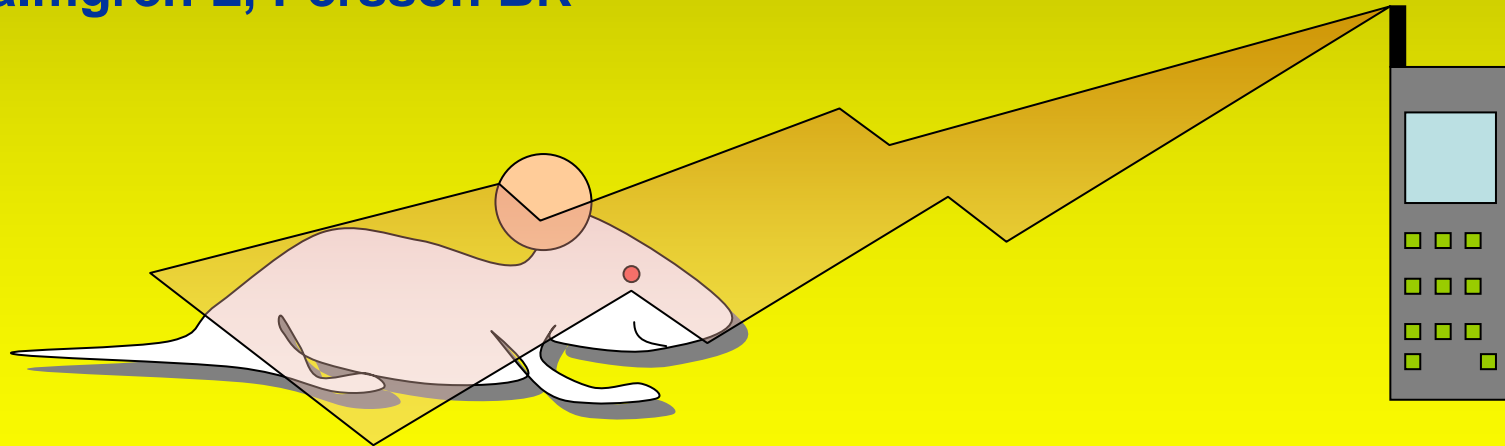


# Evidence for effects of non-thermal RF-electromagnetic fields upon the mammalian brain

**Professor Leif G. Salford**

**Dept. of Neurosurgery, Lund University, Sweden  
and the EMF research group, the Rausing Laboratory:  
Brun A, Eberhardt J, Grafström G, Nittby H,  
Malmgren L, Persson BR**



FONDATION

2<sup>èmes</sup> Rencontres Scientifiques de la  
Fondation Santé et Radiofréquences

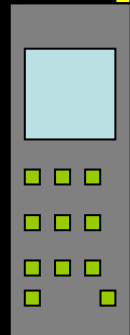
**25% of the world's population soon  
volunteer as guinea-pigs in  
the World's largest  
biological  
experiment**

**Salford LG  
European  
Parliament  
2000**



Today two thirds of the world's population volunteer as guinea-pigs in the World's largest biological experiment

Fondation  
Santé et  
Radiofréquences  
2009



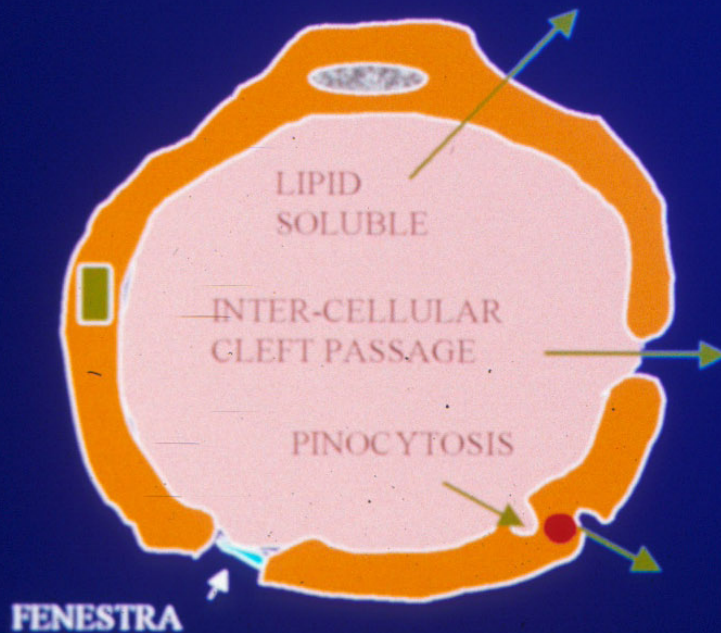
**EFFECTS UPON**

**the**

**BLOOD-BRAIN BARRIER**

# The Blood-Brain Barrier (BBB)

GENERAL CAPILLARY

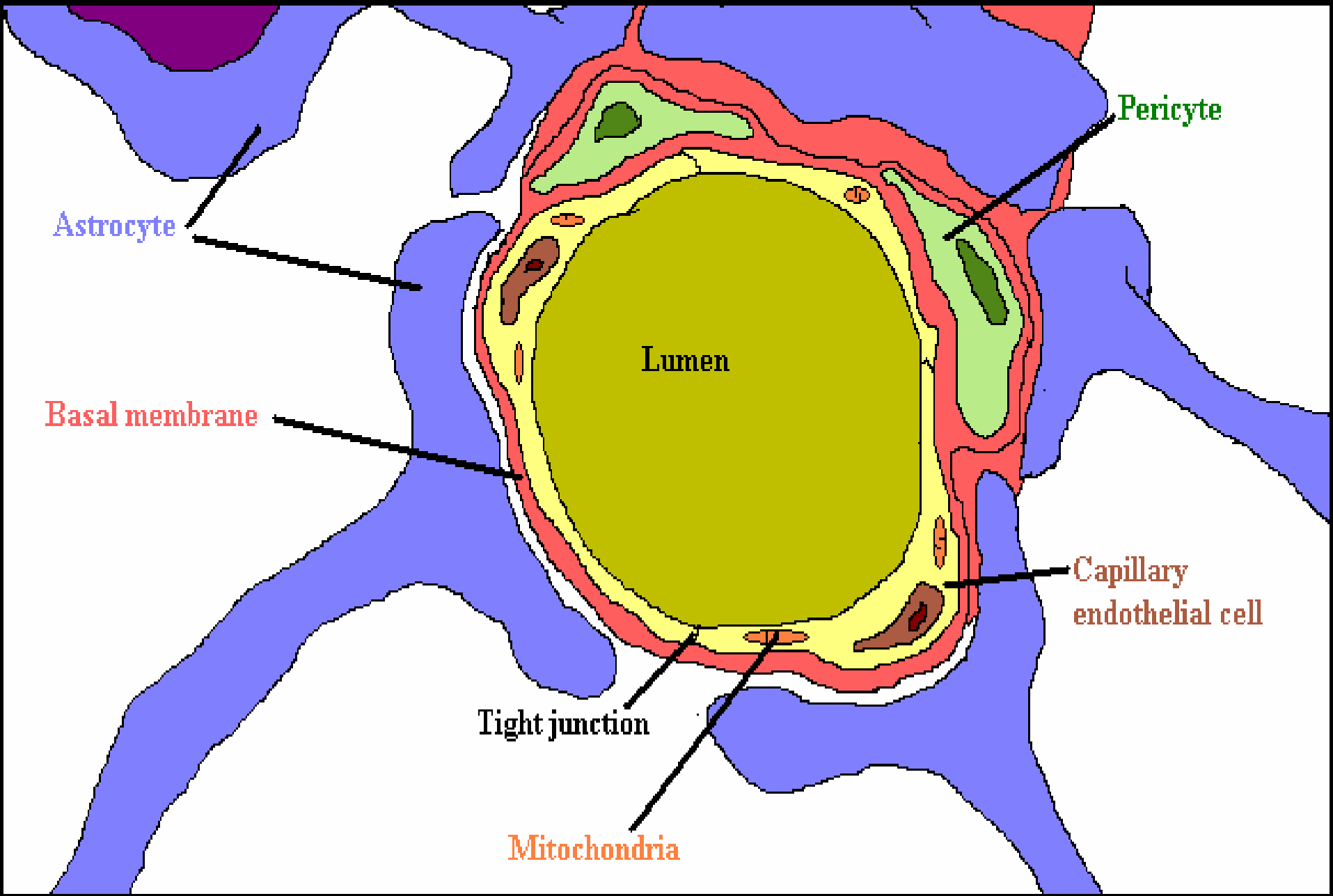


BRAIN CAPILLARY



Salford, Bar Parl 0006

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!



The BBB

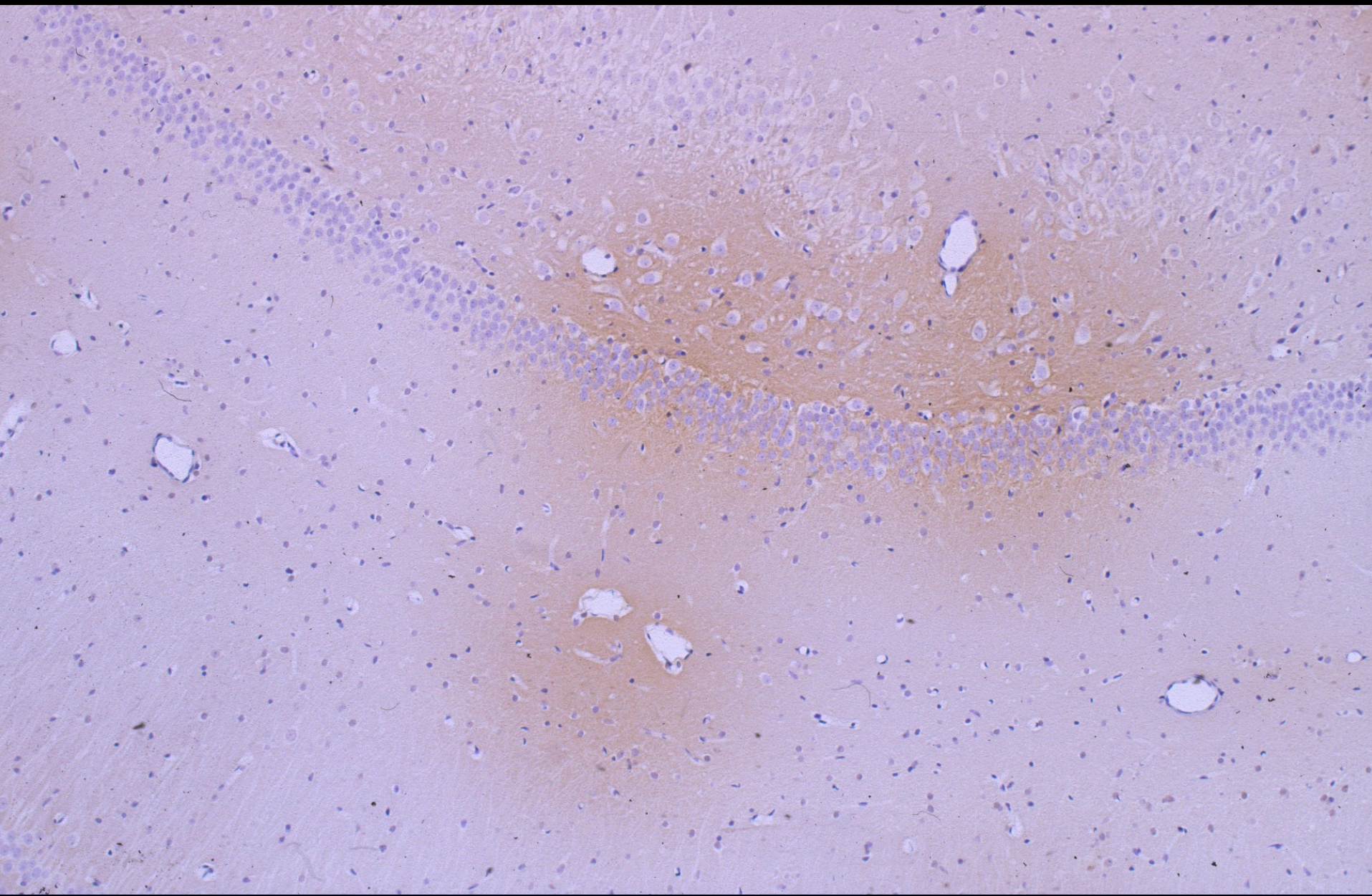
Earlier experiments in the Rausing lab:  
Always Non-thermal energy < 2W/Kg

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









”Biological window”

1/1000 and 1/10000

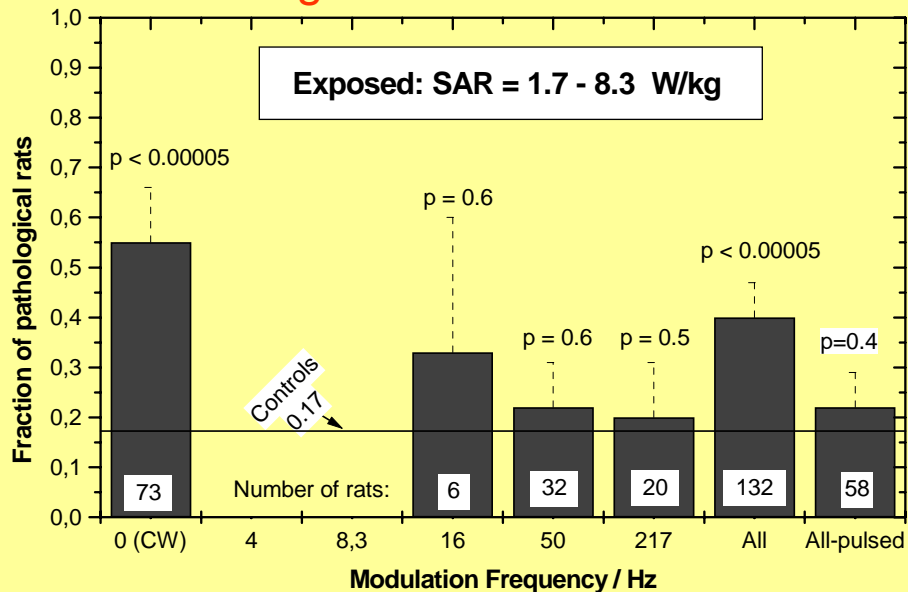
of the energy at the antenna

of the mobile phone opens

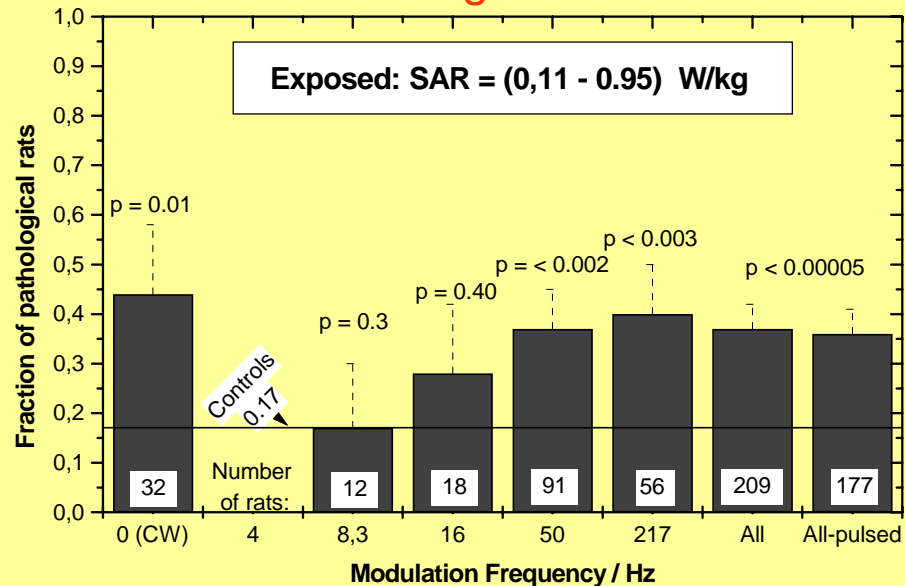
the BBB more efficiently

than the energy at the antenna

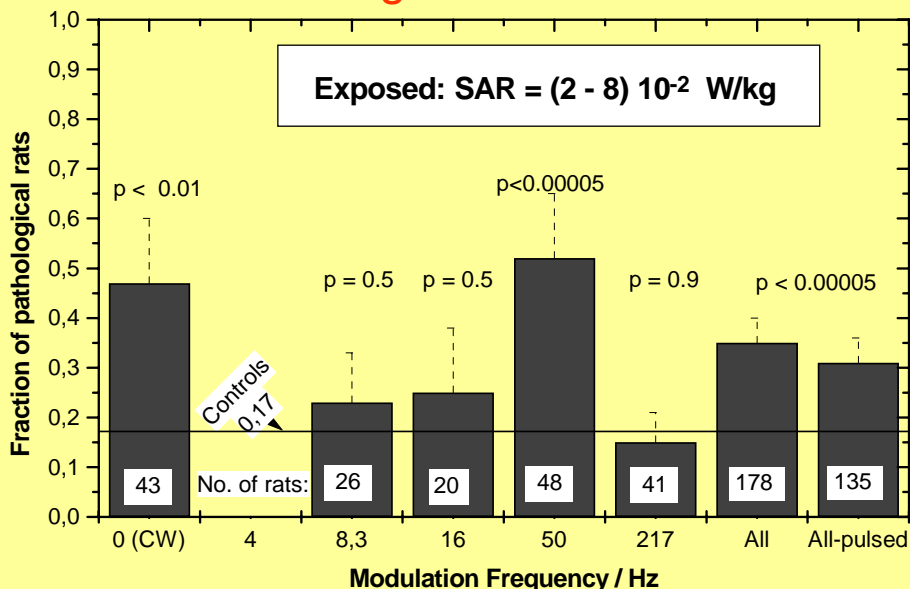
### 1 – 8 W/kg



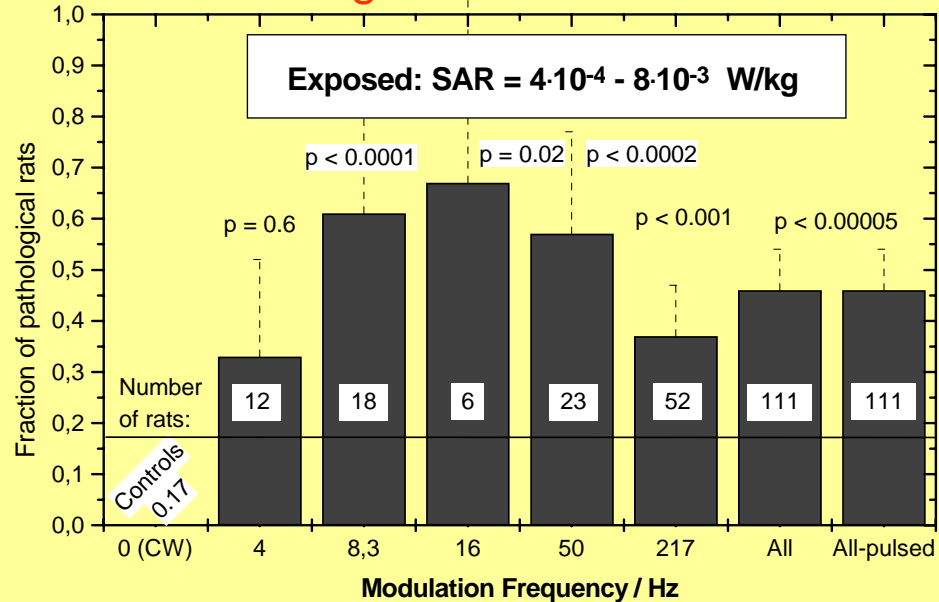
### 100 – 950 mW/kg



### 20-80 mW/kg



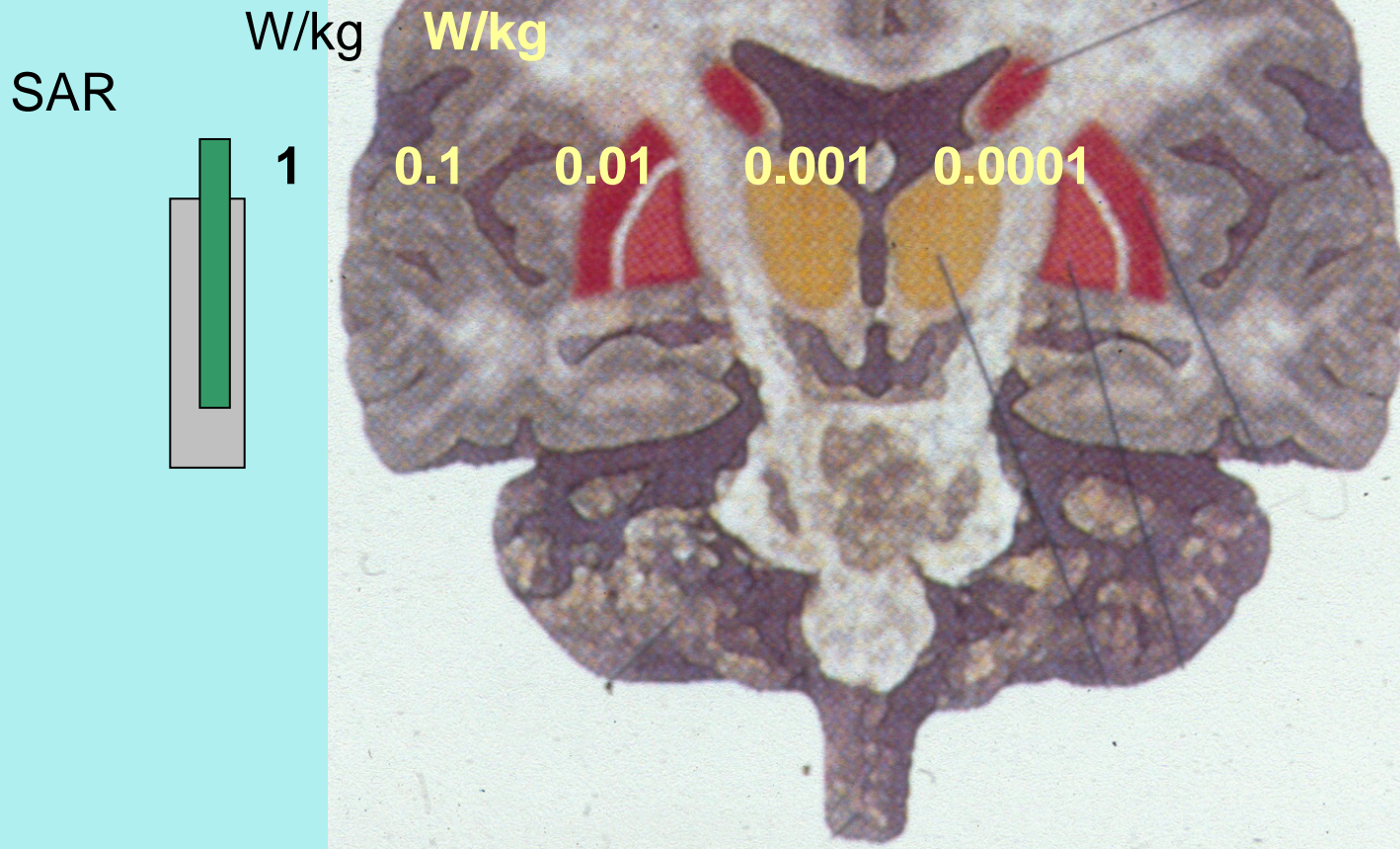
### 0.4-8 mW/kg



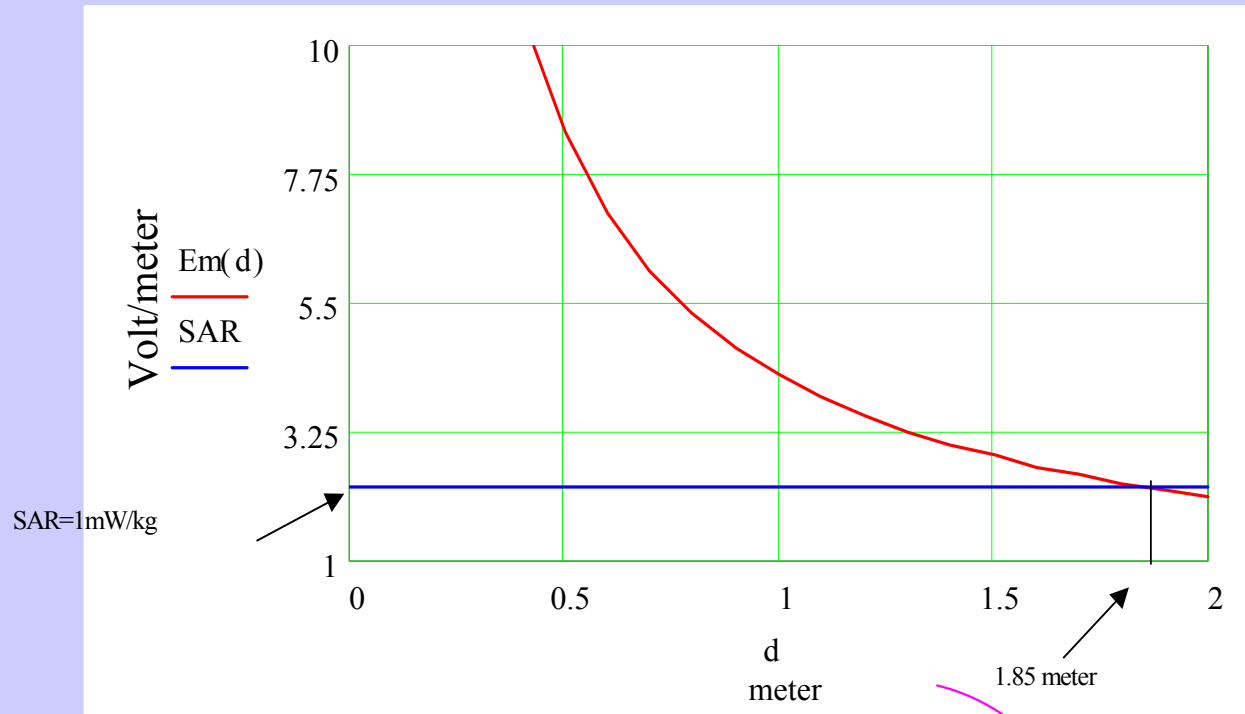
## Difference in albumin extravasation between exposed and control animals at different SAR values

<b>SAR (mW/kg)</b>	<b>Number of animals, exposed + controls</b>	<b>Difference significance</b>
<b>0.2–4</b>	<b>48 + 48</b>	<b>p &lt; 0.001</b>
<b>25–50</b>	<b>22 + 22</b>	<b>Ns</b>

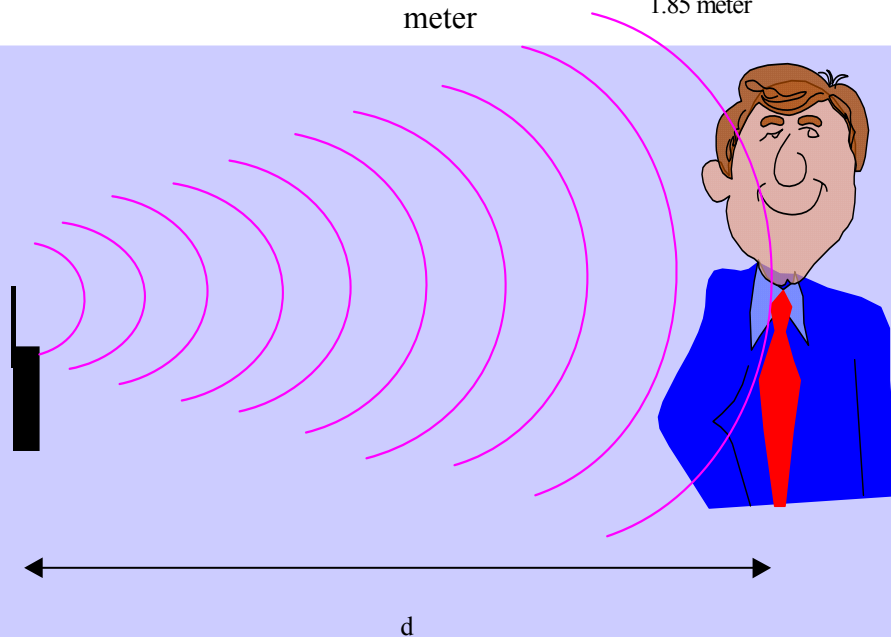
Antenna 1,4 cm from human head, 915 MHz, SAR values derived from Anderson and Joyer 1995 and Dimylow 1994

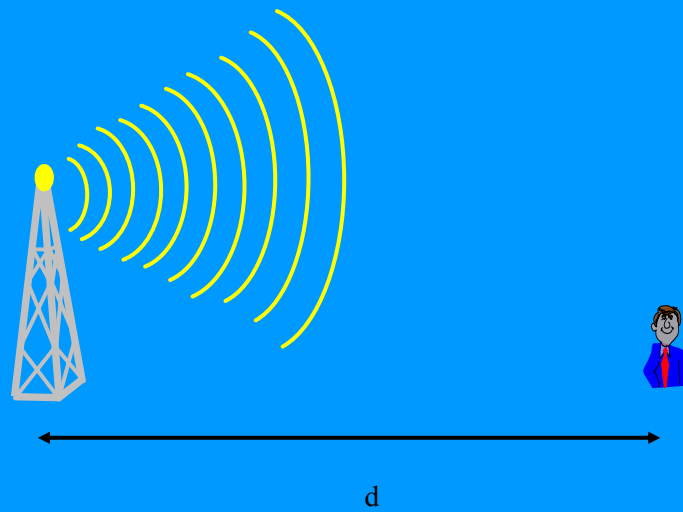
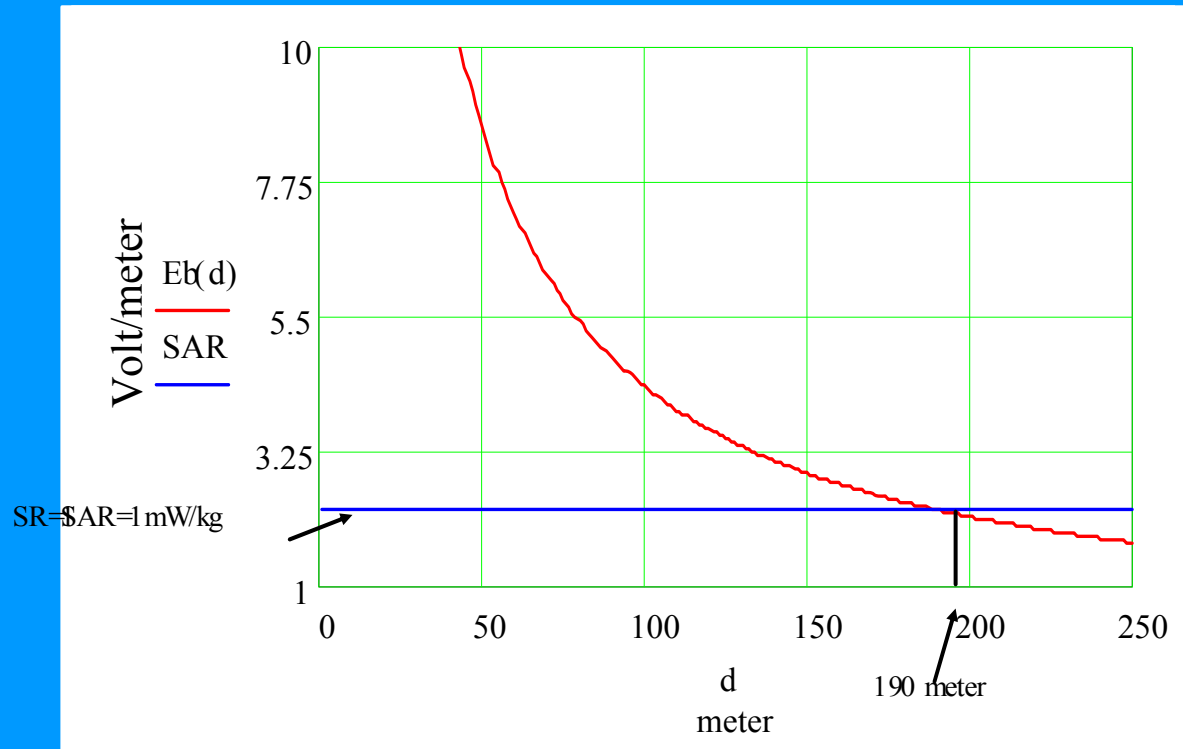


Salford and  
Persson



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







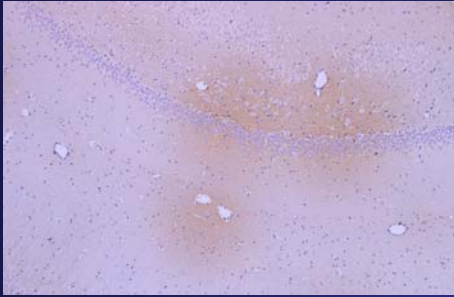
# Exposed vs sham

7d

14 d

28 d

50 d



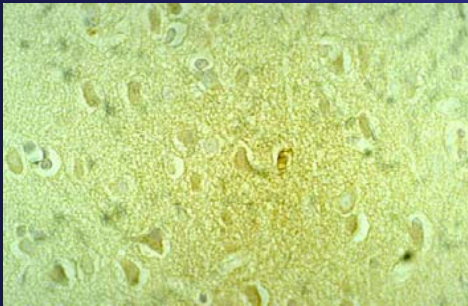
**Albumin  
foci**

**0.04**

**0.02**

**ns**

**0.04**



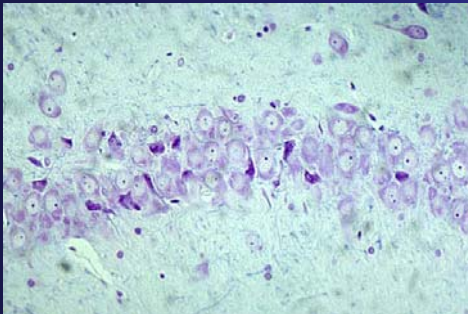
**Neuronal  
albumin**

**0.02**

**0.005**

**ns**

**ns**



**Dark  
neurons**

**ns**

**ns**

**0.01**

**0.001**

**EFFECTS UPON**

**COGNITIVE FUNCTION**

# Exposure

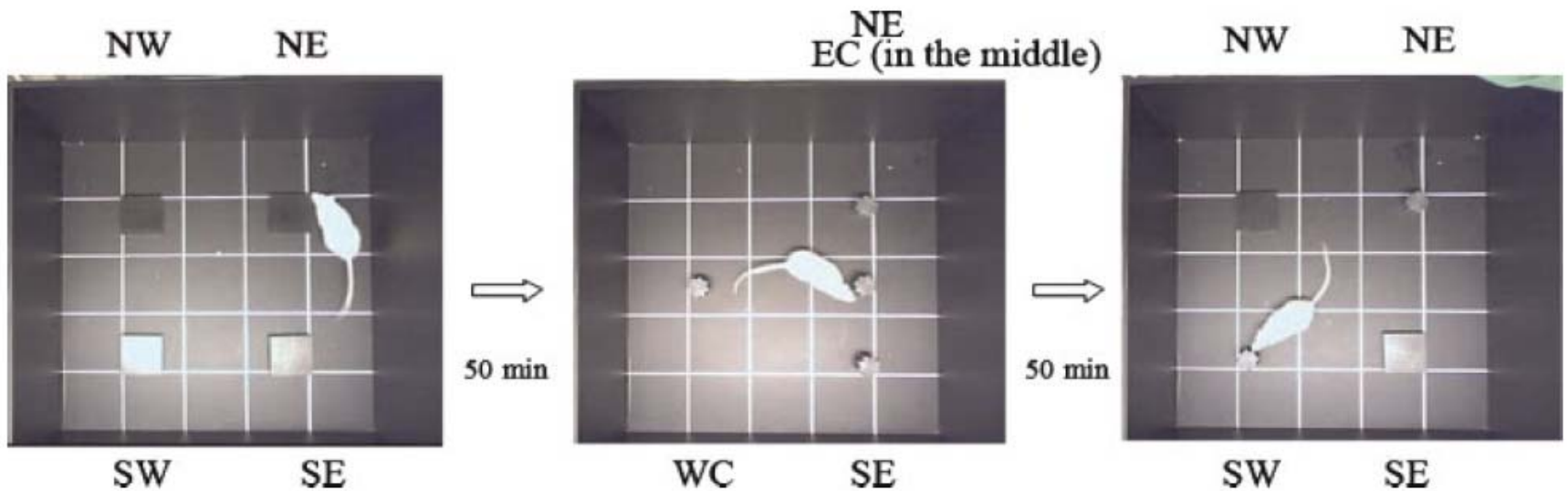
2 hours weekly for 55 weeks  
GSM-900 mobile phone

Number of Fischer 344 rats (Totally 56)	Exposure (at the initiation)
16 (8 ♀, 8 ♂)	0.6 mW/kg (5mW to TEM-cell)
16 (8 ♀, 8 ♂)	60 mW/kg (0.5W to TEM-cell)
16 (8 ♀, 8 ♂)	Sham
8 (4 ♀, 4 ♂)	Cage controls



# Episodic-Like Memory Test

Long-term memory of different objects



# Results

## GSM exposure vs sham

- Impaired episodic memory
- Impaired memory for objects
- Impaired memory for their temporal order of presentation
- Spatial memory not affected

Cage controls have more reduced performance than both sham and GSM exposed rats.

**Corroborating evidence:**

**EFFECTS UPON**

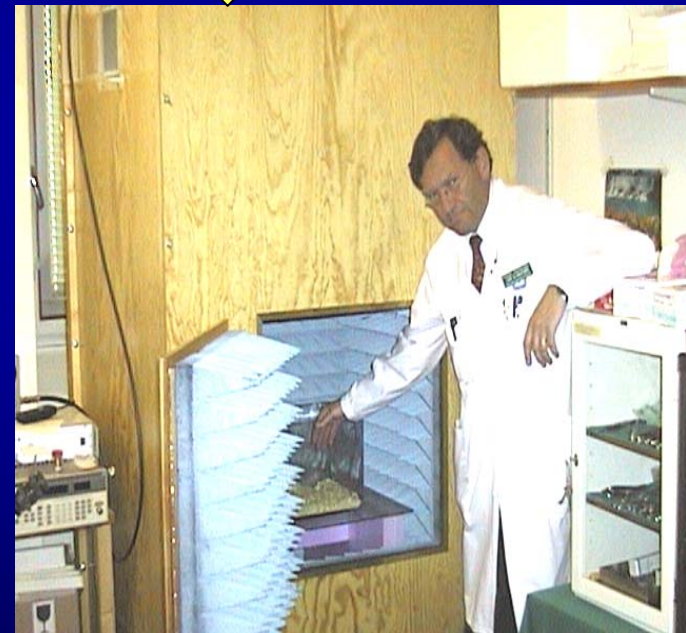
**GENE EXPRESSION**

# Effects upon DNA?

6 hours exposure to radiation in anechoic chamber  
from a GSM-1800 mobile test  
phone, SAR 13mW/kg  
All animals awake

4 exposed Fischer 344 rats  
4 sham controls

Analyses of gene expression  
in cortex and hippocampus



# Effects upon DNA?

We have shown that a large number of predefined functional categories of genes, according to Gene Ontology Analysis (GO), are altered.

25 GO categories altered in cortex

20 GO categories altered in hippocampus

A large number are connected with membrane functions

Corroborates our earlier observation of albumin transport through the cerebral endothelium



# Top separating categories microarray Salford et al 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  
integral 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

June 2003

VOLUME 111 | NUMBER 7  
PAGES A363–A422 & 877–992  
ehponline.org

**Measuring Exposures,  
Determining Risks**

**A Word of Caution  
on Mobile Phones**

MINI-MONOGRAPH  
**World Trade Center  
Dust Characterized**

**Nerve cell damage in  
mammalian brain after  
exposure to microwaves  
from GSM mobile phones.  
Salford et al 2003**



•“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”.

Evidence for  
interaction of ELF  
with protein-bound  
ions in membranes  
(spinach vesicles)

# **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 Ca<sup>2+</sup> channel protein in the cell membrane, and we could quantitatively confirm the model proposed by Blanchard”**

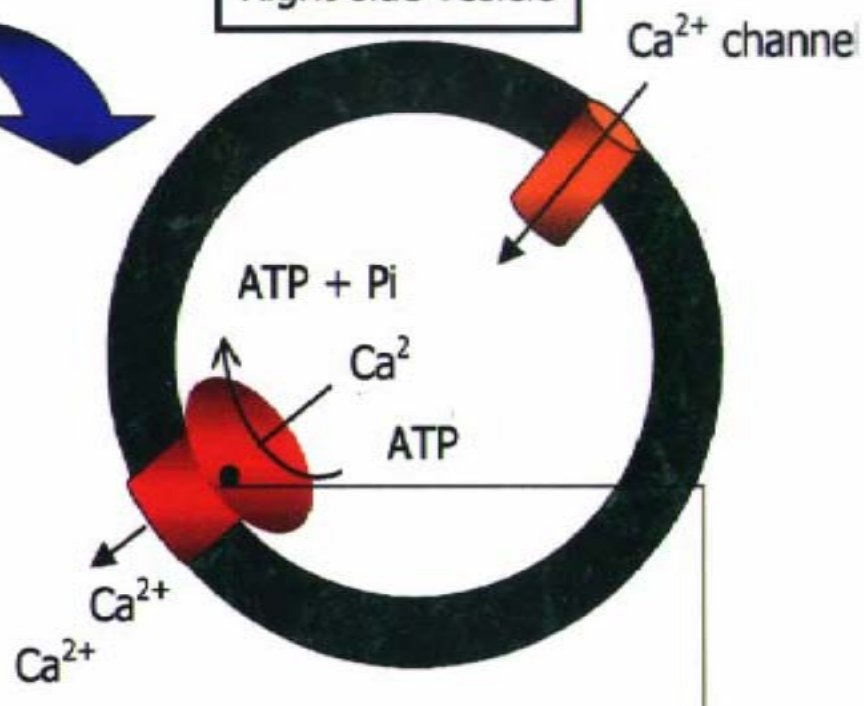


Spinach cells

Two-phase  
partitioning

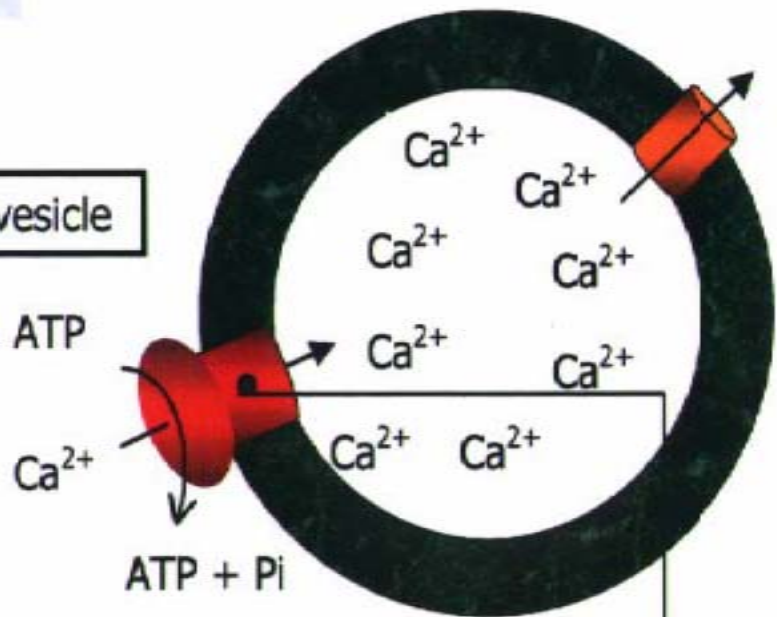


Right-side vesicle



Ca<sup>2+</sup>-ATPase

Inside-out vesicle



Ca<sup>2+</sup>-ATPase

Brij 58



9h00 – 11h30 > **Session 4 : Biological studies**

Chairman : **Gérard Ledoigt**

**Invited talk: Chris DAVIS** (University of Maryland, USA)

- Exposure to a Wi-Fi signal in young animals : effects of the brain – I.LAGROYE and al.  
– EPHE,

IMS Bordeaux

- Effect of RF fields on memory process and attention in the rat – R. DE SEZE and al. -  
INERIS

- DNA microarray for physiological studies – D.ROUX and al. – University of Clermont

- Co-genotoxicity of 1.8 GHz-GSM exposure on human cells – A.PERRIN - CRSSA

- Observation and identification of athermal mechanisms of the interactions between  
charge carriers

and the RF electromagnetic field. Application to biomolecules – A.FOURRIER-LAMER  
and al. -

UPMC

**Moderator: Jean-Claude DEBOUZY** (CRSSA, France)

**Leif G. SALFORD** (Dept Neurosurgery, Lund University, Lund, Sweden)

# The Rausing Laboratory

for Experimental Neurosurgery and Radiation Physics  
The microwave research section



Gustav Grafström

Bertil Persson

Lars Malmgren

Leif G Salford

Jacob Eberhardt

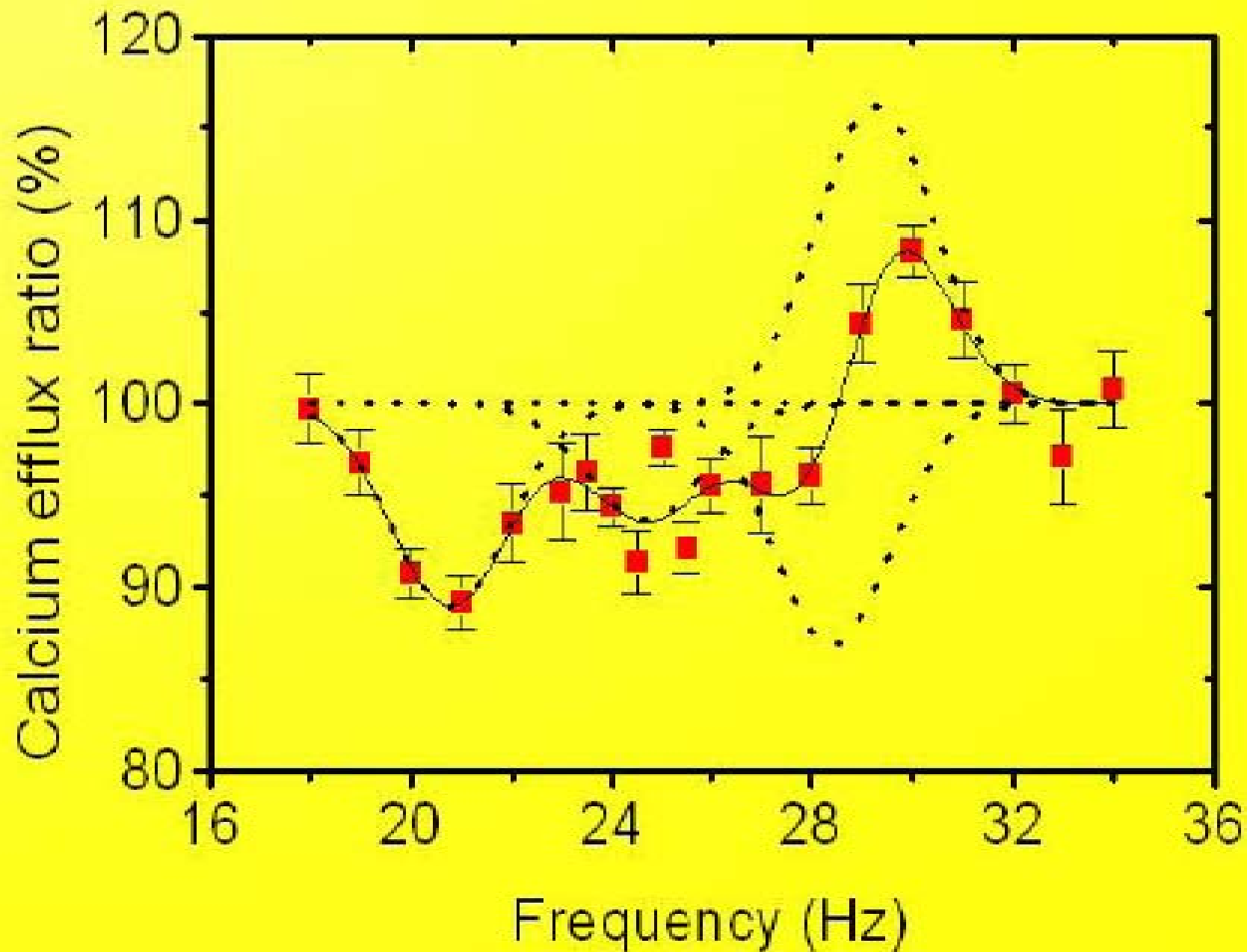


Arne Brun



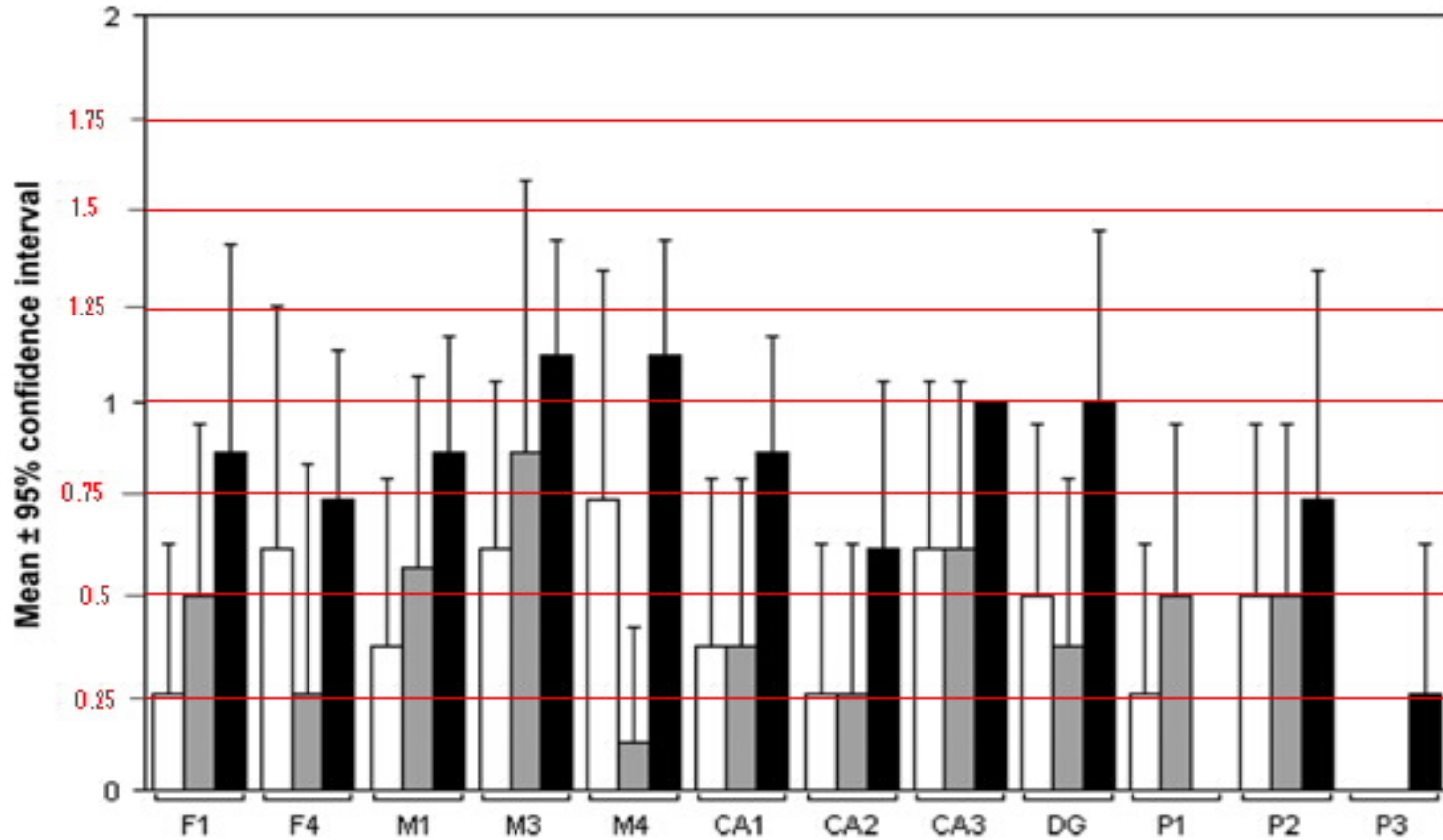
+ Henrietta  
Nittby

(Thesis 2008)



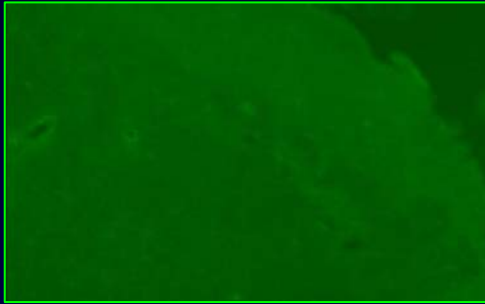


# The Bordeaux group 2009

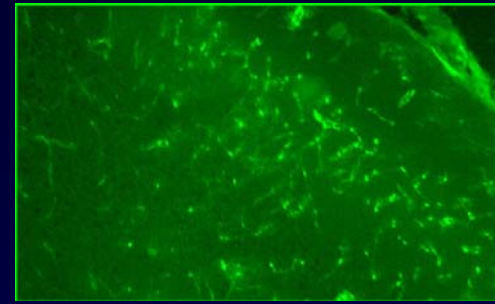


Dark neurons 50 days after exposure to 0, sham (white), 014 (grey) or 2W/kg (black)

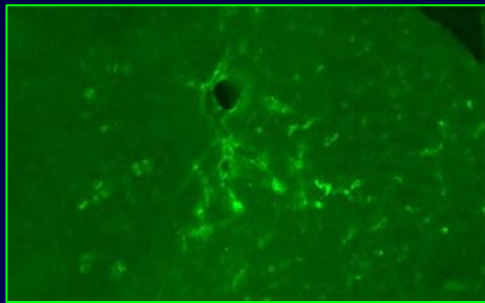
# Effects of 2-h exposure to GSM microwaves : Brain Aubineau and Töre



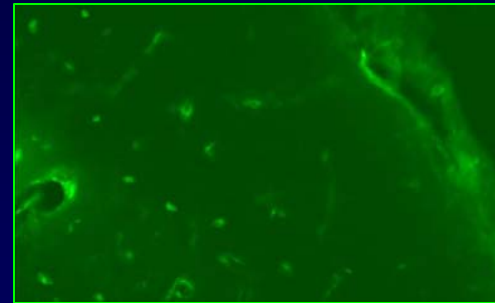
**Sham-exposed**



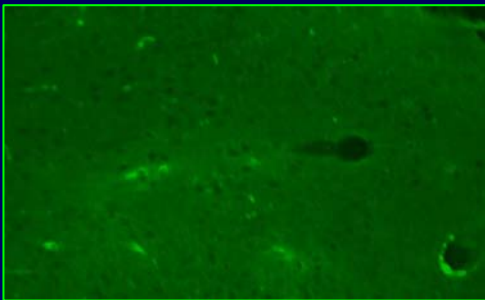
**Positive control**



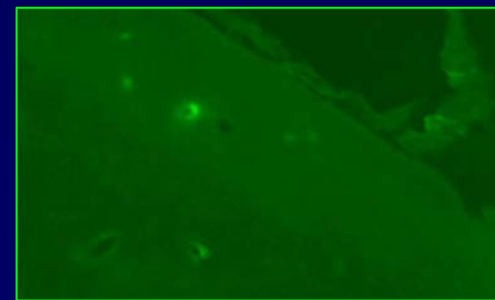
**Exposed (3 W/kg)**



**Anaesthetized (3 W/kg)**



**Exposed (1.5 W/kg)**



**Exposed (0.75 W/kg)**

# RF EMF and the BBB

## Duplication of the Lund studies:

Fritze et al, Acta Neuropathol. 94:465-470, 1997

Exposure of in total 30 rats in a carousel (Motorola) at SAR values 0.3, 1.5 and 7.5 W/kg gave the same type of extravasation of albumin as reported by the Lund group. Significant difference between sham controls and exposed was reported for the 10 animals in the 7.5 W/kg (a thermal level).

**Fisher exact probability test (two tailed) reveals significant difference for the subthermal level groups (SAR = 0.3 W/kg plus 1.5 W/kg) where in total 10 animals out of 20 showed one or more extravasations direct after exposure.**

# RF EMF and the BBB

## Duplication of the Lund studies:

Fritze et al, Acta Neuropathol. 94:465-470, 1997

	n		Fisher-		Fisher
		t-test	test	t-test	test
		Sham	Sham	All contr	All contr
Cage Control	20				
Sham exposed	20				
Total control	40				
7.5 W/kg	10	0.03	0.08	0.03	0.01
1.5 W/kg	10	0.12	0.08	0.06	0.01
0.3 W/kg	10	0.10	0.08	0.06	0.01
1.5+0.3 W/kg	20	0.02	0.04	<0.01	0.001

## INTRACELLULAR ALBUMIN

Pulsed (Hz)	Power	0/1	2/3	Total	%
16	0.0018	22	11	33	33
217	0.0025	24	9	33	27
Sham	n/a	36	8	44	18
Home cage	n/a	37	5	42	12

15%

**p-value  
ADDED  
by Salford**

**<0.05 !**

**ns**

(Fisher exact probability test and Chi<sup>2</sup> test)