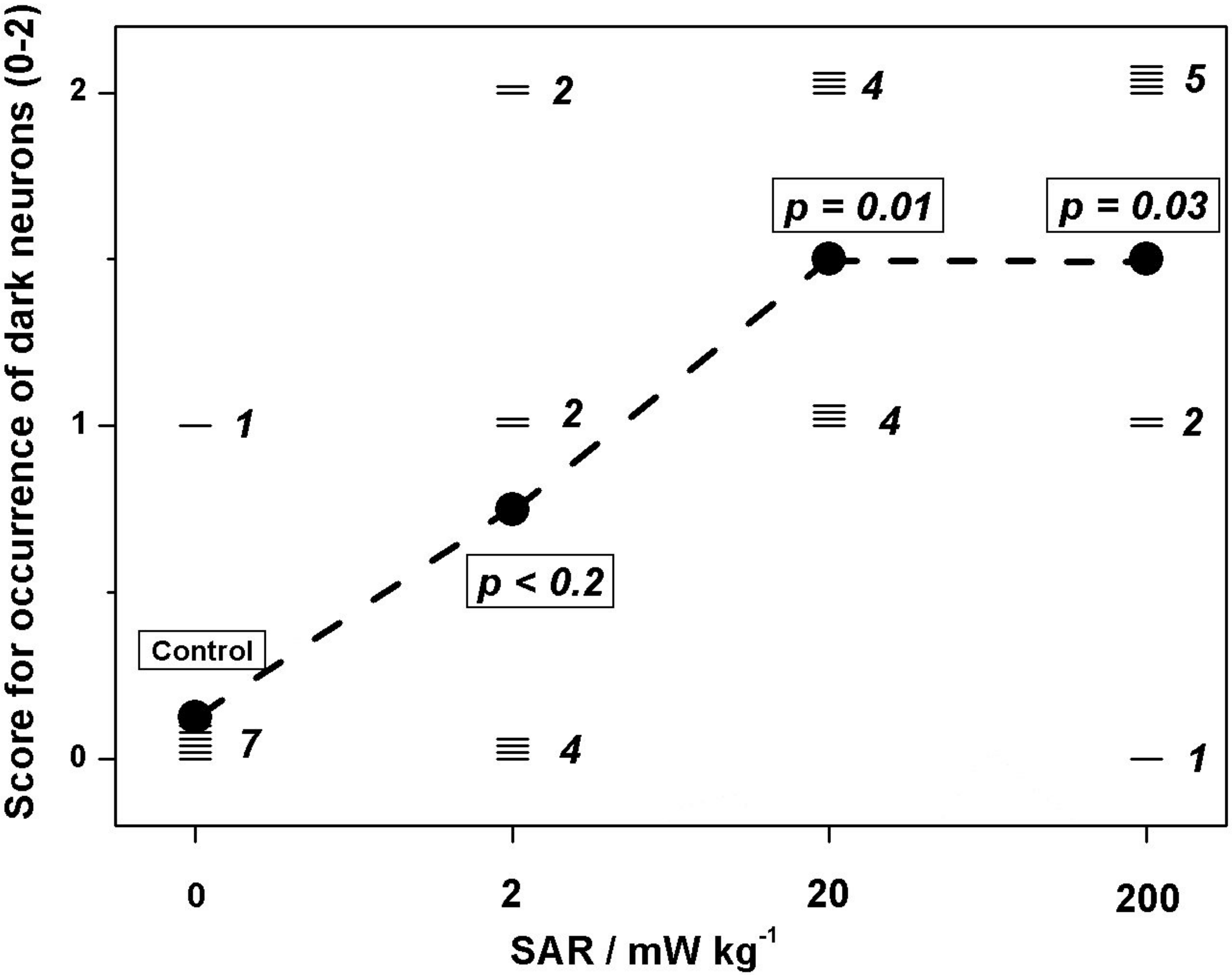
”Dark neurons”
50 days after
2 hours GSM-
exposure!


Hippocampus


Img 25


Cortex


Img 31


Score for occurrence of dark neurons (0-2)
2
1
0
2
4
5
p = 0.01
p = 0.03
1
2
4
2
p < 0.2
Control
7
4
1
0
2
20
200
SAR / mW kg-1

Up to 2% of the neurons are damaged 50 days after a 2-hour GSM exposure

Significance $p=0,002$

(Kruskal Wallis)

- “The intense use of mobile phones by youngsters is a serious memento. A neuronal damage of the kind, here described, may not have immediately demonstrable consequences, even if repeated. It may, however, in the long run, result in reduced brain reserve capacity that might be unveiled by other later neuronal disease or even the wear and tear of ageing. We can not exclude that after some decades of (often), daily use, a whole generation of users, may suffer negative effects maybe already in their middle age”.

- **Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. Environmental Health Perspectives on-line 29/1 2003 and in print June 2003.**

Leif G. Salford, Arne Brun, Jacob Eberhardt, Lars Malmgren, Bertil R.R. Persson

- Depts of Neurosurgery, Neuropathology, Medical Radiation Physics and Applied Electronics, Lund University, the Rausing Laboratory and Lund University Hospital, S-22185, Lund, Sweden.

Continued work, completed:

Connection albumin leakage – neuronal uptake - damage?

 # rats

1600 **48** **48** **32**

Neuronal uptake and damage

Albumin leakage

2 hours exposure

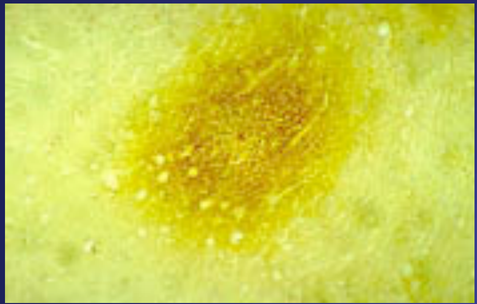
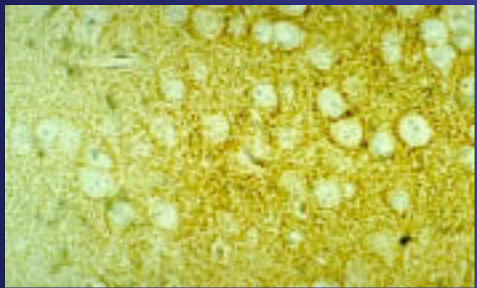
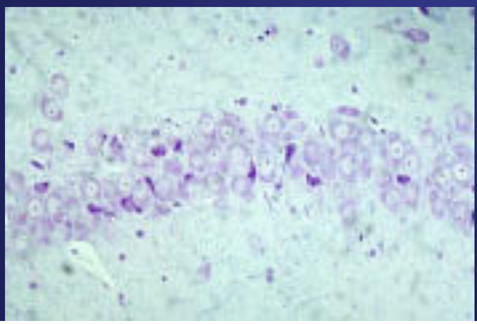
0 **14** **28** **50** **days**

© Salford et al

Exposure scheme, number of animals

Recovery time (days)	sex	sham	SAR (mW/kg)			
			0.2	2	20	200
14	m	8	4	4	4	4
14	f	8	4	4	4	4
28	m	8	4	4	4	4
28	f	8	4	4	4	4
50	m	4		4	4	4
50	f	4		4	4	4

Exposed vs sham

		14 d	28 d	50 d
	**Albumin foci**	**0.02**	**ns**	**0.04**
	**Diffuse albumin**	**ns**	**ns**	**ns**
	**Neuronal albumin**	**0.005**	**ns**	**ns**
	**Dark neurons**	**ns**	**0.01**	**0.001**

Continued work:
Long term exposure:

56 male and female Fischer 344 rats have been exposed to GSM 100mW/kg, 1mW/kg, or sham exposed for 2 hours in our TEM-cells once a week for more than a year.
Behavioural tests 3-5 weeks after last expos.
Exam of perfusion fixed brains and eyes
Spared in formaldehyde: testis
Spared in -80C: testis, ovary, kidney, spleen, liver, bone marrow, blood

Ongoing analysis

- Different markers for brain ageing
- Gliosis (GFAP staining)
- Pigment in neurons (histological fluorescence)
- Synaptic functionality (immunostaining)
- Apoptosis (but was not found in the 50 day recovery time study)

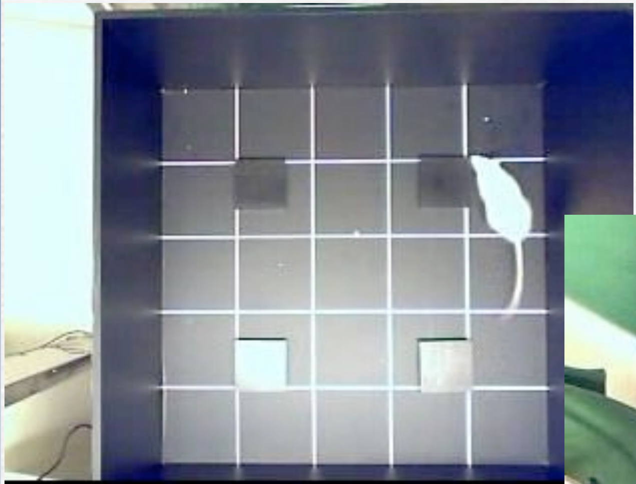
Behavioural tests
long term experiments (14 months)
2 hours per week GSM 100 and 1 mW/kg

Episodic memory test

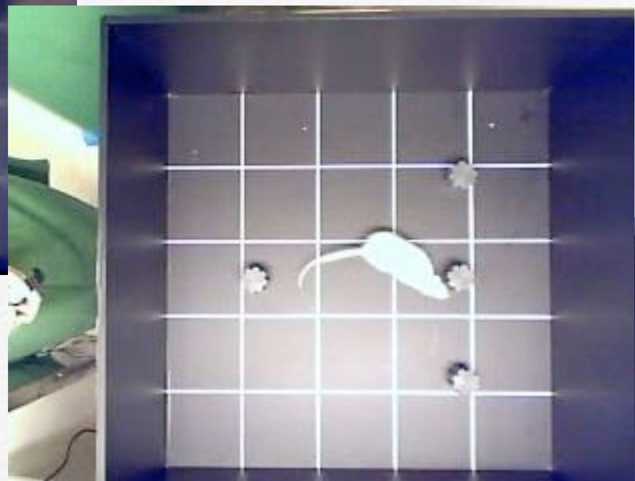
- “recollection of a unique past experience in terms of what happened and where and when it happened”
- Episodic memory test for mice and rats has been described in the literature

Episodic memory test

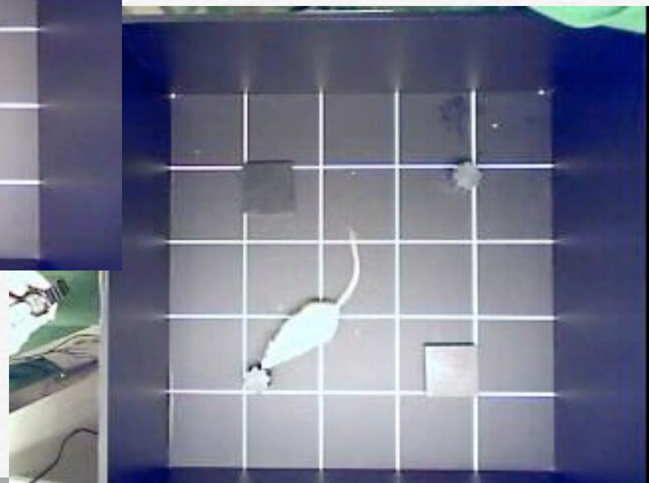
Training 1



Training 2



Test



Results Episodic memory test

- Exposed animals have a significantly ($p=0.02$) shorter exploration time of the old objects, than the sham exposed which may indicate that the exposed animals have “forgotten” about the old objects
- No differences between males and females.
- No significant differences between the 2 exposed groups (100 vs 1 mW/kg)

GSM RF non-thermal effects *in vitro* upon gene expression

GSM RF non-thermal effects *in vitro* upon gene expression in human cultured cells.

Author	Celltype	RF	time
Pacini et al. 2002	Human fibroblasts	GSM phone	1 hour

Signif. biol.eff. mitogenic signaltransduct. and apoptosis genes upregul.

Author	Celltype	RF	time
Lee et al. 2005	Human HL-60 cells	2.45 GHz	2 hours 6 hours

221genes altered after 2 hours and 759 after 6 hours
Apoptosis related up- and cell cycle genes downregulated

Author	Celltype	RF	time
Remondini et al. 2006 REFLEX	6 human cell lines	900 MHz 1800 MHz Mob. Phone	

3 cell types (endothelial, lymphoblastoma and leukemia) had 12 to 34 altered gene expr for ribosomal proteins upregulating cellular metabolism

GSM RF non-thermal effects *in vitro* upon gene expression in human and rat cultured cells.

Author	Celltype	RF	time
Lezczynski et al. 2002	human endo-thelial cell line	900 MHz GSM	1 hour

Altered phosphorylation status hsp27 and p38MAPK (mitogen-activated prot. kinase)
Hypoth: facilitates brain cancer, increase in BBB permeability

Zhao et al. 2006	Neurons from new-born rats	1.8 GHz 217 Hz SAR 2W/kg	24 hours

34 out of 1200 genes up or down regulated.
Map 2 up regulated, crucial for neuronal function

GSM RF non-thermal effects *in vivo* upon gene expression

Continued work, completed:

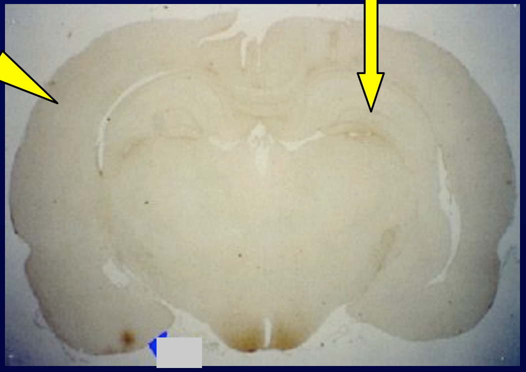
Gene response to 915 MHz GSM

cerebellum — Belyaev et al.

400 mW/kg

cortex and hippocampus — Salford et al.

25 mW/kg



Gene response to 915 MHz GSM 400mw/kg

8800 rat genes analyzed with Affymetrix Microarray Suite
Cerebellum from 8 Fischer 344 rats, 4 exposed and 4 controls

11 genes upregulated 1.34 – 2.74 fold
1 gene downregulated 0.48 fold
$p<0.0025$

The induced genes encode proteins with functions including neurotransmittor regulation, BBB and melatonin production

---

But no induction of PFGE-detectable DNA double stranded breaks or changes in chromatin conformation (AVTD) by 915 MHz GSM

Belyaev I. et al. Bioelectromagnetics 2006

Cortex and hippocampus   Salford et al.

Microarray analysis of 40.000 rat genes (including splicing variants) in cortex and hippocampi of 8 Fischer 344 rats, 4 animals exposed to GSM EMF SAR 25mW/kg for 6 hours in TEM cells and 4 controls kept as long in unexposed TEM cells
Gene ontology analysis of the differentially expressed genes for cortex/hippocampi of the exposed animals versus the control group.

© Salford et al

Top separating categories microarray Salford ea 2006

Cortex

cell communication e-15
plasma membrane e-11
G-prot coupled rec.prot e-11
extracellular region e-11
signal transducer activity e-10
intrinsic to plasma membr e-10
intregral to membr e-10
membrane e-10
intrinsic to membrane e-10
synaptic vesicle amine trpt e-9
transmembr receptor act -9
surface receptor linked signal transduct. e-9

Hippocampi

extracellular region e-23
extracellular space e-22
signal transducer activity e-15
transmembrane receptor activity e-15
receptor activity e-14
Integral to membrane e-13
intrinsic to membrane e-13
organismal physiol process e-11
rhodopsin-like receptor activity e-9
G-prot coupl rec.prot sign. pathw. e-9
cell surface receptor linked sign. trd e-8
neurotransmitter receptor activity e-8

© Salford et al

Top separating categories

10 of the 12 Hippocampal top categories are the same as 10 of the 19 Cortical top categories (e-)

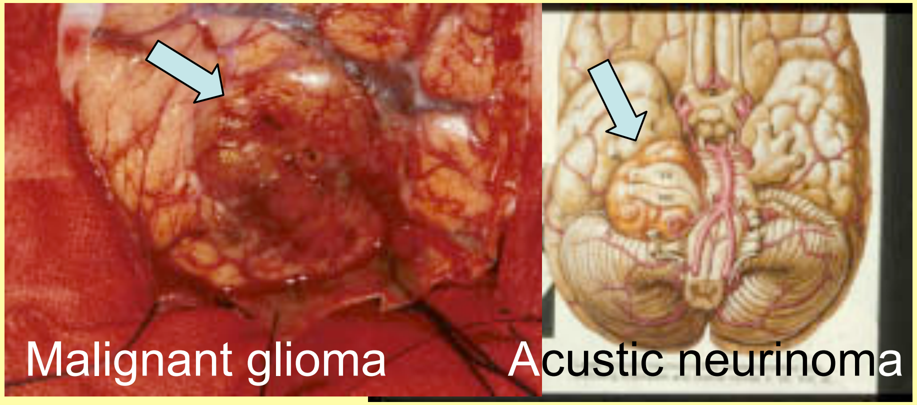
	# genes
extracellular region e-23 (e-11)	1417
extracellular space e-22 (e-8)	1188
signal transducer activity e-15 (e-10)	1455
transmembrane receptor activity e-15 (e- 9)	603
receptor activity e-14 (e-9)	935
integral to membrane e-13 (e-10)	1937
intrinsic to membrane e-13 (e-10)	1949
organismal physiol process e-11 (e-8)	950
G-prot coupled recept. prot sign. pathw e-9 (e-11)	467
cell surface receptor linked sign. transd e-8 (e-9)	118

© Salford et al

The fact that a large number of these categories are connected with membrane functions may have a relation to our earlier observation of albumin transport through the cerebral endothelium

Mobile phones and Brain tumours

Bioinitiative report July 2007



Lennart Hardell, MD, PhD, Dept of Oncology, Örebro University Hospital, Sweden
Kjell Hansson Mild, PhD, Dept of Radiation Physics, Umeå University, Sweden
Michael Kundi Ph.D., med.habil, Inst. of Env. Health, Vienna, Austria

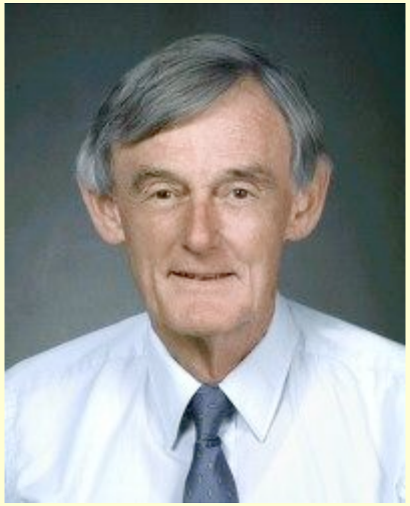
”In summary we conclude that our review yielded a consistent pattern of an increased risk for acoustic neuroma and glioma after > 10 years mobile phone use. We conclude that current standard for exposure to microwaves during mobile phone use is not safe for long-term brain tumor risk and needs to be revised”.

Mobile phone emission modulates interhemispheric functional coupling of EEG alpha rhythms

Fabrizio Vecchio et al. European Journal of Neuroscience, Vol. 25, pp. 1908–1913, 2007

Compared to sham stimulation, GSM stimulation for 45 minutes modulated the interhemispheric frontal and temporal coherence at alpha 2 (about 8–10 Hz) and alpha 3 (about 10–12 Hz) bands.

Prolonged mobile phone emission affects not only the cortical activity but also the spread of neural synchronization conveyed by interhemispherical functional coupling of EEG rhythms.



Ross Adey, 1922-2004,
studied amplitude-modulated radiofrequency fields. “If we made a radio signal look like a brain wave, would it influence behavior? We showed in cats very clearly, and monkeys to some extent, that you could make the brain wave pattern follow the modulation on the radio signal.”

The inverted U-function as a response characteristic in connection of RF exposure might explain why, in many studies of pharmacological effects, response is only seen at a certain dose range, and not at higher or lower dosages. It might constitute the basis for window effects observed in connection to RF exposure.

MECHANISMS?

Mechanism behind possible, direct, non-thermal effects of RF radiation upon the central nervous system are not clear. Adey in 1988 suggested the hypothesis that co-operative processes in the cell membrane might be reactive to the low energy of an electromagnetic field. This oscillating field might result in changes of the membrane potential.

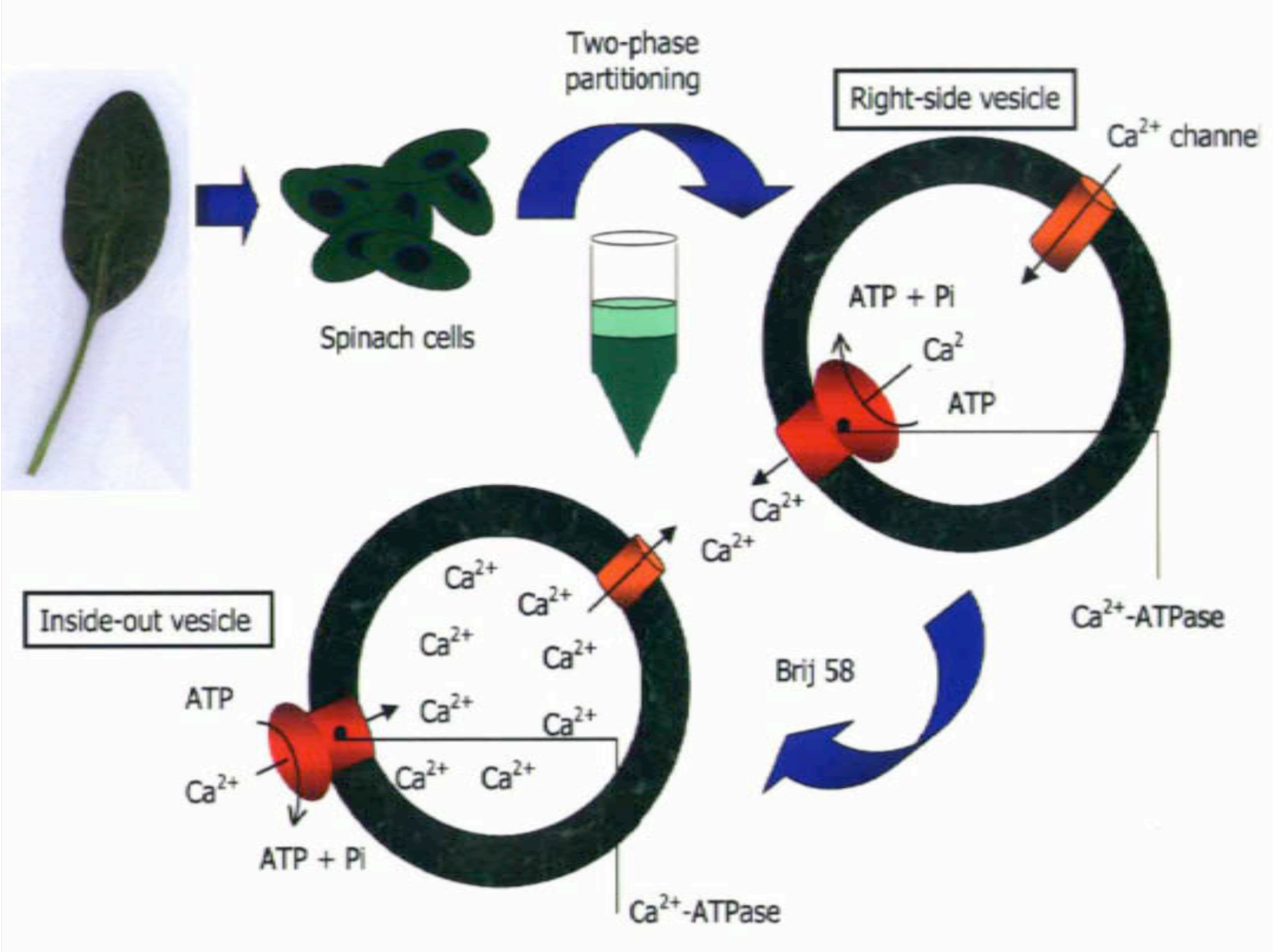
Interaction Between Weak Low Frequency Magnetic Fields and Cell Membranes

C.L.M. Bauréus Koch, M. Sommarin, B.R.R. Persson, L.G. Salford and J.L. Eberhardt

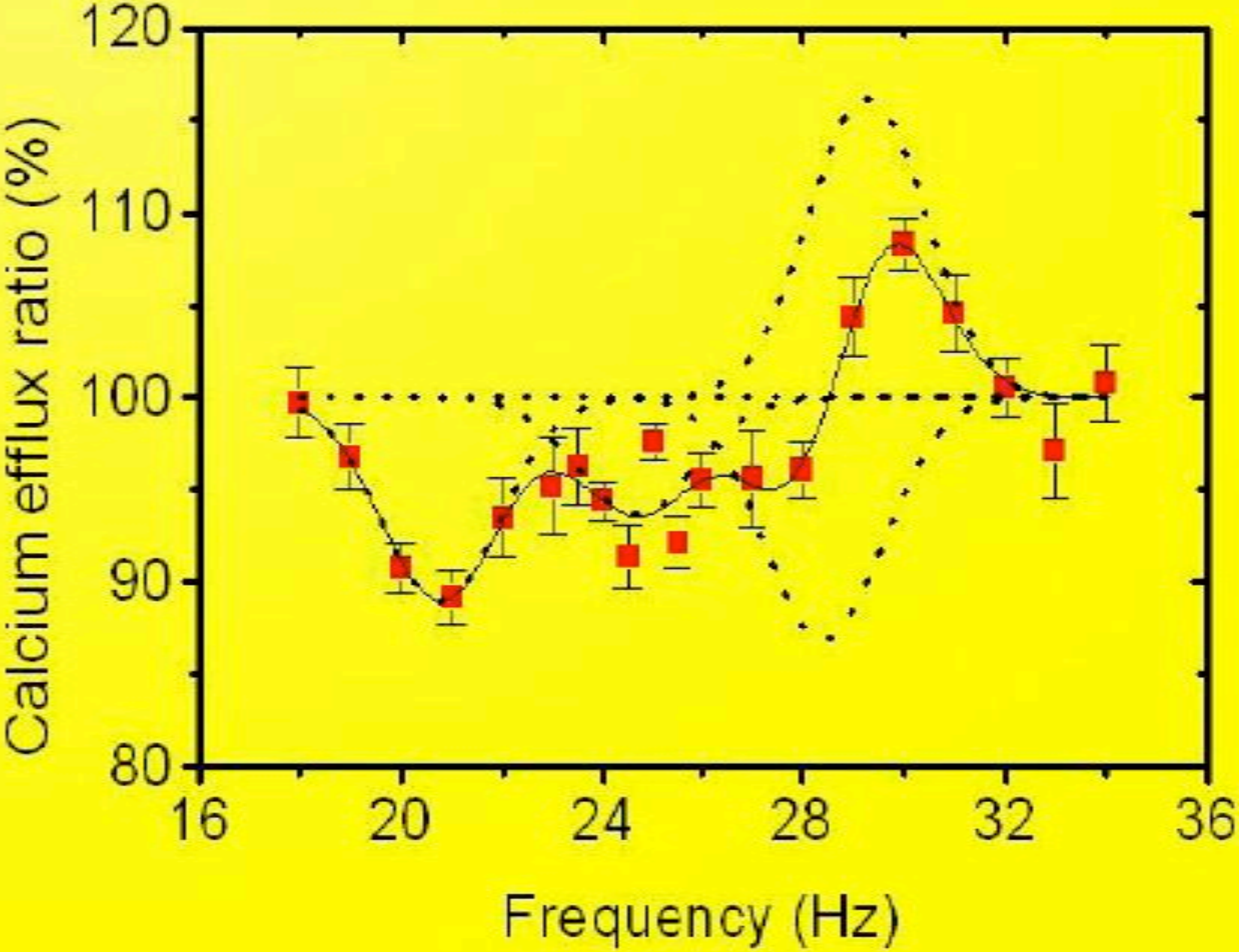
Depts of Radiation Physics, Plant Biochemistry and Neurosurgery - the Rausing Laboratory, Lund University, Lund Sweden

Bioelectromagnetics 24:395-402, 2003

”We show that suitable combinations of static and time varying magnetic fields directly interact with the Ca2+ channel protein in the cell membrane, and we could quantitatively confirm the model proposed by Blanchard”


Two-phase
partitioning
Spinach cells
Right-side vesicle
Ca^{2+} channel
ATP + Pi
Ca^{2}
ATP
Ca^{2+}
Ca^{2+}
Ca^{2+}-ATPase
Brij 58
Inside-out vesicle
Ca^{2+}
Ca^{2+}
Ca^{2+}
Ca^{2+}
Ca^{2+}
Ca^{2+}
Ca^{2+}
Ca^{2+}
ATP
Ca^{2+}
ATP + Pi
Ca^{2+}-ATPase

Blanchard



Calcium efflux ratio (%)
120
110
100
90
80
16
20
24
28
32
36
Frequency (Hz)

The effects on pain, nociception and opiate-mediated analgesia constitute one of the most reproducible and reliable effects of EMFs with observed decrease in pain threshold.

The fact that EMFs increase pain perception is of particular interest if one considers our ubiquitous exposure to various EMFs and the prevalence of pain problems in our society.

The physiological mechanisms involved require definition

Cepaea nemoralis

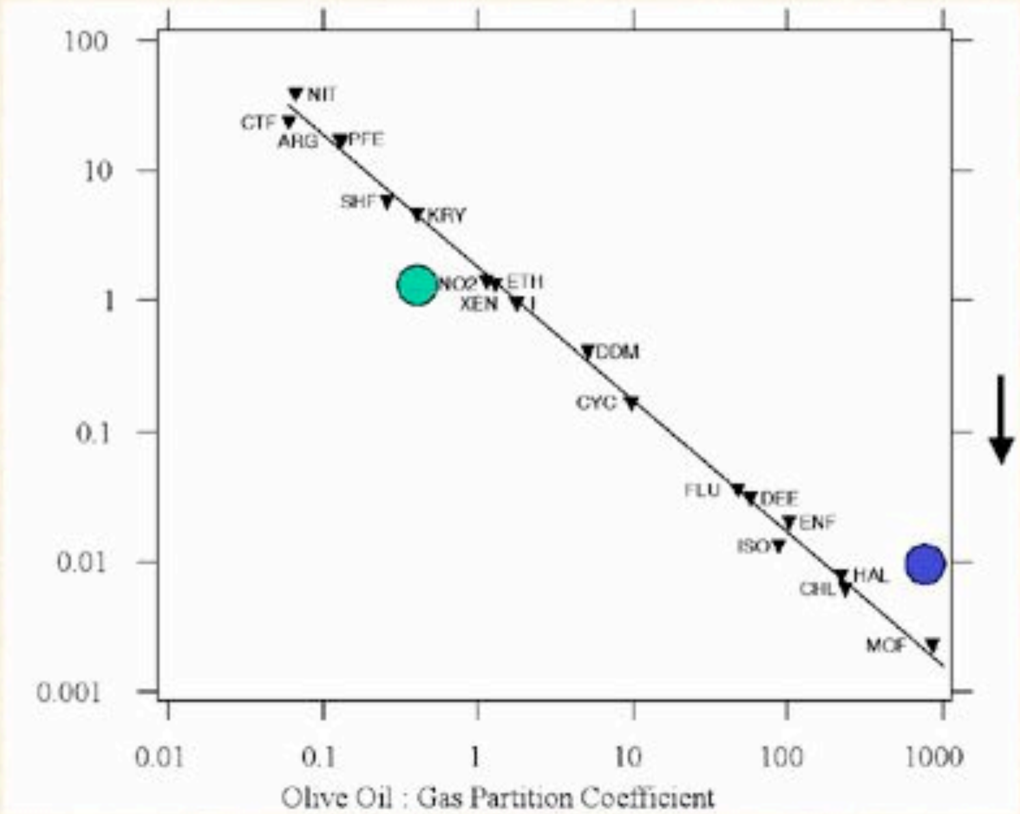
Based upon > 50 studies in snails, mice and rats
Review: Pain perception and electromagnetic fields
Del Seppiaa C, Ghionea S, Luschib P, Ossenkopp KP, Choleris E, Kavaliers M (London, Ontario)
Neuroscience and Biobehavioral Reviews 31 (2007) 619–642

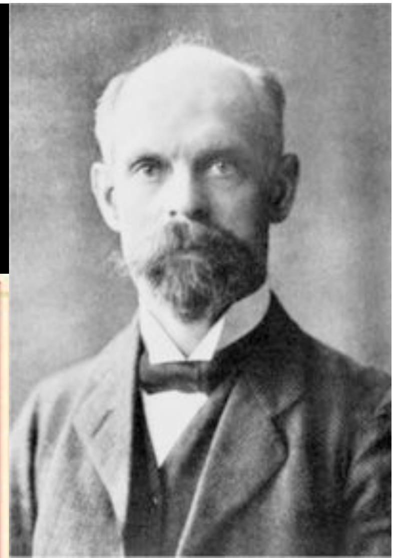
A new theory

Anaesthesia, analgesia

Meyer Overton Correlation

HAL Halothane
ISO Isoflurane
ENF Enflurane
SEV Sevoflurane
FLU Fluroxene
DES Desflurane
CYC Cyclopropane
MOF Methoxyflurane
DEE Diethylether
CHL Chloroform
DDM Dichlorodiflurormethane
PFE Perfluoroethane
CTF Carbon tetrafluroide
SHF Sulfur hexafluoride
CYC Cyclopropane
ETH Ethylene
NO2 Nitrous oxide
XEN Xenon
NIT Nitrogen
KRY Krypton
ARG Argon





Charles Ernest Overton (1865–1933) born in England

Professor of Pharmacology at Lund University, Sweden 1907 - 1930.

A new theory

Solitons instead of Hodgkin-Huxley?

On soliton propagation in biomembranes and nerves Heimburg, T. and Jackson, AD. (2005) PNAS 102, 9790-9795:

Niels Bohr Institute Copenhagen

The lipids of biological membranes and intact biomembranes display chain melting transitions close to temperatures of physiological interest. During this transition the heat capacity, volume and area compressibilities, and relaxation times all reach maxima. Compressibilities are thus nonlinear functions of temperature and pressure in the vicinity of the melting transition, and we show that this feature leads to the possibility of soliton propagation in such membranes. In particular, if the membrane state is above the melting transition solitons will involve changes in lipid state. We discuss solitons in the context of several striking properties of nerve membranes under the influence of the action potential, including mechanical dislocations and temperature changes.

The thermodynamics of general anesthesia. Biophys J. 2007 May 1;92(9):3159-65.
Anesthetics lower the temperature at which lipids become solid, making it difficult for the waves to form, thereby preventing nerves from sending pain signals.

Fig. 4. Properties of solitons and nerves

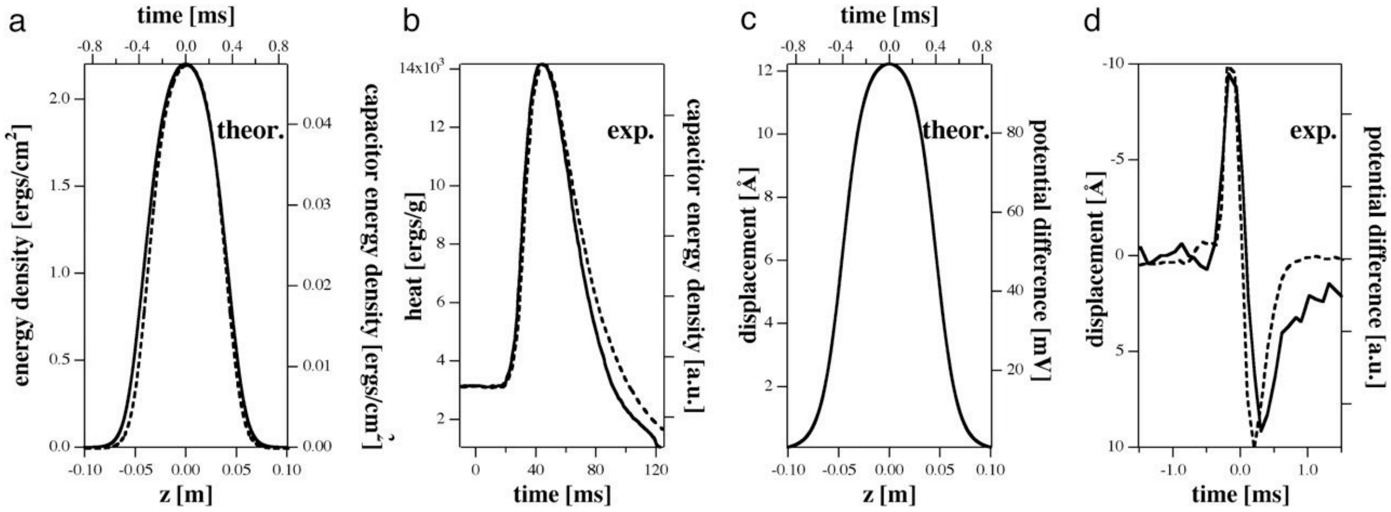


Fig. 4. Properties of solitons and nerves. (*a*) Calculated total energy and capacitive energy densities stored in the soliton during the passage. Both functions display similar time dependence. (*b*) Experimental heat changes during the action potential of garfish olfactory nerve (solid line) and the energy of charging the membrane's capacitor. Both functions display similar time dependence (adapted from ref. 13). (*c*) Calculated thickness change of a membrane cylinder (displacement) and corresponding voltage changes. Both functions display identical time dependence. (*d*) Experimentally determined differential displacement of the squid axon and the corresponding action potential (adapted from ref. 27). Both functions display identical time dependence. The different shape of the profiles as compared with *b* are a consequence of the experimental setup.

Heimburg, Thomas and Jackson, Andrew D. (2005) Proc. Natl. Acad. Sci. USA 102, 9790-9795

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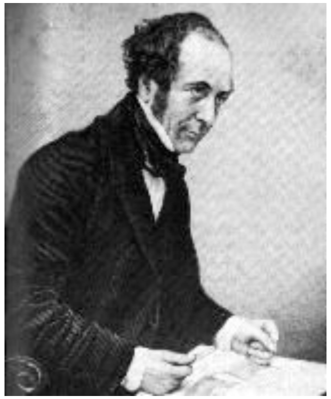
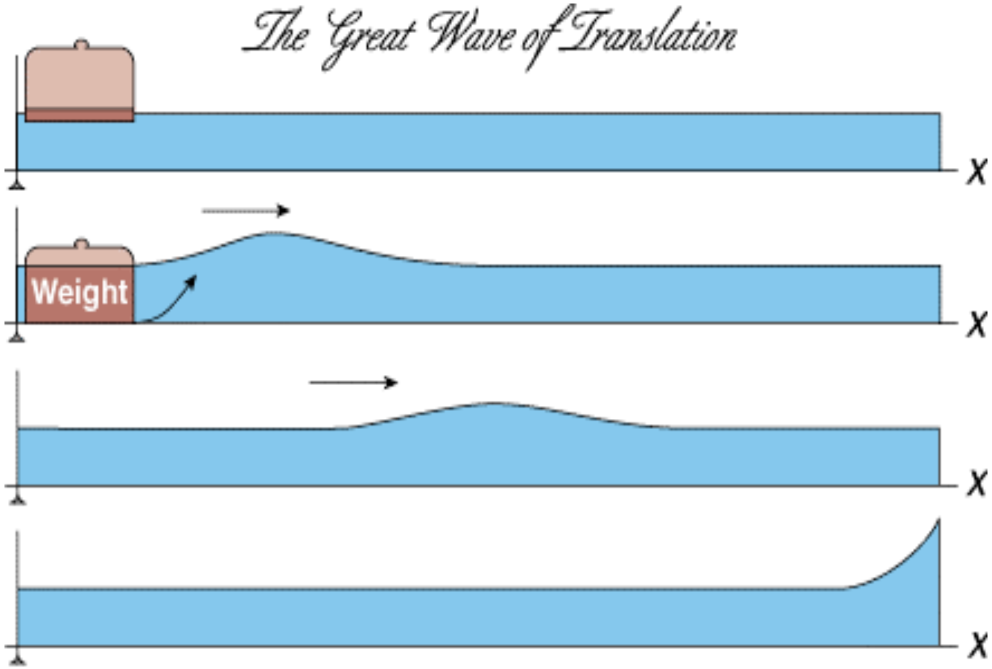
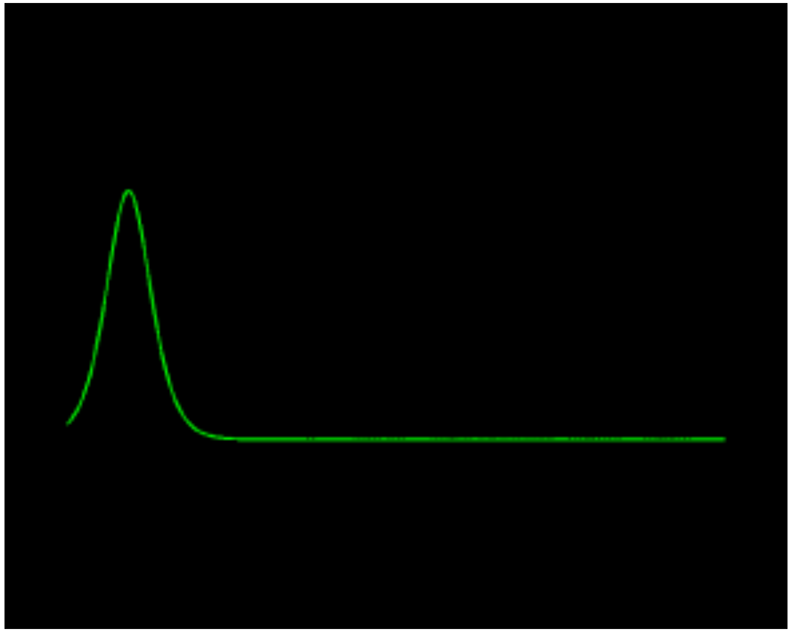
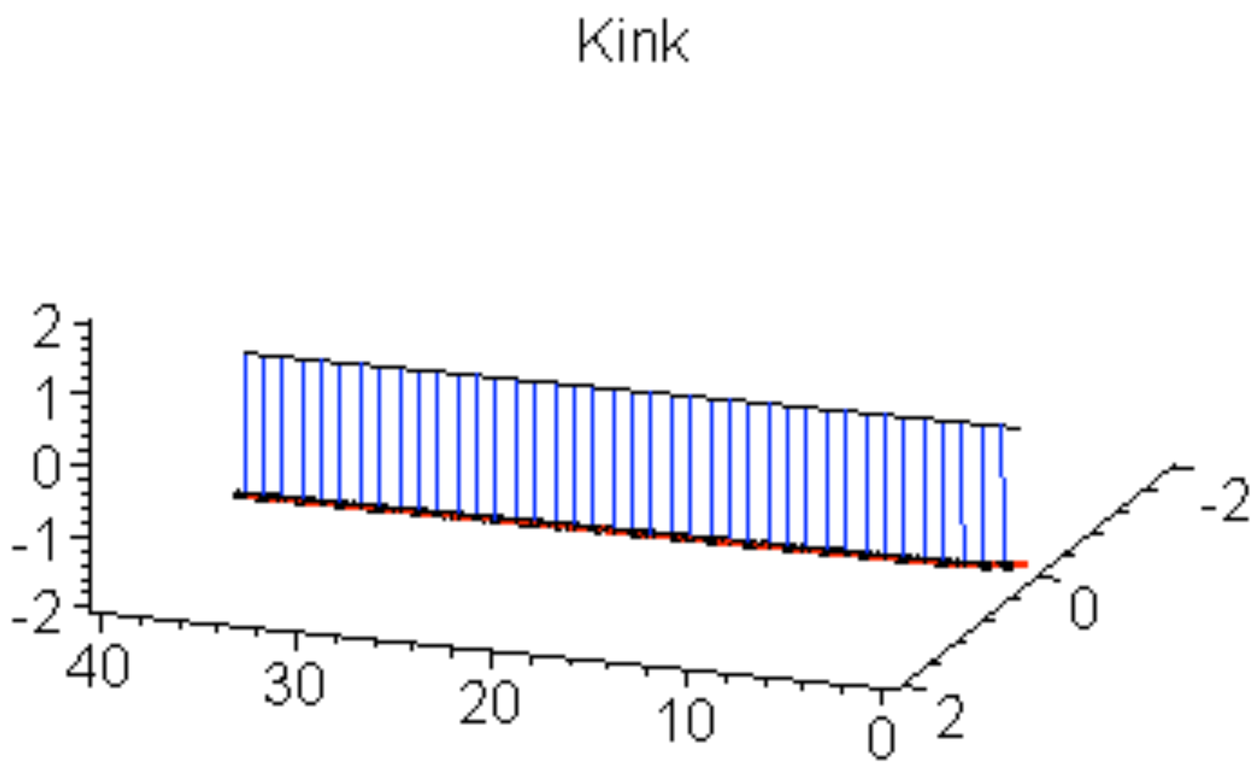


John Scott Russell and the solitary wave
In 1834, while conducting experiments to determine the most efficient design for canal boats, a young Scottish engineer named John Scott Russell (1808-1882) made a remarkable scientific discovery, which he described it in his "Report on Waves" after his first sighting of a soliton or solitary wave on the Union Canal near Edinburgh.





The Soliton



In the frame of the pendulum model the kink is the solitary wave of counter clockwise rotation of pendulums through the angle 2π

Resonant Microwave Absorption of Selected DNA Molecules

G. S. Edwards and C. C. Davis
Chemical Physics Program and Electrical Engineering Department, University of Maryland, College Park, Maryland 20742

and

J. D. Saffer
Laboratory of Biochemistry, National Cancer Institute, National Institutes of Health, Bethesda, Maryland 20205

and

M. L. Swicord
Center for Devices and Radiological Health, Food and Drug Administration, Rockville, Maryland 20857
(Received 5 July 1984)

The resonant absorption of microwave energy by aqueous solutions containing DNA of known length is experimentally demonstrated. The resonances observed have relaxation times of hundreds of picoseconds. Absorption by linear and supercoiled circular DNA molecules is discussed in terms of a mechanism involving microwave excitation of acoustic modes of the double helix.

[redacted]

In a pioneering paper appeared in 1980, Englander, Kallenbach, Heeger, Krumhansl and Litwin [8] suggested that nonlinear excitations in the DNA double chain could be instrumental in this process and allow the motion of the transcription bubble to occur at near-zero energy cost. In particular, as the fundamental motion undergone by DNA nucleotides in this process is a roto/torsional one, they suggested to model the DNA molecule as a double chain of coupled pendulums; the relevant nonlinear excitations would then be (topological) solitons pretty much like those well known in the sine-Gordon equation. We refer to their work for detail.

Proc. Natl. Acad. Sci. USA
Vol. 77, No. 12, pp. 7222–7226, December 1980
Biophysics

Nature of the open state in long polynucleotide double helices: Possibility of soliton excitations

(hydrogen exchange/DNA dynamics/base pair opening/DNA "breathing")

S. W. ENGLANDER*, N. R. KALLENBACH†, A. J. HEEGER‡, J. A. KRUMHANSL*§, AND S. LITWIN¶

*Departments of Biochemistry and Biophysics, †Biology, and ‡Physics, University of Pennsylvania, Philadelphia, Pennsylvania 19104; and ¶Institute for Cancer Research, Philadelphia, Pennsylvania 19111

Communicated by Bruno H. Zimm, September 2, 1980

*Departments of Biochemistry and Biophysics, †Biology, and ‡Physics, University of Pennsylvania, Philadelphia, Pennsylvania 19104; and ¶Institute for Cancer Research, Philadelphia, Pennsylvania 19111

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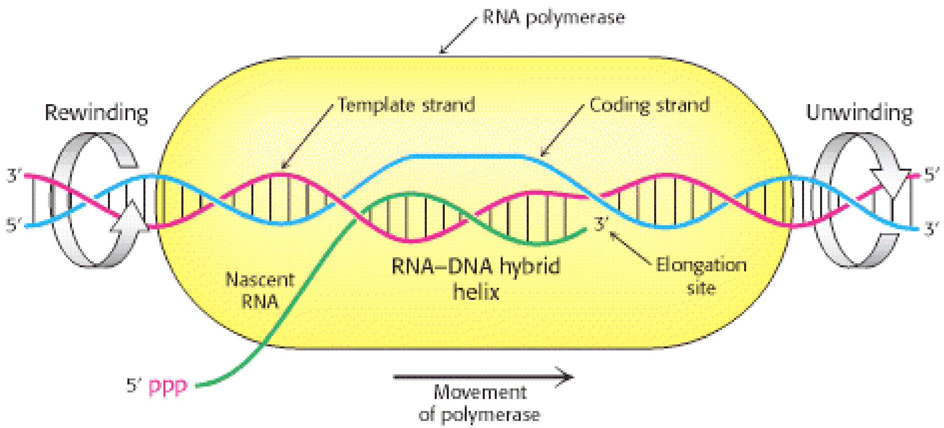


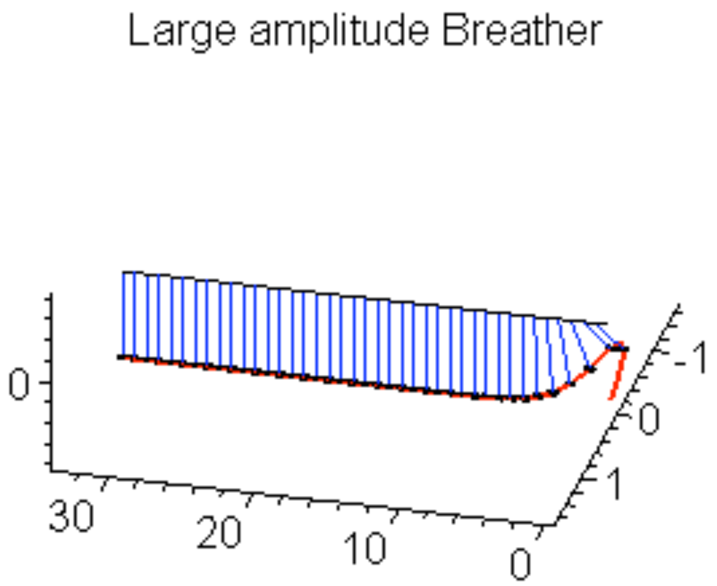
Transcription Bubble. A schematic representation of a transcription bubble in the elongation of an RNA transcript. Duplex DNA is unw ound at the forward end of RNA polymerase and rewound at its rear end. The RNA-DNA hybrid rotates during elongation.

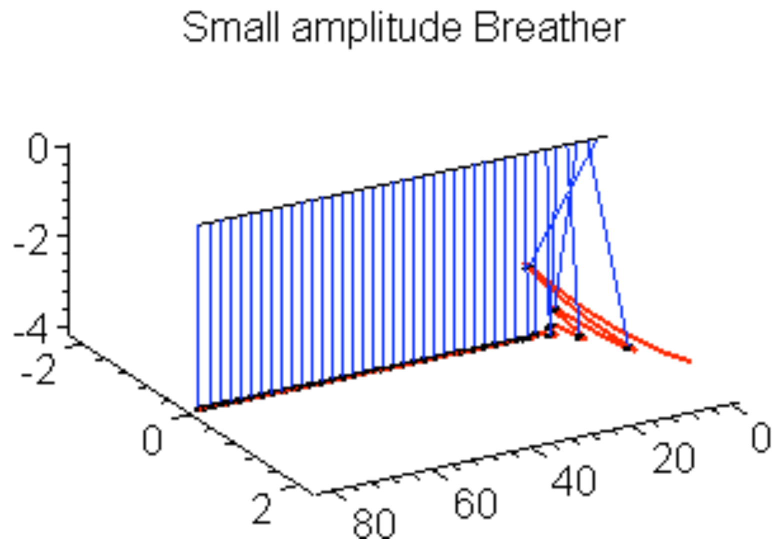
PHYSICAL REVIEW A VOLUME 38, NUMBER 3 AUGUST 1, 1988

Solitons hiding in DNA and their possible significance in RNA transcription

E. W. Prohofsky
Department of Physics, Purdue University, West Lafayette, Indiana 47907
(Received 16 February 1988)

We find that the hydrogen-bond–stretch bands of the double helix appear to be nonlinear enough to support solitary-wave energy concentration. Coupling this fact to predictions of our self-consistent theory of helix melting gives rise to speculations of a mechanism for base pair melting in RNA transcription which is consistent with the known energy needs of that process.





PHYSICAL REVIEW A VOLUME 35, NUMBER 2 JANUARY 15, 1987

Soliton excitations in deoxyribonucleic acid (DNA) double helices

Chun-Ting Zhang

Department of Physics, Tianjin University, Tianjin, the People's Republic of China

(Received 2 September 1986)

Dynamical theory of soliton excitations in deoxyribonucleic acid (DNA) double helices has been studied by a revised Hamiltonian in which the diole-dipole interaction and the dipole–induced-dipole interaction between two bases in a complementary base pair are taken into account in addition to the hydrogen-bond energy. The motion equations of bases are a set of coupled sine-Gordon equations. The soliton solutions of these equations are studied in detail and the results are compared with the experimental data in the H-D exchange masurements of DNA chains.

PHYSICAL REVIEW A VOLUME 40, NUMBER 4 AUGUST 15, 1989

Harmonic and subharmonic resonances of microwave absorption in DNA

Chun-Ting Zhang

Center of Theoretical Physics, Chinese Center of Advanced Science and Technology (World Laboratory) and Department of Physics, Tianjin University, Tianjin, China

(Received 4 November 1988; revised manuscript received 10 April 1989)

We have studied theoretically the movement of large molecular groups of DNA double helices in solution, which are driven by the electromagnetic field. The longitudinal vibration of nucleotides and the torsional movement of bases are taken into account at the same time. A set of coupled nonlinear partial differential equations has been established, and we have solved these equations by the method of perturbation. The result shows that there exists resonant absorption of microwave energy for both longitudinal and torsional modes. The resonant frequencies for the former and the latter are in the region of gigahertz and subterahertz, respectively. In addition to an nth-harmonic resonance at ω_n, our theory also predicts a subharmonic resonance at $\omega_n/2$. The strength of the latter is proportional to l^{-3}, where l is the length of DNA. The necessary conditions to observe these resonances are also discussed.

Journal of Experimental and Theoretical Physics, Vol. 101, No. 2, 2005, pp. 372–379.
From Zhurnal Éksperimental'noi i Teoreticheskoi Fiziki, Vol. 128, No. 2, 2005, pp. 428–437.
Original English Text Copyright © 2005 by Golo.

STATISTICAL, NONLINEAR, AND SOFT MATTER PHYSICS

Three-Wave Interaction between Interstrand Modes of the DNA[¶]

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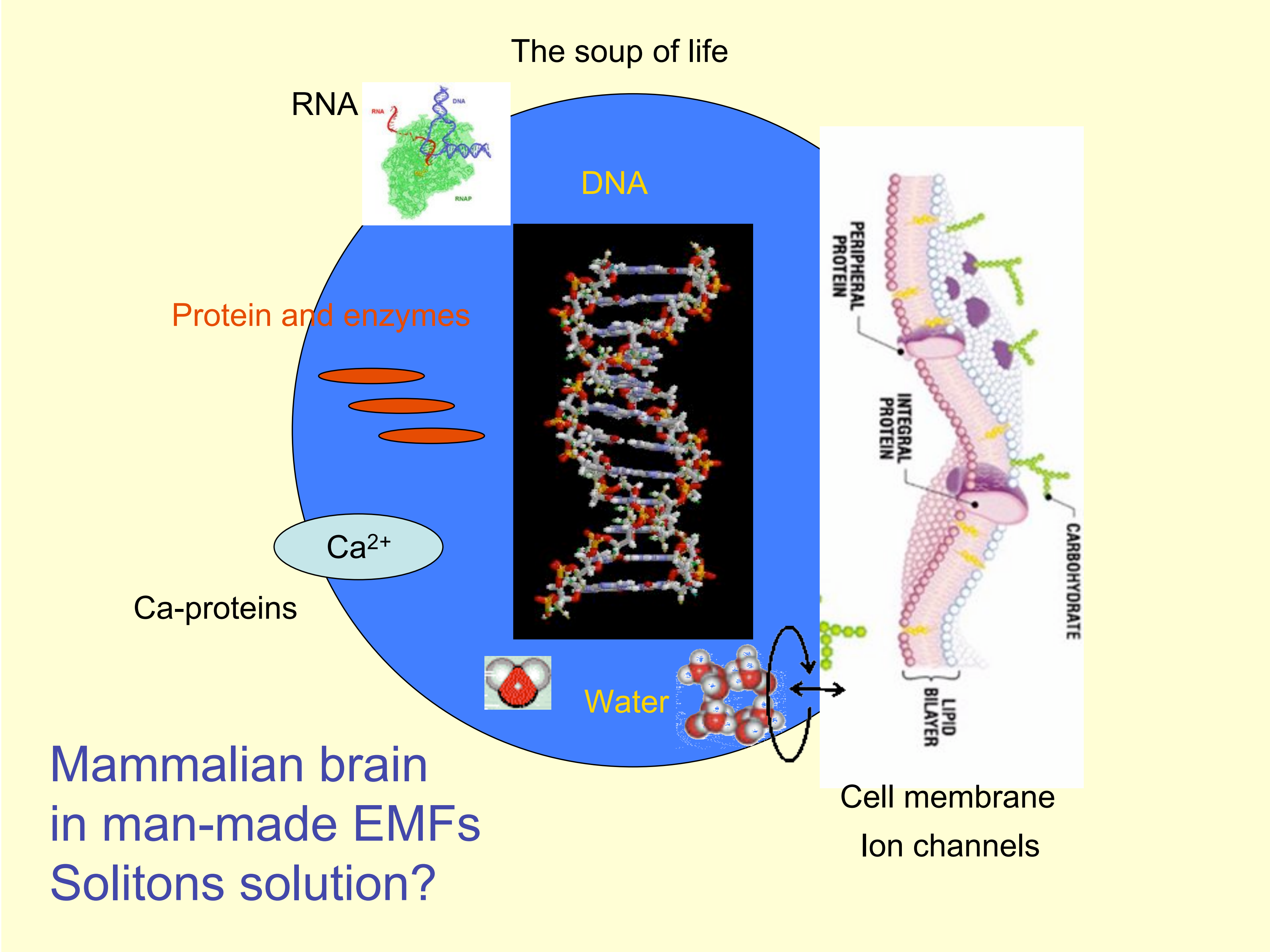
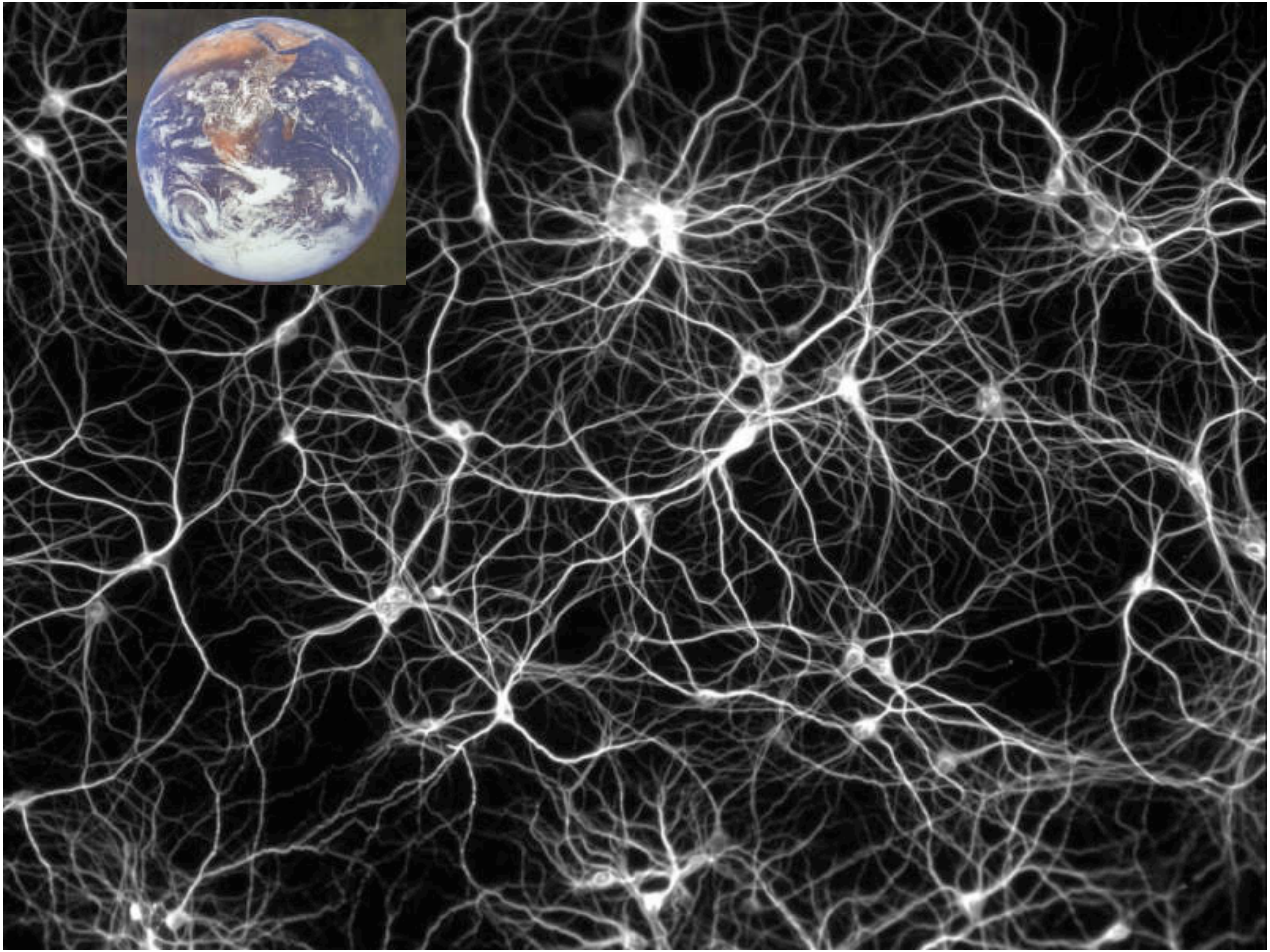
e-mail: golo@mech.math.msu.su

Received February 21, 2005

Abstract—We consider the regime in which the bands of the torsional acoustic (TA) and hydrogen-bond-stretch (HBS) modes of DNA interpenetrate each other. We propose a simple model accommodating the helix structure of DNA and, within its framework, find a three-wave interaction between the TA and HBS modes. The phenomenon could be useful for studying the action of microwave radiation on a DNA molecule. Thus, using Zhang's mechanism of the interaction between the system of electric dipoles of a DNA molecule and microwave radiation, we show that the latter could bring about torsional vibrations that maintaining HBS vibrations. We show an estimate of the microwave power density necessary for generating the HBS mode, which significantly depends on the viscous properties of the ambient medium. © *2005 Pleiades Publishing, Inc.*


The soup of life
RNA
DNA
RNA
RNAP
DNA
Protein and enzymes
Ca2+
Ca-proteins
Water
PERIPHERAL PROTEIN
INTEGRAL PROTEIN
CARBOHYDRATE
LIPID BILAYER
Cell membrane
Ion channels
Mammalian brain
in man-made EMFs
Solitons solution?




Scanned at the American
Institute of Physics
Domo Arigato Masatoshi Murase et al.

ENGLANDER et al. Demonstrated the existence of transiently open states in DNA and synthetic poly-nucleotide double helices by hydrogen exchange measurements; base pairs reversibly separate and reclose, exposing nucleotide protons to exchange with solvent protons.

They considered the possibility that the low energy and slow opening and closing rates observed reflect a deformation involving several adjacent base pairs.

Assuming a mobile open unit capable of diffusing along the double helix, they found that available data are consistent with structures of 10 or so adjacent open pairs. It is further suggested that these structures correspond to thermally induced **soliton** excitations of the double helix, which retain coherence by sharing the energy of a twist deformation among several base pairs.

Solitons are nonlinear excitations that can travel as cohererent solitary waves, and have been recognized as an important mechanism for mediating conformational changes in polymers and condensed systems generally.

Comparison of the double helix with simple mechanical analogs suggests that **soliton excitations** may well exist within DNA chains, and that the hydrogen exchange open state is consistent with these.

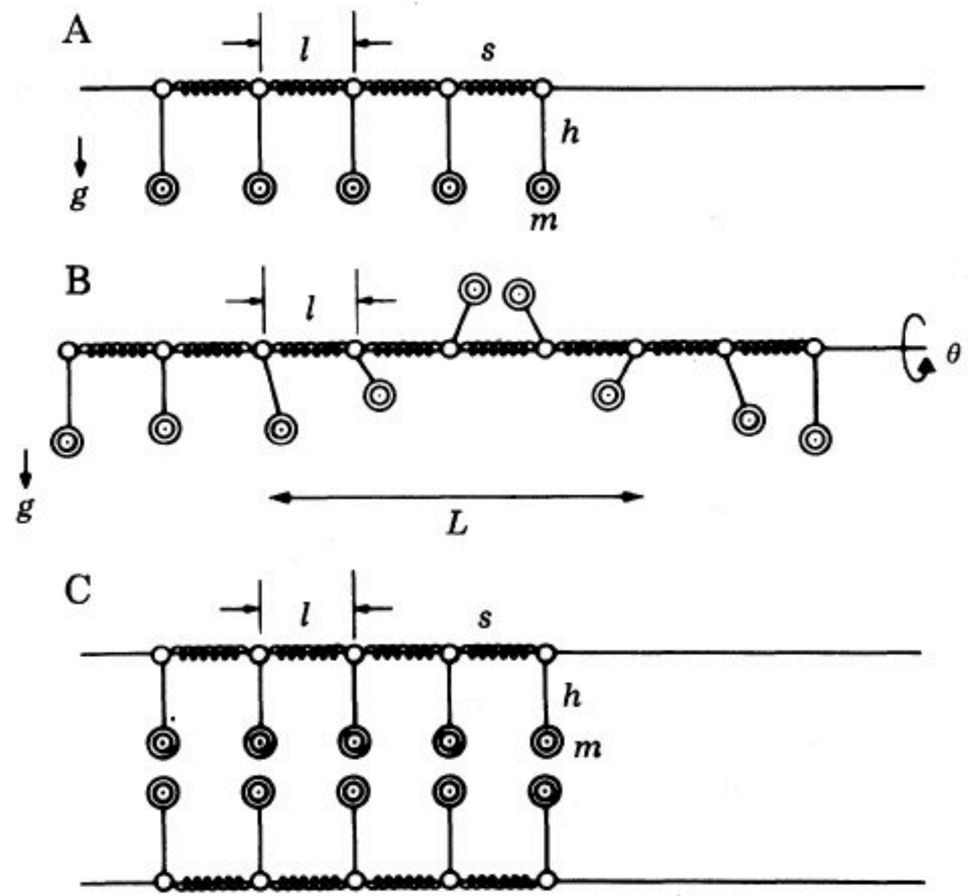


FIG. 3. Mechanical analog of the strands of a double helix possessing soliton excitations. (C) The ground state of the double helix modeled as two linear chains of pendula (the bases) connected by springs (the sugar-phosphate backbones). Each pendulum is of mass m and length h, spaced at $l \approx 3.4$ Å along the helix axis. (A) One strand of the duplex capable of undergoing torsional oscillations (angle θ) about the backbone axis in the presence of a restoring force mg. (B) Soliton excitation mode involving a large-amplitude excursion of one pendulum with spreading of the excitation to a group of L. Note that the system also possesses small-oscillation wave solutions that propagate along the lattice but which damp and do not exhibit nonlinear behavior.

PHYSICAL REVIEW A VOLUME 40, NUMBER 4 AUGUST 15, 1989

Harmonic and subharmonic resonances of microwave absorption in DNA

Chun-Ting Zhang
Center of Theoretical Physics, Chinese Center of Advanced Science and Technology (World Laboratory) and Department of Physics, Tianjin University, Tianjin, China
(Received 4 November 1988; revised manuscript received 10 April 1989)

We have studied theoretically the movement of large molecular groups of DNA double helices in solution, which are driven by the electromagnetic field. The longitudinal vibration of nucleotides and the torsional movement of bases are taken into account at the same time. A set of coupled nonlinear partial differential equations has been established, and we have solved these equations by the method of perturbation. The result shows that there exists resonant absorption of microwave energy for both longitudinal and torsional modes. The resonant frequencies for the former and the latter are in the region of gigahertz and subterahertz, respectively. In addition to an nth-harmonic resonance at ω_n, our theory also predicts a subharmonic resonance at $\omega_n/2$. The strength of the latter is proportional to l^{-3}, where l is the length of DNA. The necessary conditions to observe these resonances are also discussed.

Journal of Experimental and Theoretical Physics, Vol. 101, No. 2, 2005, pp. 372–379.
From Zhurnal Éksperimental'noĭ i Teoreticheskoĭ Fiziki, Vol. 128, No. 2, 2005, pp. 428–435.
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STATISTICAL, NONLINEAR, AND SOFT MATTER PHYSICS

Three-Wave Interaction between Interstrand Modes of the DNA¶

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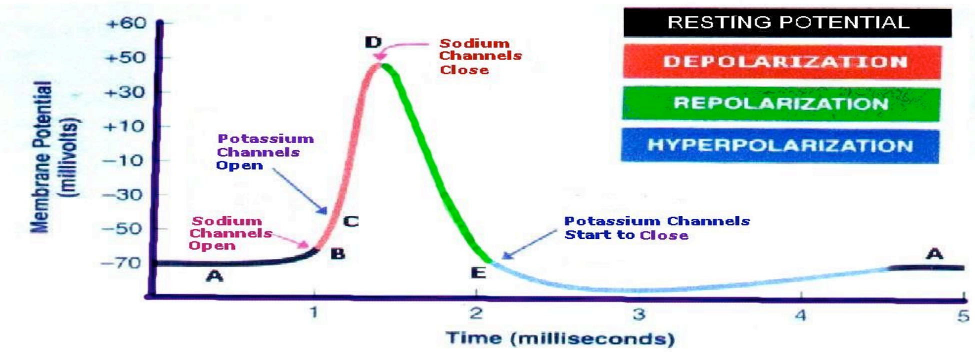
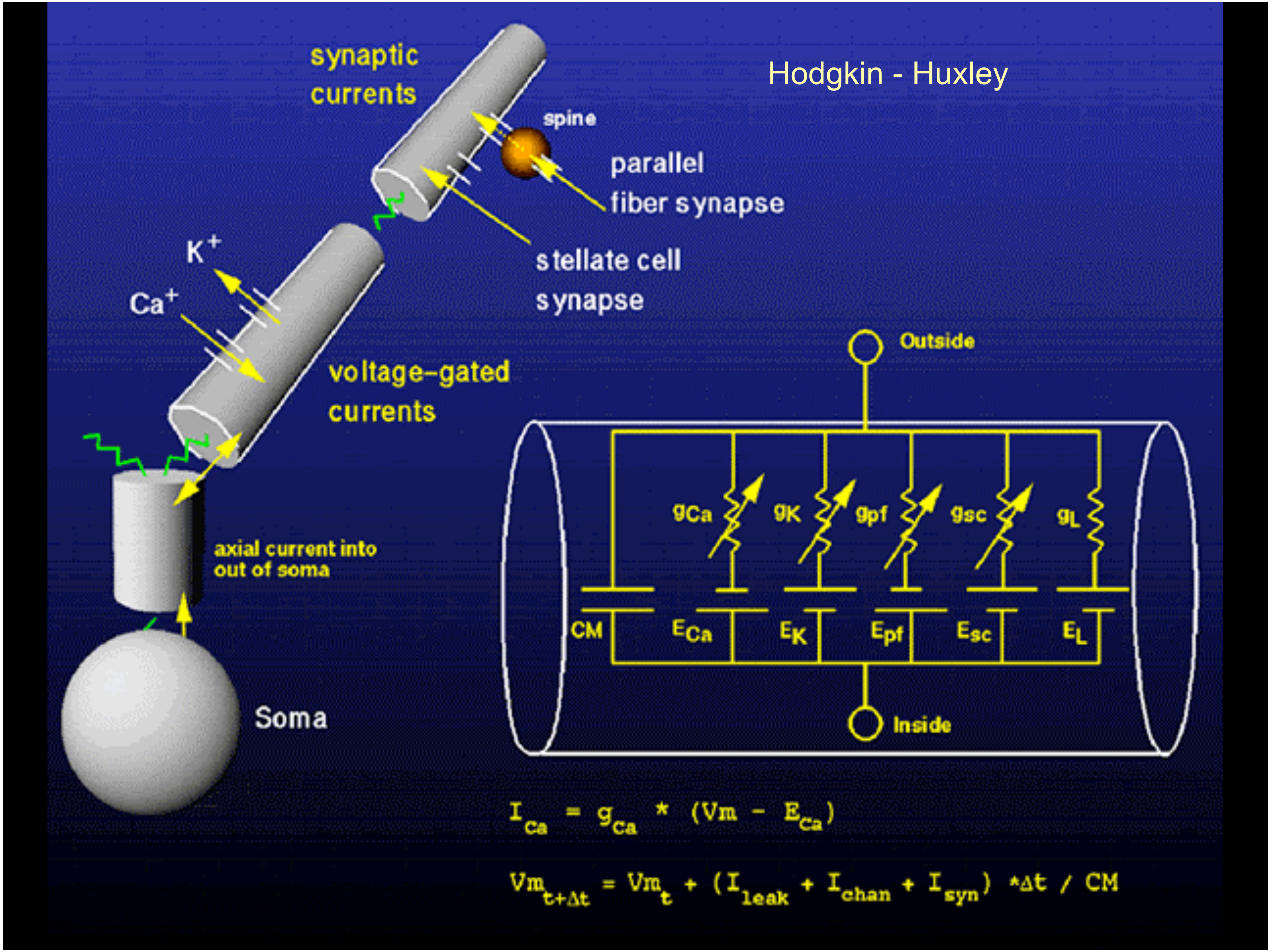
Received February 21, 2005

Abstract—We consider the regime in which the bands of the torsional acoustic (TA) and hydrogen-bond-stretch (HBS) modes of DNA interpenetrate each other. We propose a simple model accommodating the helix structure of DNA and, within its framework, find a three-wave interaction between the TA and HBS modes. The phenomenon could be useful for studying the action of microwave radiation on a DNA molecule. Thus, using Zhang's mechanism of the interaction between the system of electric dipoles of a DNA molecule and microwave radiation, we show that the latter could bring about torsional vibrations that maintaining HBS vibrations. We show an estimate of the microwave power density necessary for generating the HBS mode, which significantly depends on the viscous properties of the ambient medium. © *2005 Pleiades Publishing, Inc.*

Ionic Movements during the Action Potential



Outside: Na+ K+ Cl⁻ **A** -70mv Inside: Na+ K+ Protein⁻	**Resting Membrane Potential** • Na+ concentrated on outside. • K+ concentrated on inside. • Negatively charged proteins found inside the axon only.
Outside: Na+ K+ Cl⁻ **B** -70mv Inside: Na+ K+ Protein⁻	**Depolarization Begins** • Na+ gates open and sodium begins to flow rapidly into the axon along the concentration and electrical gradients. • Negatively charged proteins do not move because they are too large to pass through the axonal membrane.
Outside: Na+ K+ Cl⁻ **C** -40mv Inside: Na+ K+ Protein⁻	**Depolarization Continues** • Na+ continues to flow rapidly into the axon along the concentration and electrical gradients. • K+ gates open and K+ begins to flow slowly out of the axon (along the concentration gradient but against the electrical gradient).
Outside: Na+ K+ Cl⁻ **D** +40mv Inside: Na+ K+ Protein⁻	**Depolarization Peaks** • Na+ channels close and Na+ stops flowing into the axon. • K+ has only just started to leave the axon. • Na+ and K+ are now both briefly concentrated on the inside of the axon resulting in the inside being (briefly) positive relative to the outside of the axon.
Outside: Na+ K+ Cl⁻ **E** -80mv Inside: Na+ K+ Protein⁻	**Hyperpolarization Begins** • Now that the Na+ channels are closed, the Na+ pump forces the Na+ out of the axon, back to where it started. • K+ Channels start to close. Because the positive ions (Na+ and K+) are both concentrated on the outside of the axon, the outside is now more positive than when the axon is at rest. In other words, the inside is more negative than normal. • The K+ pump now begins to pump K+ back into the axon.
Outside: Na+ K+ Cl⁻ **A** -70mv Inside: Na+ K+ Protein⁻	**Axon Returns to the Resting State** • Na+ has been pumped back outside. • K+ has been pumped back inside. • Negatively charged proteins have stayed inside the axon through this entire process.


Hodgkin - Huxley
synaptic currents
spine
parallel fiber synapse
stellate cell synapse
K+
Ca+
voltage-gated currents
axial current into out of soma
Soma
Outside
gCa
gK
gpf
gsc
gL
CM
ECa
EK
Epf
Esc
EL
Inside
$I_{ca} = g_{ca} * (Vm - E_{ca})$
$Vm_{t+\Delta t} = Vm_t + (I_{leak} + I_{chan} + I_{syn}) * \Delta t / CM$

Conduction pathways in microtubules, biological quantum computation, and consciousness
Stuart Hameroff Alex Nip, Mitchell Porter and Jack Tuszynski 2001

The Rausing Laboratory

for Experimental Neurosurgery and Radiation Physics

The microwave research section

Gustav Grafström

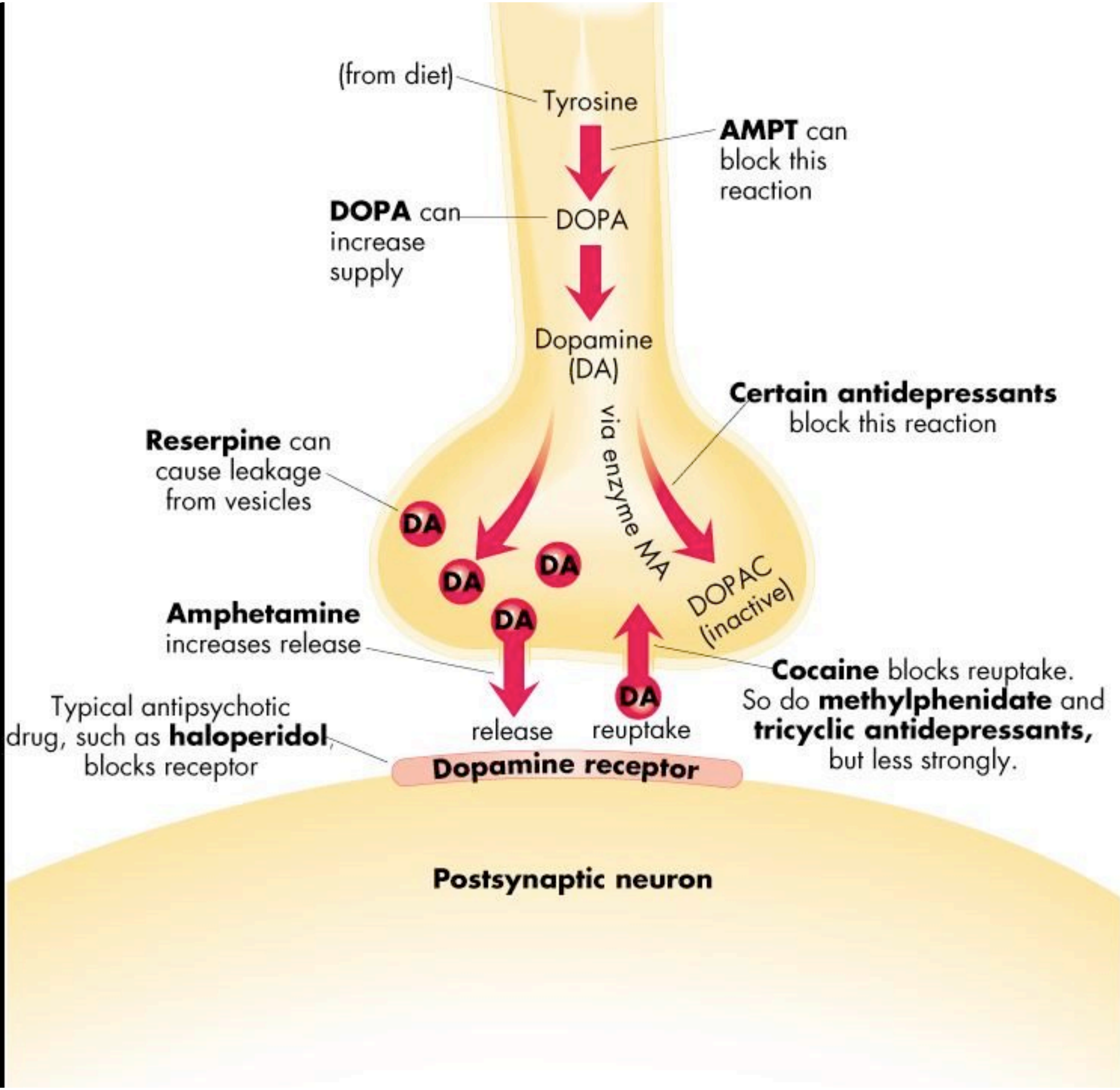
Bertil Persson

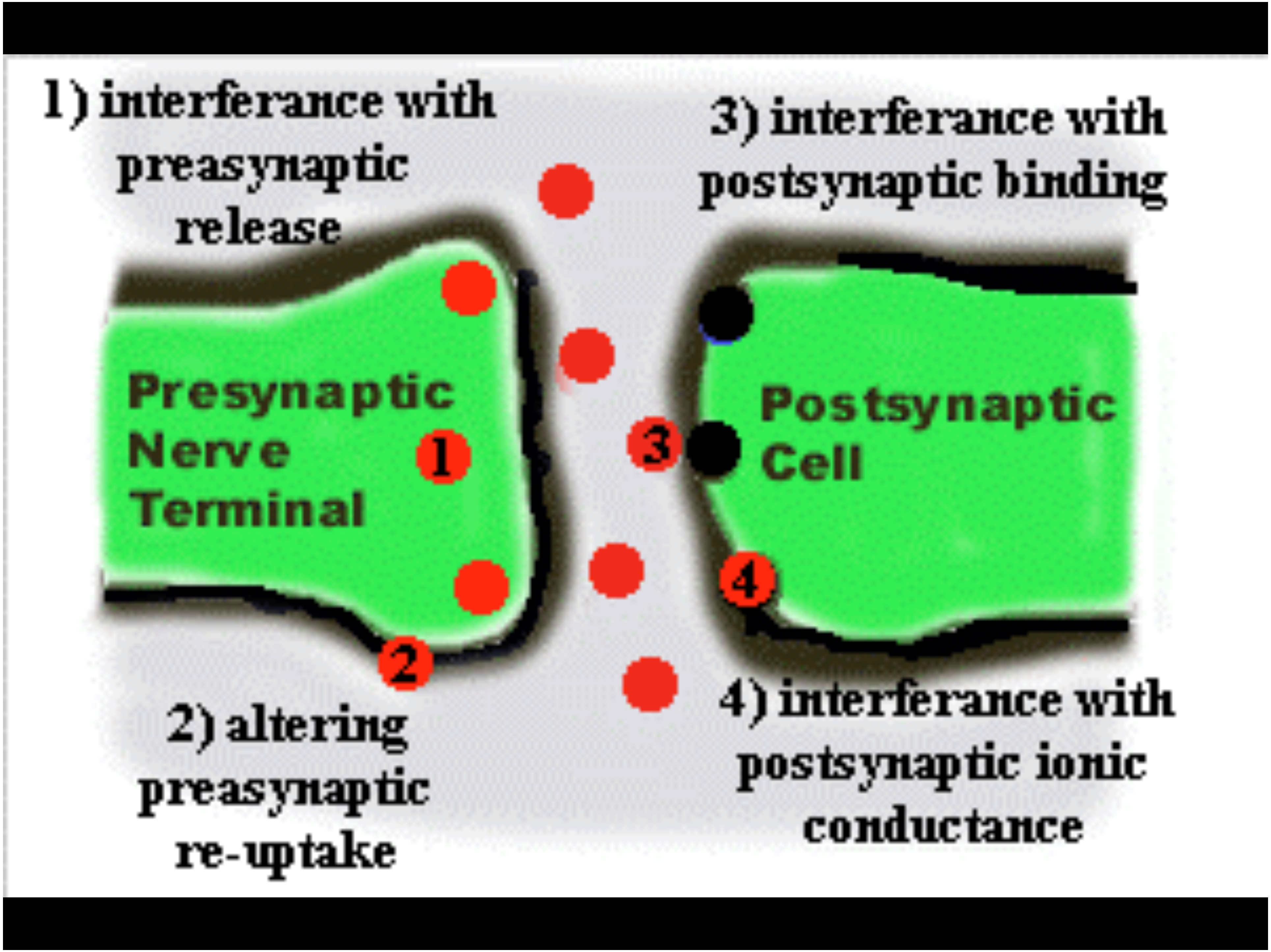
Lars Malmgren

Leif G Salford

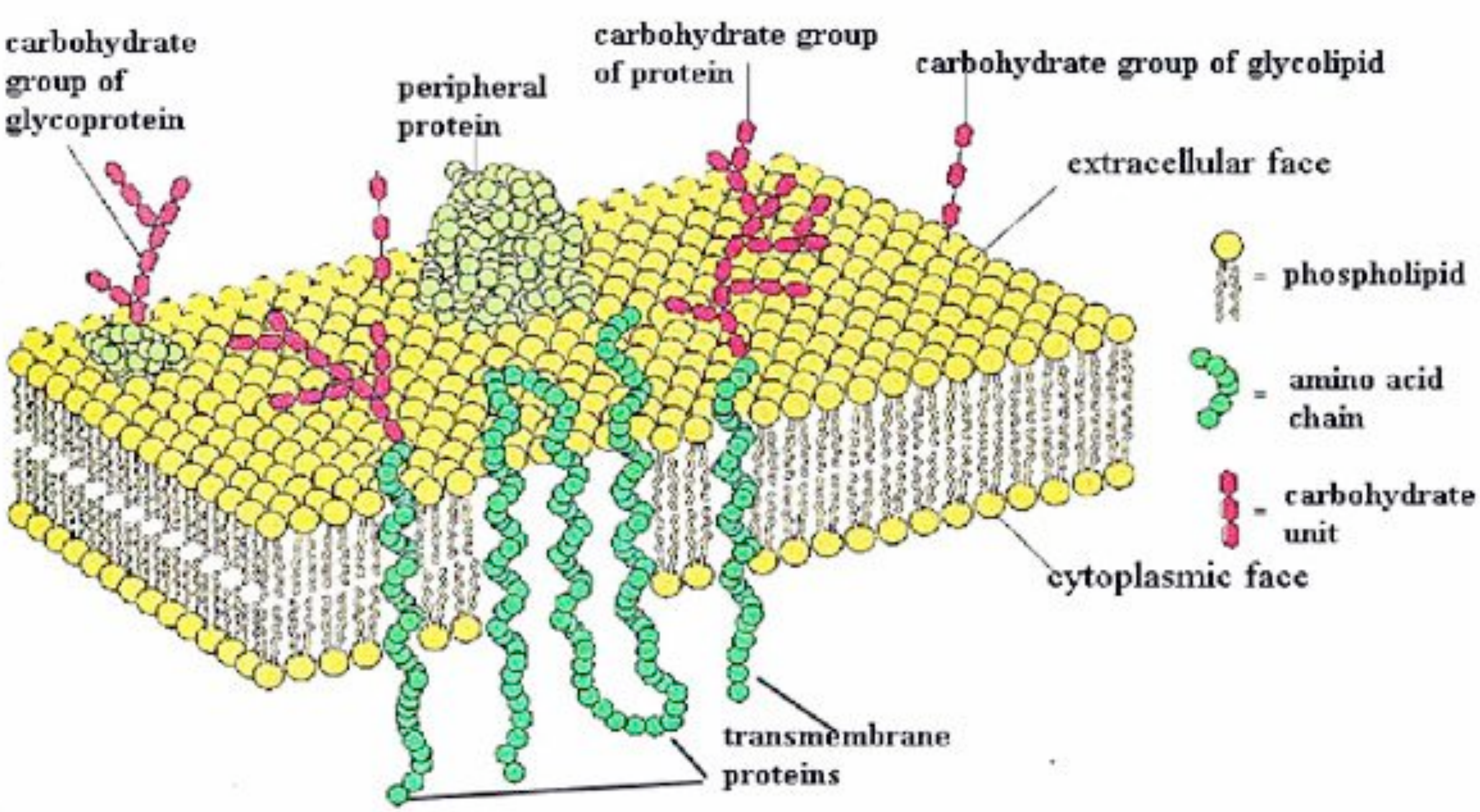
Jacob Eberhardt

Arne Brun


(from diet)
Tyrosine
AMPT can block this reaction
DOPA
DOPA can increase supply
Dopamine (DA)
via enzyme MA
Certain antidepressants block this reaction
Reserpine can cause leakage from vesicles
DA
DA
DA
DA
DOPAC (inactive)
Amphetamine increases release
Cocaine blocks reuptake. So do methylphenidate and tricyclic antidepressants, but less strongly.
DA
Typical antipsychotic drug, such as haloperidol, blocks receptor
release
reuptake
Dopamine receptor
Postsynaptic neuron

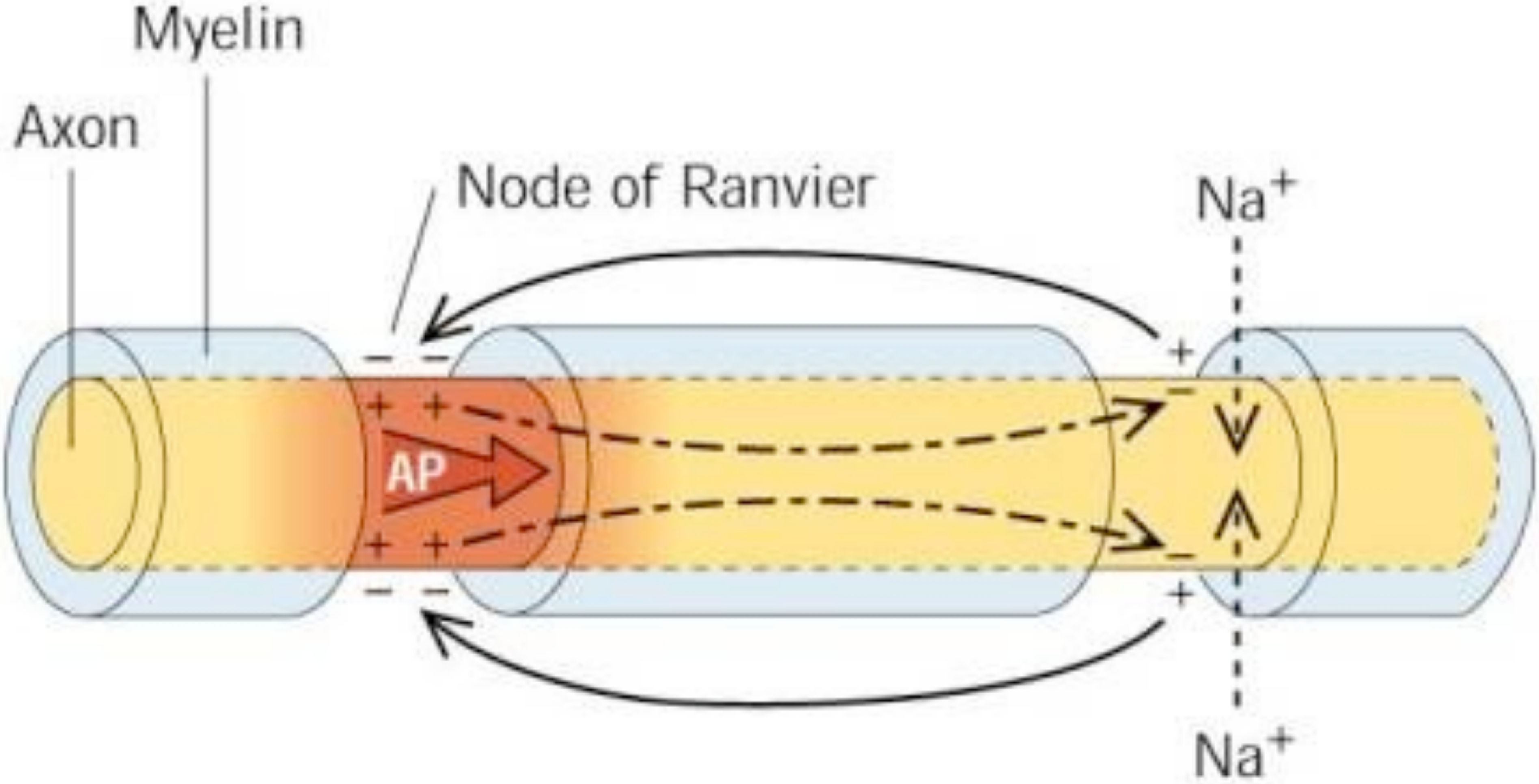


1) interferance with preasynaptic release
3) interferance with postsynaptic binding
Presynaptic Nerve Terminal
1
3
Postsynaptic Cell
4
2
2) altering preasynaptic re-uptake
4) interferance with postsynaptic ionic conductance

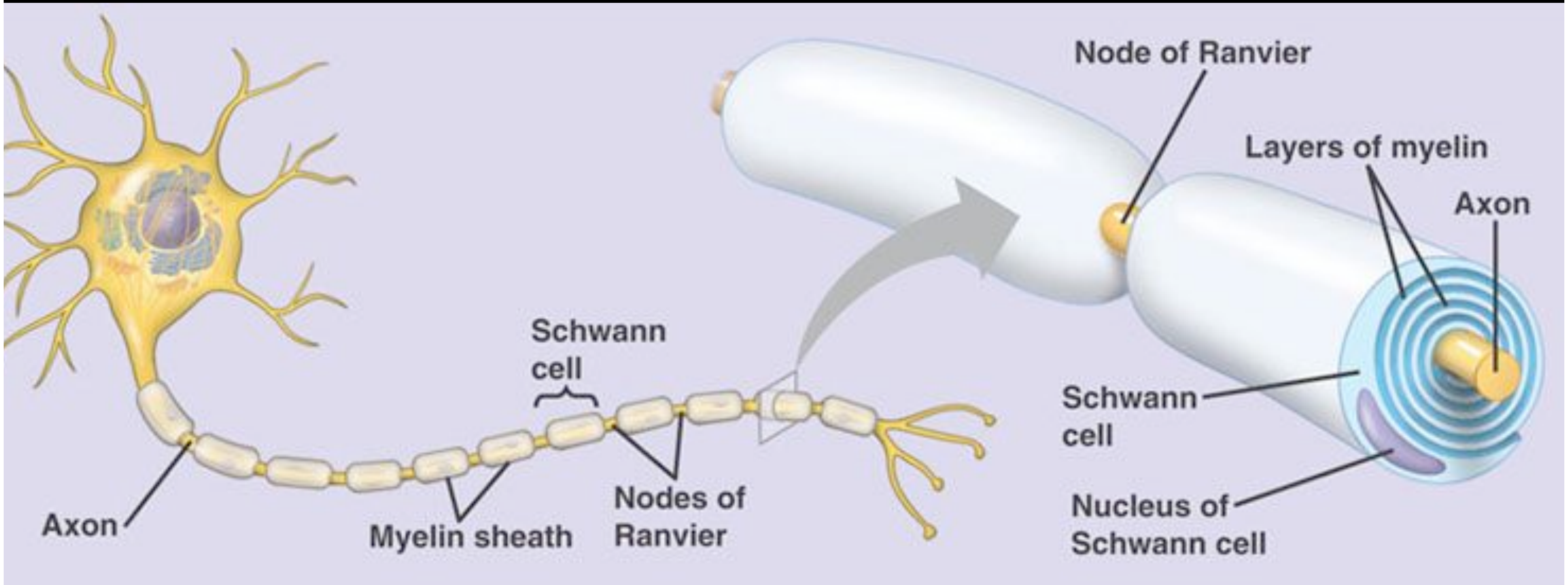


carbohydrate group of glycoprotein
peripheral protein
carbohydrate group of protein
carbohydrate group of glycolipid
extracellular face
= phospholipid
= amino acid chain
= carbohydrate unit
cytoplasmic face
transmembrane proteins

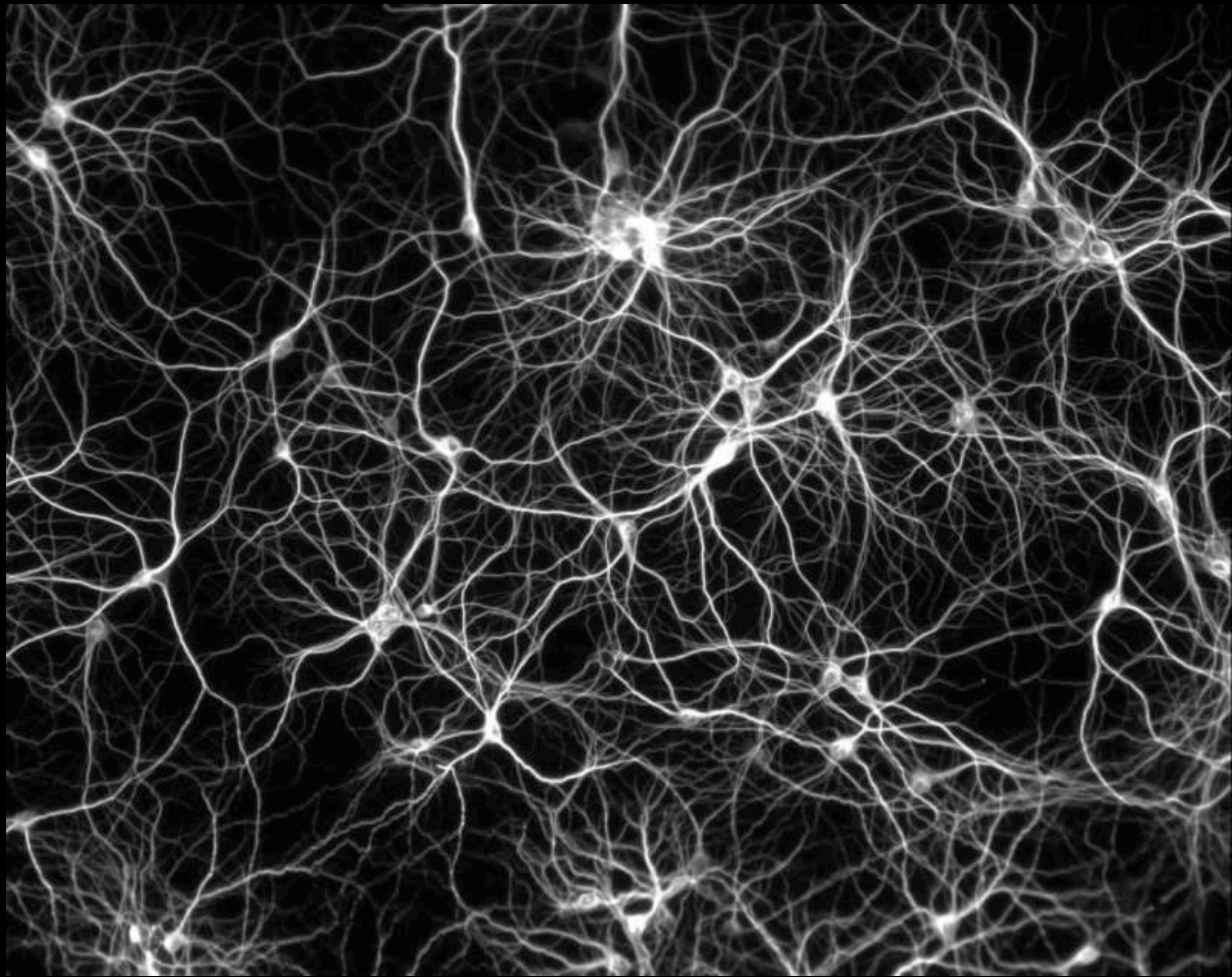
[redacted]

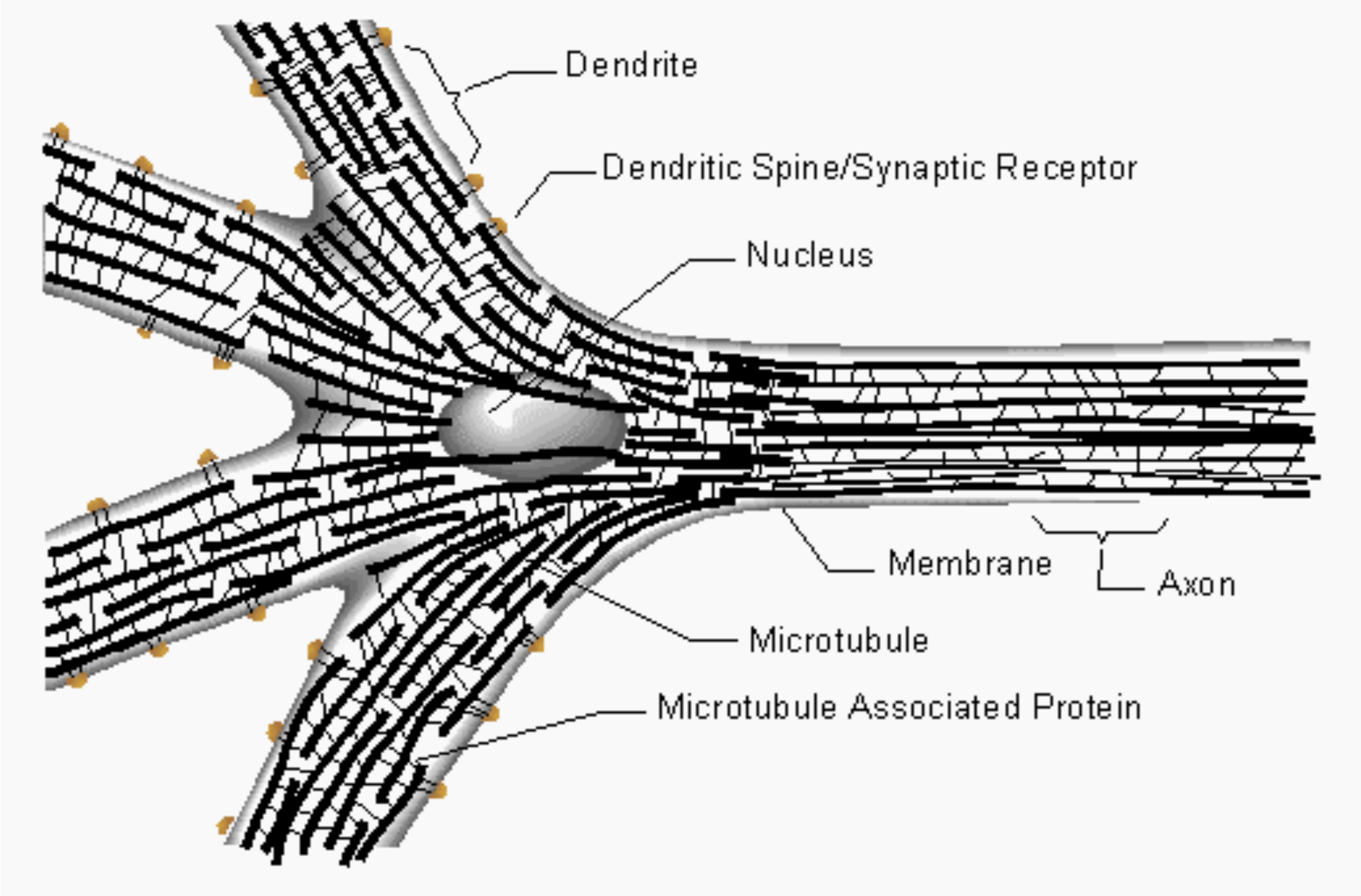


[redacted]



Node of Ranvier
Layers of myelin
Axon
Schwann cell
Schwann cell
Nucleus of Schwann cell
Axon
Myelin sheath
Nodes of Ranvier




Dendrite
Dendritic Spine/Synaptic Receptor
Nucleus
Membrane
Axon
Microtubule
Microtubule Associated Protein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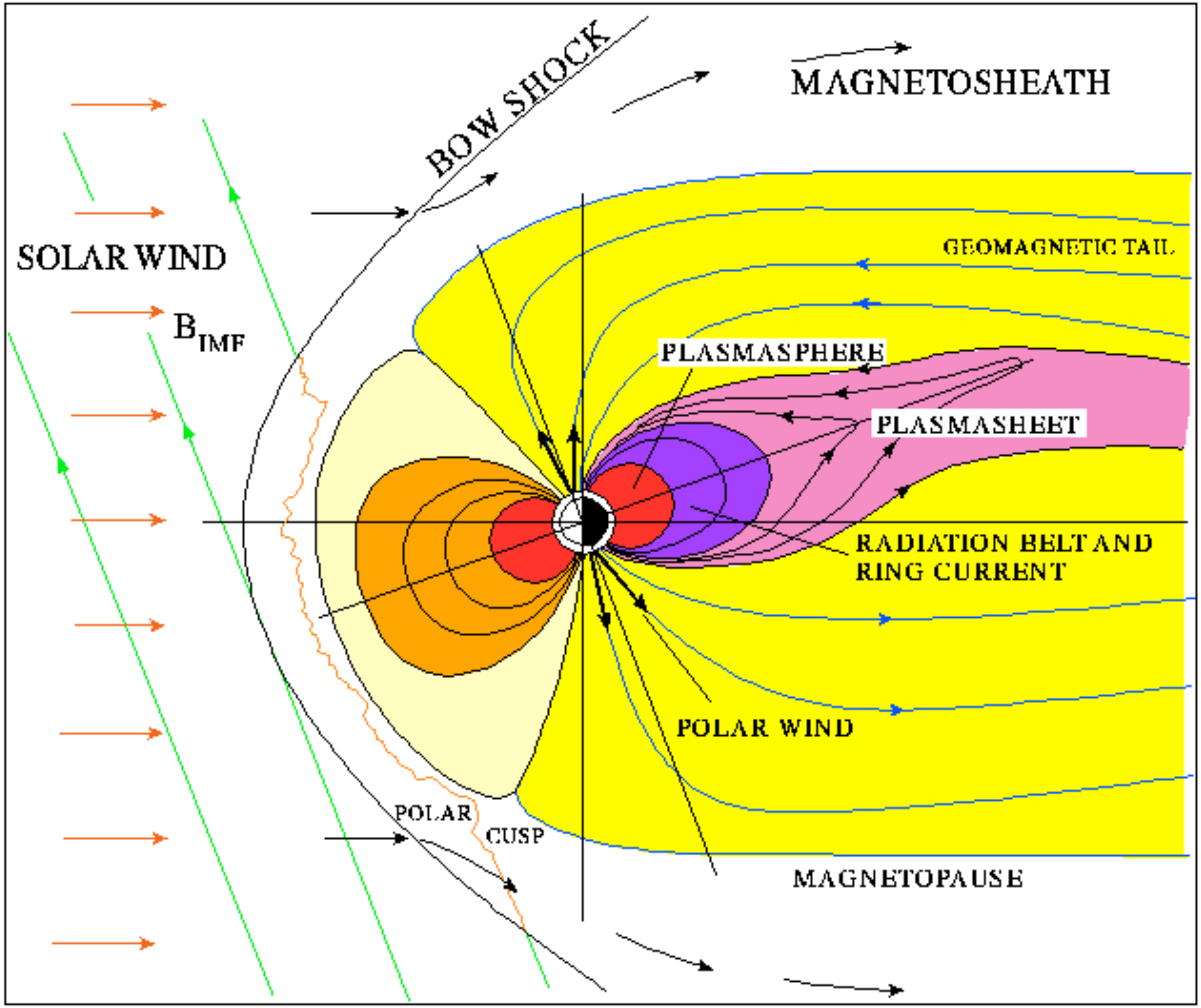
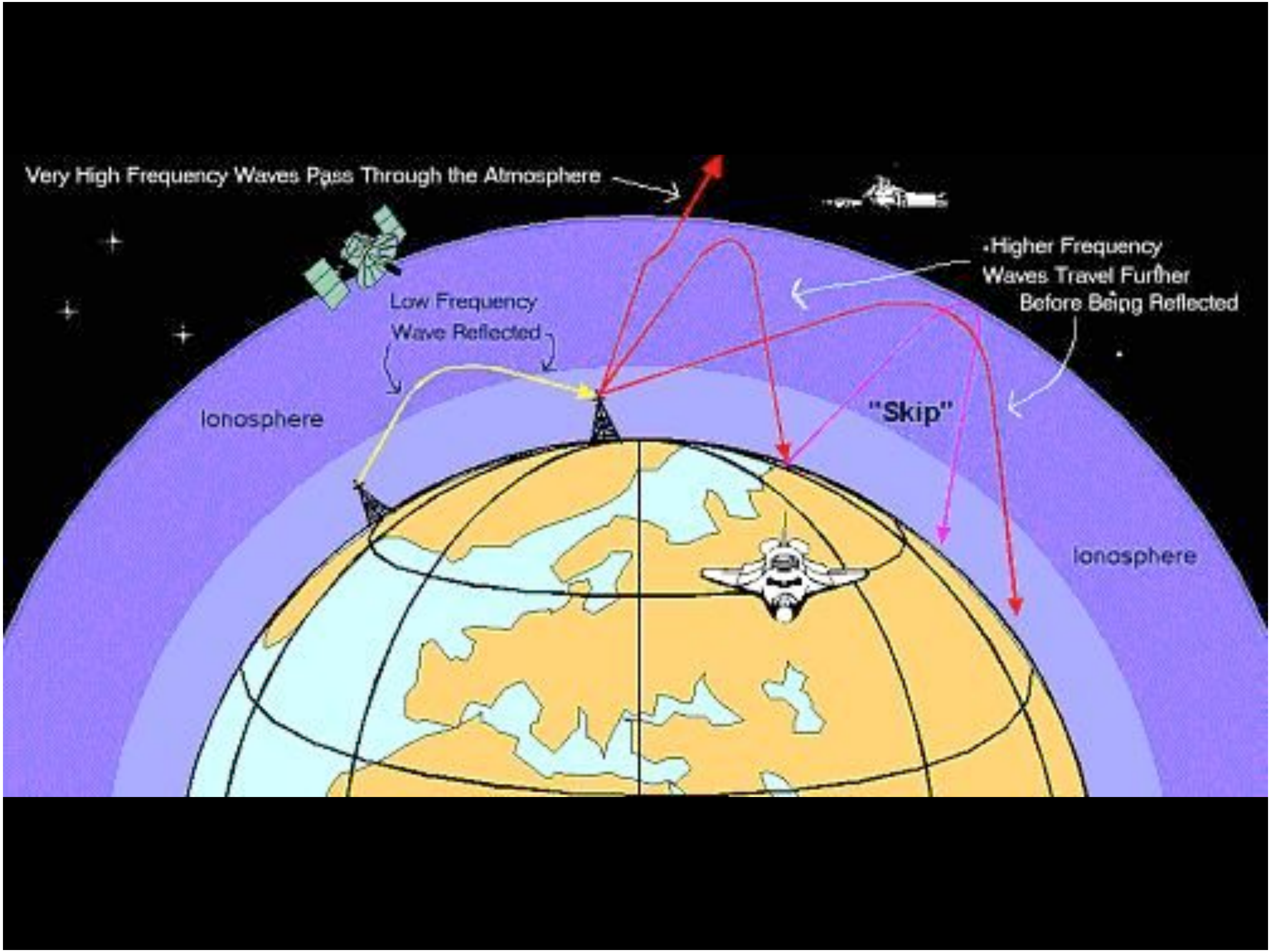
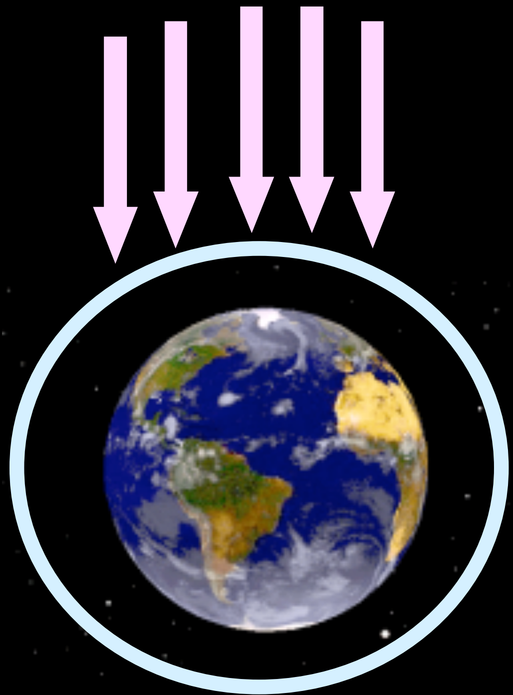
Main sources of electromagnetic fields
Natural sources of electromagnetic fields
Static
Geomagnetic field
Time-varying
Local thunderstorms
Solar storms
Human-made sources of electromagnetic fields
Static
Static-electric and magnetic fields
Time-varying
Extremely low-frequency electric and magnetic fields
Radio waves
Microwaves
Infra-red
Visible spectrum
Ultra violet radiation (ionizing radiations)
X-rays (ionizing radiations)
Gamma rays (ionizing radiations)
Time-varying complex
Weak complex magnetic fields
Complex neuroelectromagnetic pulse (Cnp)
Ultra Wideband Electromagnetic Pulses (UWB)


BOW SHOCK
MAGNETOSHEATH
SOLAR WIND
B_{IMF}
GEOMAGNETIC TAIL
PLASMASPHERE
PLASMASHEET
RADIATION BELT AND
RING CURRENT
POLAR WIND
POLAR
CUSP
MAGNETOPAUSE


Very High Frequency Waves Pass Through the Atmosphere
Higher Frequency
Waves Travel Further
Before Being Reflected
Low Frequency
Wave Reflected
Ionosphere
"Skip"
Ionosphere

Extremely Low Frequency EMF

Volta: the electric battery 1800

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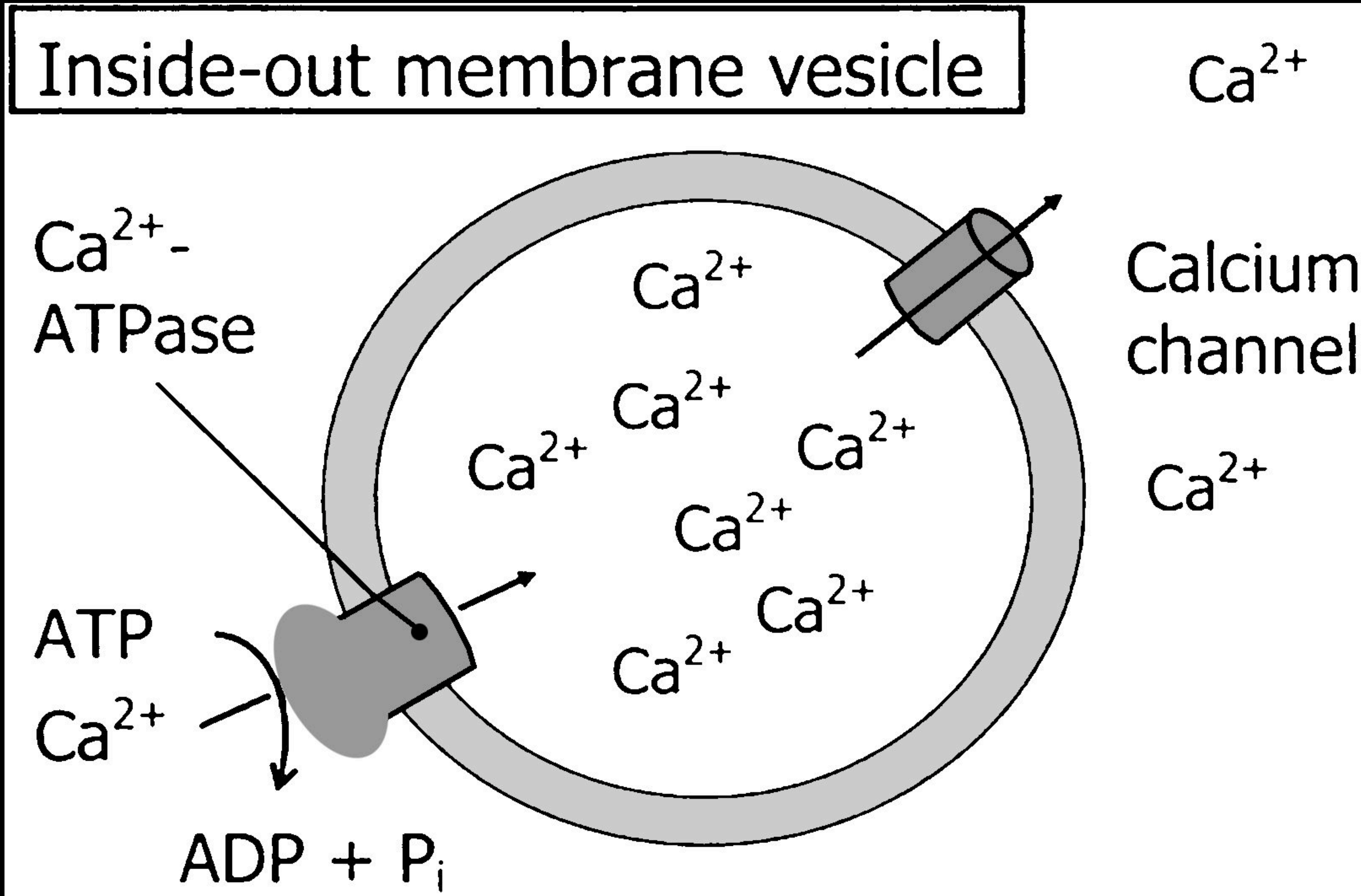
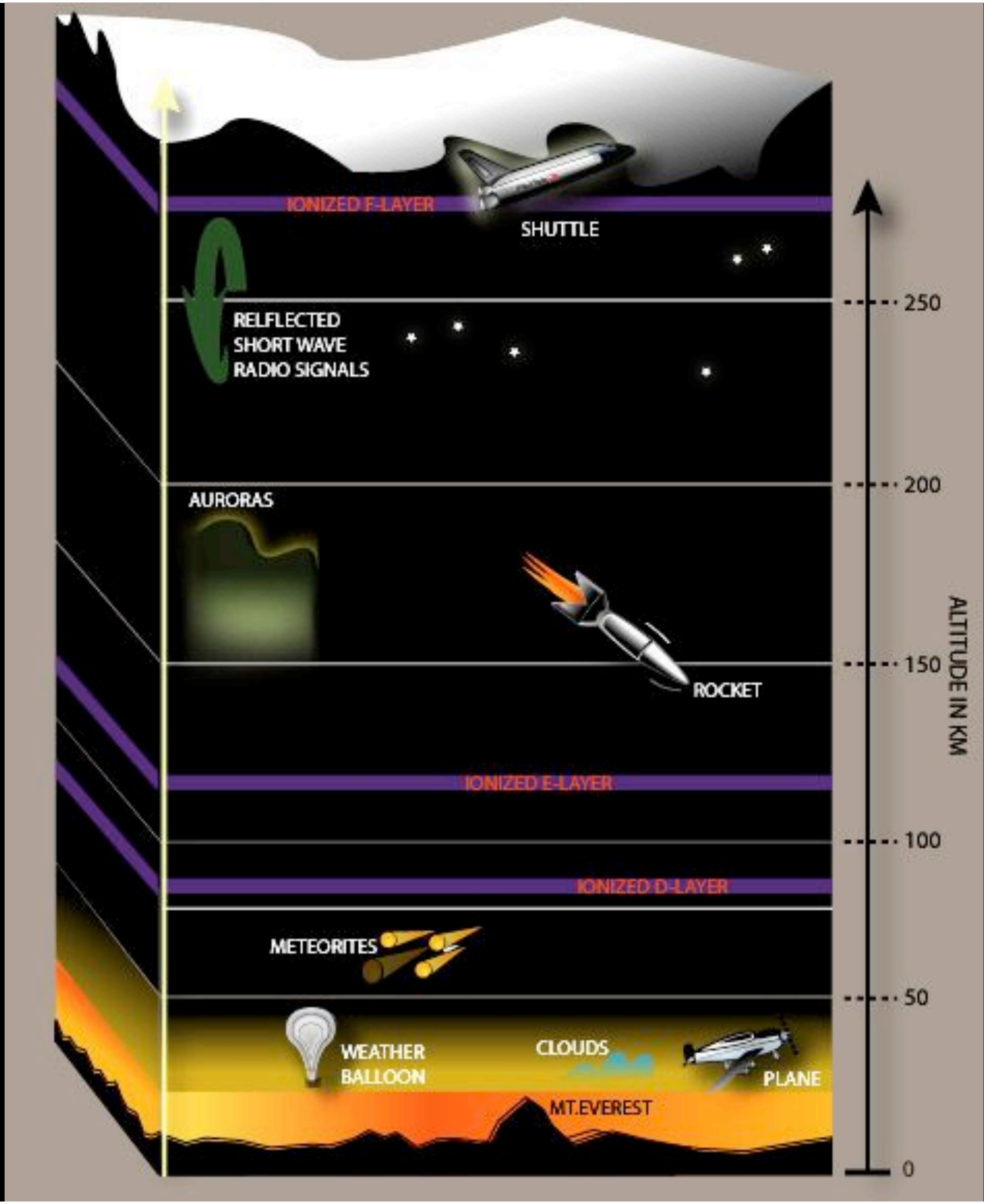
Volpe
The divergences encountered in the literature with respect to the MF-dependence of given biological structures and functions are due not only to the differences of equipment facilities or experimental accuracy, but rather to the intrinsic adequacy of proposed methodological approaches. In addition, there is still a largely recognized lack of theoretical analysis to explain the mechanisms which underlie the interactions between the MFs and the various cellular targets.

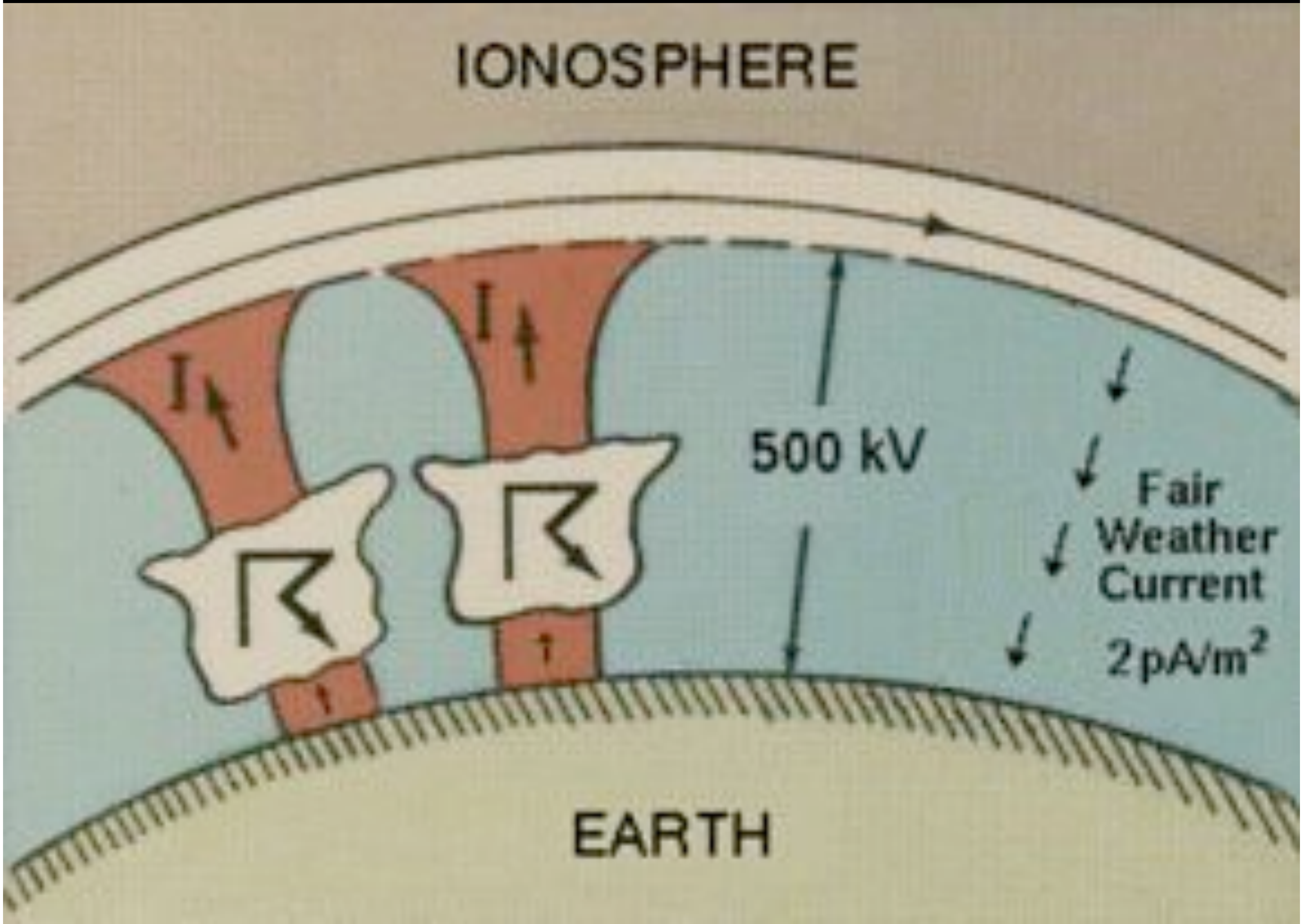
Efter Egna studierna:
Mekanismerna
Egna vesicle forsök
Calcium
Solitonerna DNA enl Xhang och Zvicord
Solitonerna i nervmembran enl Niels Bohr inst.
Overton
Sannolikheten för solitoner kanske bevisas av snigelförsöken (London Ontario) smärta opiater anestesi etc
Kanske mekanismen?
Det fortsatta sökandet efter sanningen

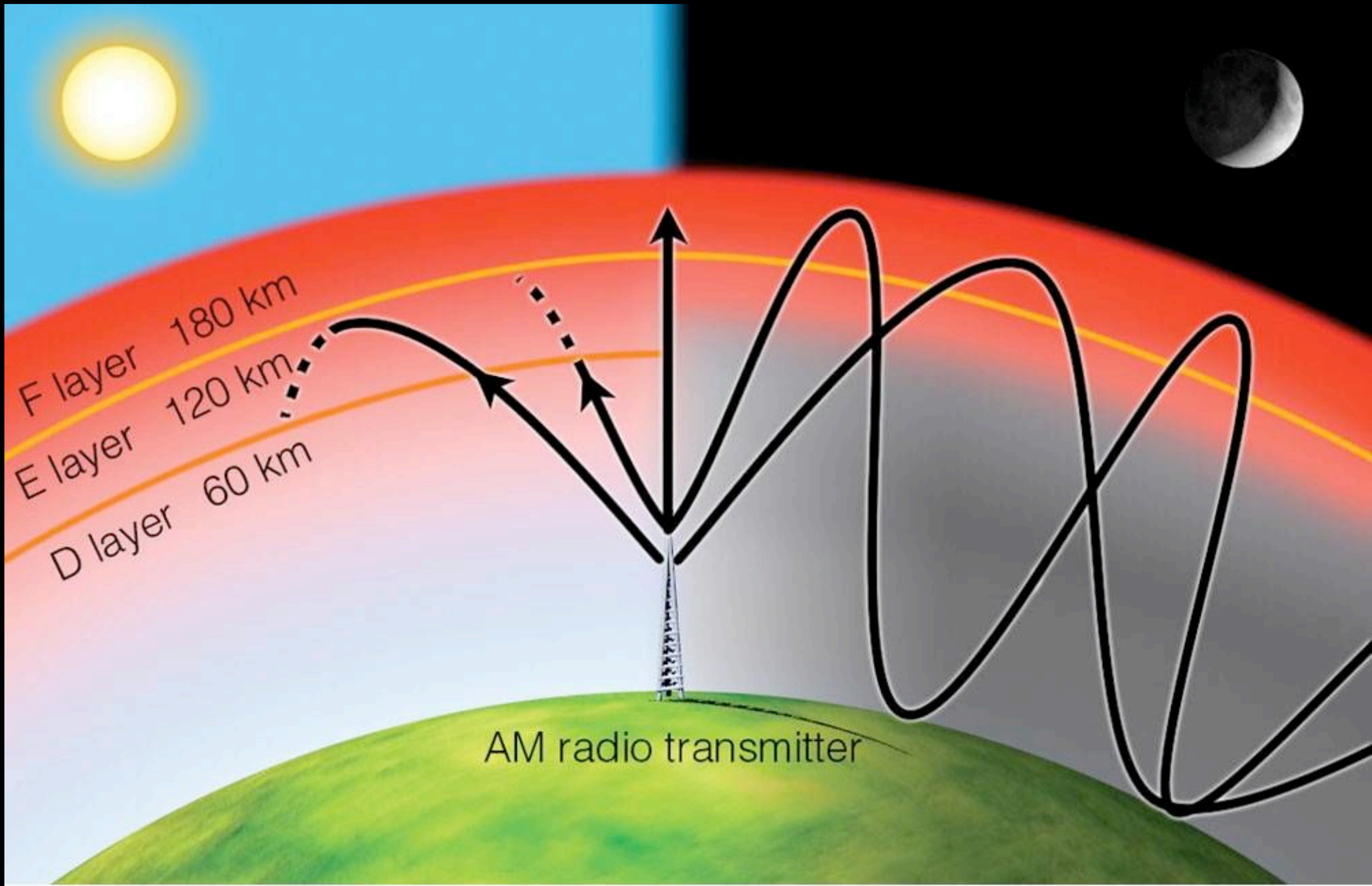

Inside-out membrane vesicle
Ca2+
Ca2+-
ATPase
Ca2+
Calcium
channel
Ca2+
Ca2+
Ca2+
Ca2+
Ca2+
Ca2+
Ca2+
ATP
Ca2+
ADP + Pi

Cepaea nemoralis



IONIZED F-LAYER
SHUTTLE
RELFLECTED
SHORT WAVE
RADIO SIGNALS
AURORAS
ROCKET
IONIZED E-LAYER
IONIZED D-LAYER
METEORITES
WEATHER
BALLOON
CLOUDS
PLANE
MT.EVEREST
250
200
150
100
50
0
ALTITUDE IN KM


IONOSPHERE
I
I
500 kV
Fair
Weather
Current
2 pA/m²
EARTH



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Results neuropathology

- Very little albumin leakage, no difference between exposed, sham exposed and cage controls.
- Dark neurons were found but no statistical differences between exposure conditions could be detected.

Possible hypotheses for non-thermal effects according to the Lund group:

*Quantum mechanical model for interaction with protein-bound ions. Ref: the Lund group: Bauréus K et al: Bioelectromagnetics 24:395-402 2003

*Microwaves have effect directly on the protein-conformation (vibration energy levels) Ref: de Pomerai et al FEBS Letters 543:93-97, 2003

*Interaction microwaves –> water molecules bound in biologically active molecules

*Autooxidative processes which lead to oxidation in the cells Ref: Ilhan et al Clin Chim Acta 340:153-162, 2004

Top separating categories continued, CORTEX

dopamine biosynthesis e-9
receptor activity e-9
surface receptor linked signal transduct. e-9
alpha-type channel activity e-8
channel or pore class transporter act e-8
signal transduction e-8
organismal physiological process e-8
voltage-gated ion channel activity e-8
regulation of dopamine metabolism e-8
extracellular space e-8
behaviour e-8
ion channel activity e-8
metal ion transport e-7
G-protein coupled receptor activity e-7
plus 14 more with p-values e-7 and e-6
all highly significant

© Salford et al

Top separating categories cont., HIPPOCAMPI

neurotransmitter receptor activity e-8

cell surface receptor linked sign. transd e-8

peptide binding e-8

peptide receptor activity G-prot coupl. e-8

extracellular matrix e-8

extracellular matrix (sensu Metazoa) e-7

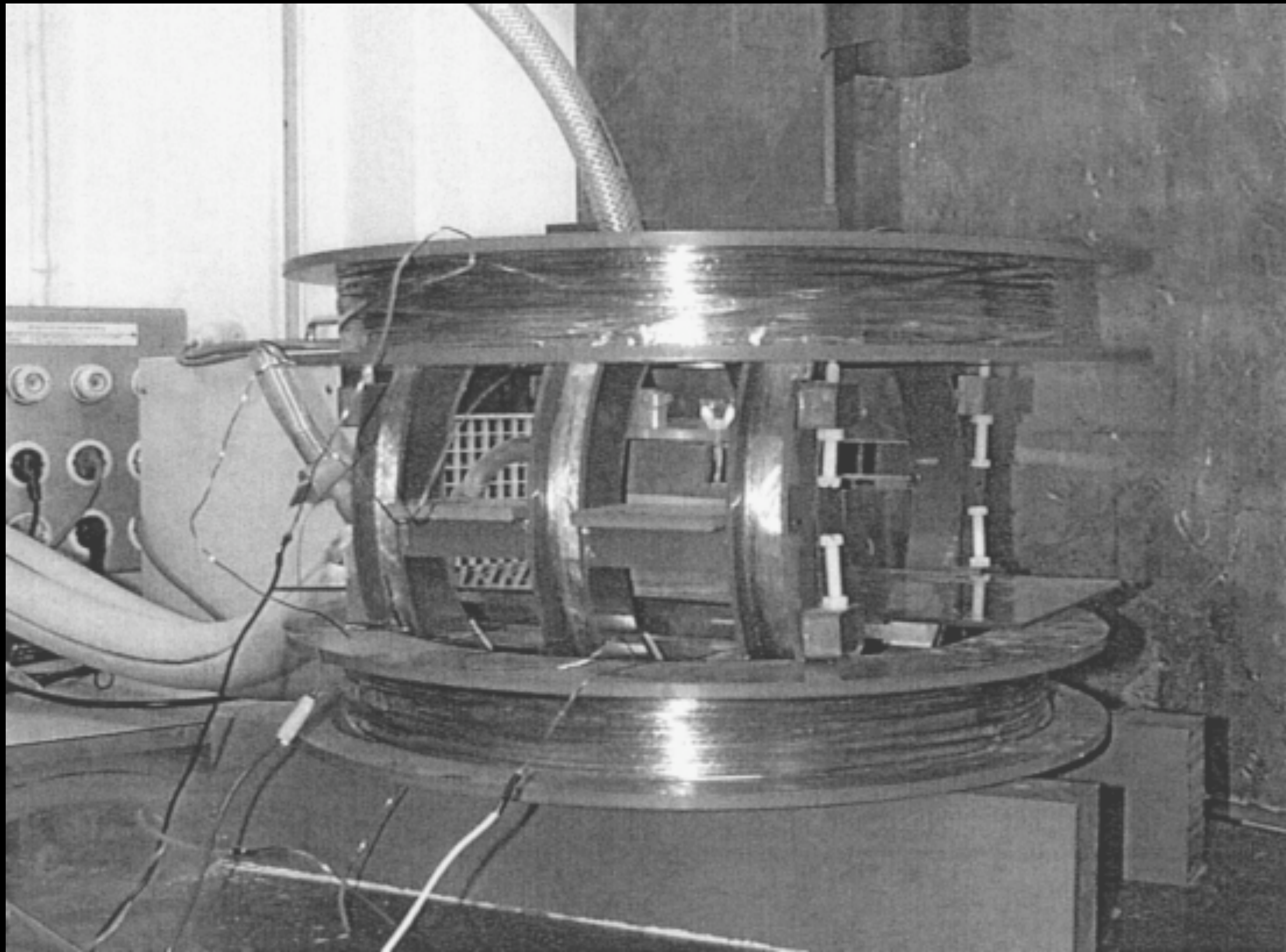
plus 7 more with p-values e-7 and e-6 highly significant

© Salford et al

Gene response to 914.8 MHz GSM,
of importance for BBB function

Affymetrix Probeset	Fold change	Gene symbol	Gene name	Function
BBB function				
M96601_at	1.56 ± 0.23	Slc6a6	Solute carrier family 6, member 6	Taurine transporter. Predominantly glial expression.
rc_AA800851_s_at	1.34 ± 0.20	Ces3	Carboxylesterase 3	Expressed in endothelial cells of the brain.

Belyaev I. et.al. Bioelectromagnetics 2006



Lund University

The largest university
In Scandinavia
45.000 students

Resonant Microwave Absorption of Selected DNA Molecules

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Chemical Physics Program and Electrical Engineering Department, University of Maryland, College Park, Maryland 20742

and

J. D. Saffer
Laboratory of Biochemistry, National Cancer Institute, National Institutes of Health, Bethesda, Maryland 20205

and

M. L. Swicord
Center for Devices and Radiological Health, Food and Drug Administration, Rockville, Maryland 20857
(Received 5 July 1984)

The resonant absorption of microwave energy by aqueous solutions containing DNA of known length is experimentally demonstrated. The resonances observed have relaxation times of hundreds of picoseconds. Absorption by linear and supercoiled circular DNA molecules is discussed in terms of a mechanism involving microwave excitation of acoustic modes of the double helix.

S. W. ENGLANDER; N,. R. KALLENBACH,; **A.** J. HEEGERJ.; , **A .** KRUMHANSL,; S. LIT WIN

Nature of the open state in long polynucleotide double helices: Possibility of soliton excitations

Proc. Natl. Acad. Sci. USA Vol. *77,* No. 12, pp. 7222-7226, December 1980 Biophysics

ABSTRACT The existence of transiently open states in DNA and synthetic poly-nucleotide double helices has been demonstrated by hydrogen exchange measurements ; base pairs reversibly separate and reclose, exposing nucleotide protons to exchange with solvent protons. Recently it has been possible to define the equilibrium , kinetic, and activation parameters of the major open state that determines base pair hydrogen exchange. However , there is no direct information at the moment about the conformation of the open form. Here we consider the possibility that the low energy and slow opening and closing rates observed reflect a deformation involving several adjacent base pairs. Assuming a mobile open unit capable of diffusing along the double helix, we find that available data are consistent with structures of 10 or so adjacent open pairs. It is further suggested that these structures correspond to thermally induced **soliton** excitations of the double helix, which retain coherence by sharing the energy of a twist deformation among several base airs.

Solitons are nonlinear excitations that can travel as cohererent solitary waves, and have been recognized as an important mechanism for mediating conformational changes in polymers and condensed systems generally . Comparison of the double helix with simple mechanical analogs suggests that **soliton excitations** may well exist within DNA chains , and the present analysis shows that the hydrogen exchange open state is consistent with these.

PHYSICAL REVIEW A VOLUME 38, NUMBER 3 AUGUST 1, 1988

Solitons hiding in DNA and their possible significance in RNA transcription

E. W. Prohofsky
Department of Physics, Purdue University, West Lafayette, Indiana 47907
(Received 16 February 1988)

We find that the hydrogen-bond–stretch bands of the double helix appear to be nonlinear enough to support solitary-wave energy concentration. Coupling this fact to predictions of our self-consistent theory of helix melting gives rise to speculations of a mechanism for base pair melting in RNA transcription which is consistent with the known energy needs of that process.

PHYSICAL REVIEW A VOLUME 35, NUMBER 2 JANUARY 15, 1987

Soliton excitations in deoxyribonucleic acid (DNA) double helices

Chun-Ting Zhang

Department of Physics, Tianjin University, Tianjin, the People's Republic of China

(Received 2 September 1986)

Dynamical theory of soliton excitations in deoxyribonucleic acid (DNA) double helices has been studied by a revised Hamiltonian in which the diole-dipole interaction and the dipole–induced-dipole interaction between two bases in a complementary base pair are taken into account in addition to the hydrogen-bond energy. The motion equations of bases are a set of coupled sine-Gordon equations. The soliton solutions of these equations ure studied in detail and the results are compared with the experimental data in the H-D exchange masurements of DNA chains.

PHYSICAL REVIEW A VOLUME 27, NUMBER 4 APRIL 1983

Soliton excitations in deoxyribonucleic acid (DNA) double helices

S. Yomosa

Department of Physics, Nagoya University, Nagoya 464, Japan

(Received 15 December 1982)

We present in this paper a soliton theory for the open states in deoxyribonucleic acid (DNA) and synthetic polynucleotide double helices. Kink and antikink solutions for the equation of motion of the sine-Gordon form correspond to the open states with positive and negative helicities. The energy of open form and the length of the open configuration which are theoretically estimated are in the same order with the values inferred from kinetic experimental data.