Acknowledgements

- Prof. Antonio Costa (UNED)
- Prof. María Antonia Huertas (UOC)
- Prof. Fernando Pestana da Costa (UAb)
- Master on Medical Physics
  - Prof. Cristina Santa Marta (UNED)

Las Matemáticas en el máster de Física Médica: Diez años de experiencia
Mathematics in the Master of Medical Physics: Ten years of experience

J.C. Antoranz

Facultad de Ciencias

UNED

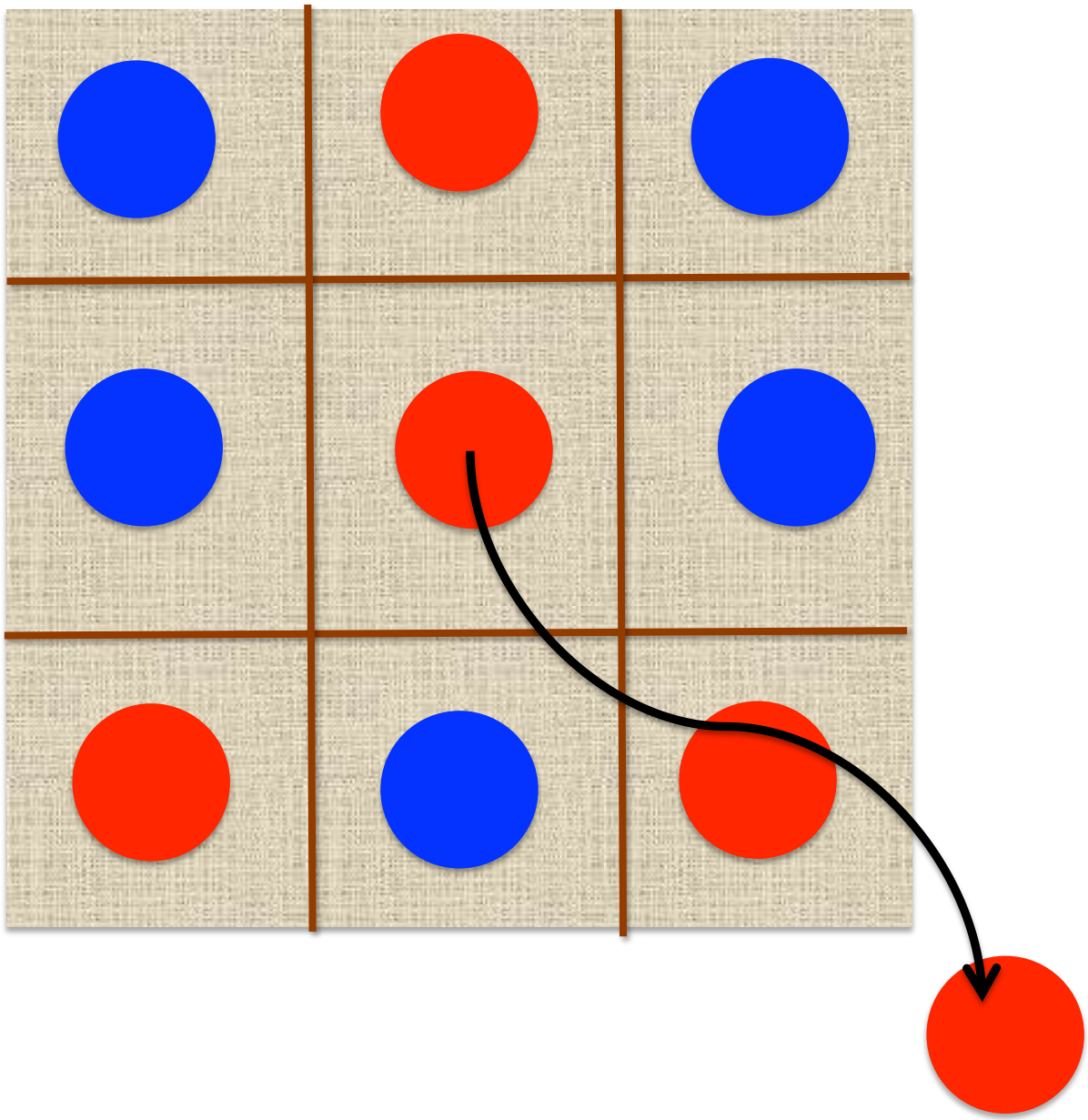
Mathematics in Medicine is more than Statistics

- "*If you torture your data long enough, they will tell you wathever you want to hear*"
- "*Like other forms of torture, it leaves no incrimination marks when done skilfully*"

James. L. Mills,

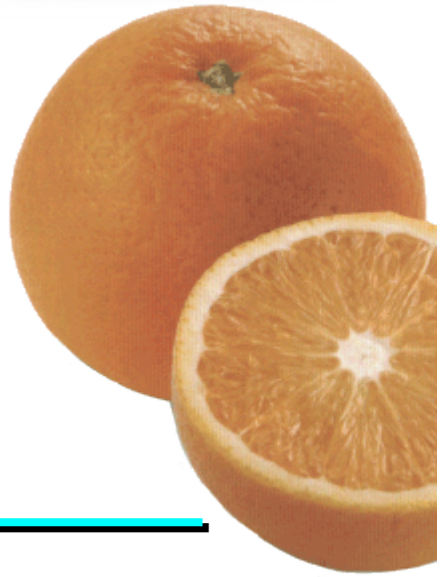
New Engl J Med Volume 329:1196-1199, 1993

Think outside the box, please!



Old style: analog sizes

Finger-meter

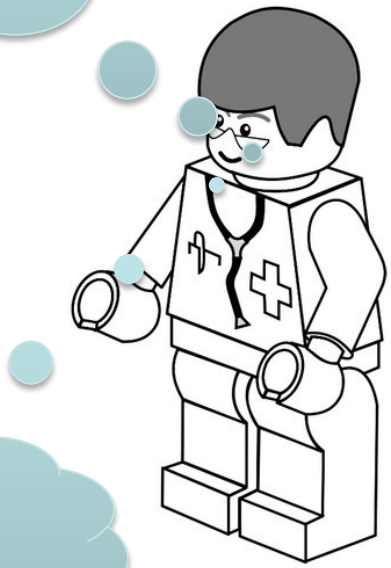


Basic ideas in medicine: A real case

I've developed an algorithm to get an area preserving morphometric statistical mapping of the brain with a smoothing kernel of 15 mm...

Some months later!

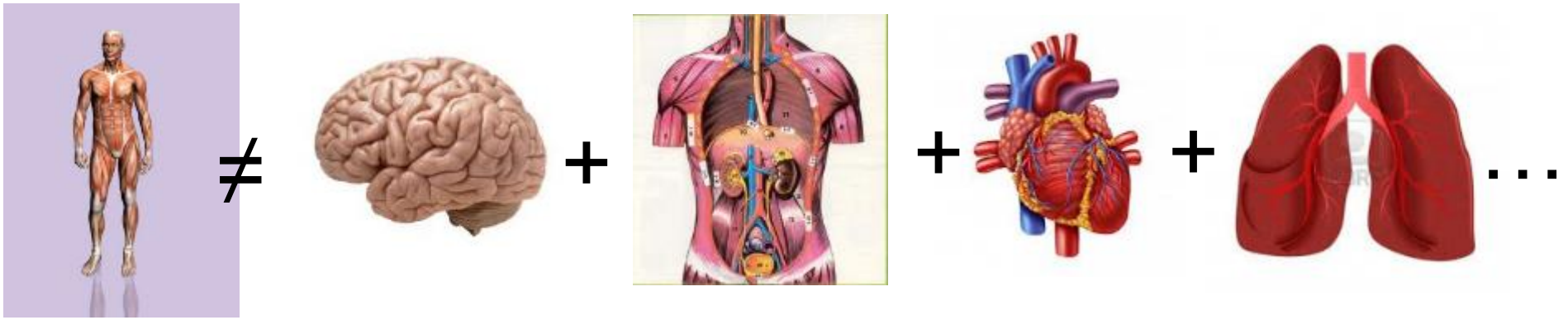
I want to measure volumes of some brain structures



Ok!, but what about my volumes?

Something to remember (RT or ChT, i.e.)

- We are not isolated organs
- So, we destroy the tumor and its surroundings (RT)
- Our body cannot undergo elevated doses without collateral damages (RT and/or ChT)



Understanding the medical language

- We must study anatomy, physiology, pathology, surgery, etc … Furthermore, we don't like it.
  - Patients are not assembly line products. Patients are not models, but …
  - There are not
    - Spherical patients
    - Linear patients
- Doctors have the same problem - and yet they study it

Are Maths and Physics more complicated …?

Alumnos	Al.	%
Biología y Geología	50.454	81,1%
CC. Soc., G. y H.	50.454	81,6%
E. Física	50.454	93,0%
E. Plástica y V.	50.454	88,1%
Física y Química	50.454	75,6%
Inglés	49.474	77,5%
L.Castellana y L.	50.454	75,8%
Matemáticas	50.454	70,9%
Música	50.454	87,5%
Religión	25.714	95,9%
H. Religiones	3.561	95,9%
Tecnologías	50.454	84,8%

CURSO 4º

Alumnos	Al.	%
Biología y Geología	25.438	91,3%
CC. Soc., G. y H.	44.529	84,6%
E. Física	44.529	95,6%
E. Plástica y V.	10.713	89,8%
Ética	44.529	94,1%
Física y Química	26.262	85,3%
Inglés	43.917	84,7%
Informática	26.224	93,7%
L.Castellana y L.	44.529	83,2%
Latín	10.517	86,4%
Matemáticas A	15.599	69,8%
Matemáticas B	28.930	81,9%
Música	9.530	92,0%
Religión	22.669	96,8%
H. Religiones	2.975	97,5%

For instance, 2009/2010 Comunidad de Madrid, 3º y 4º ESO data

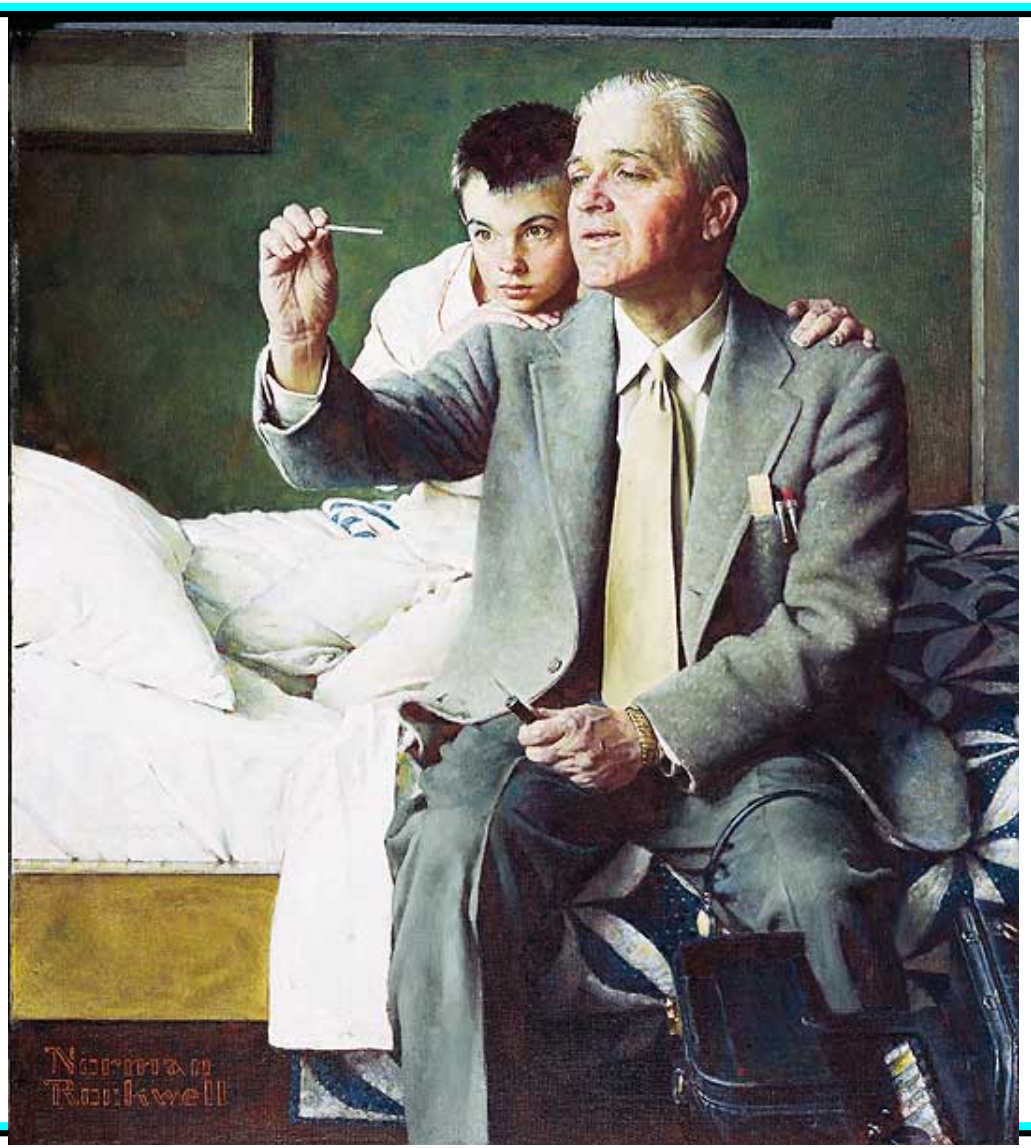
Madrid University entrance exam‘ 18

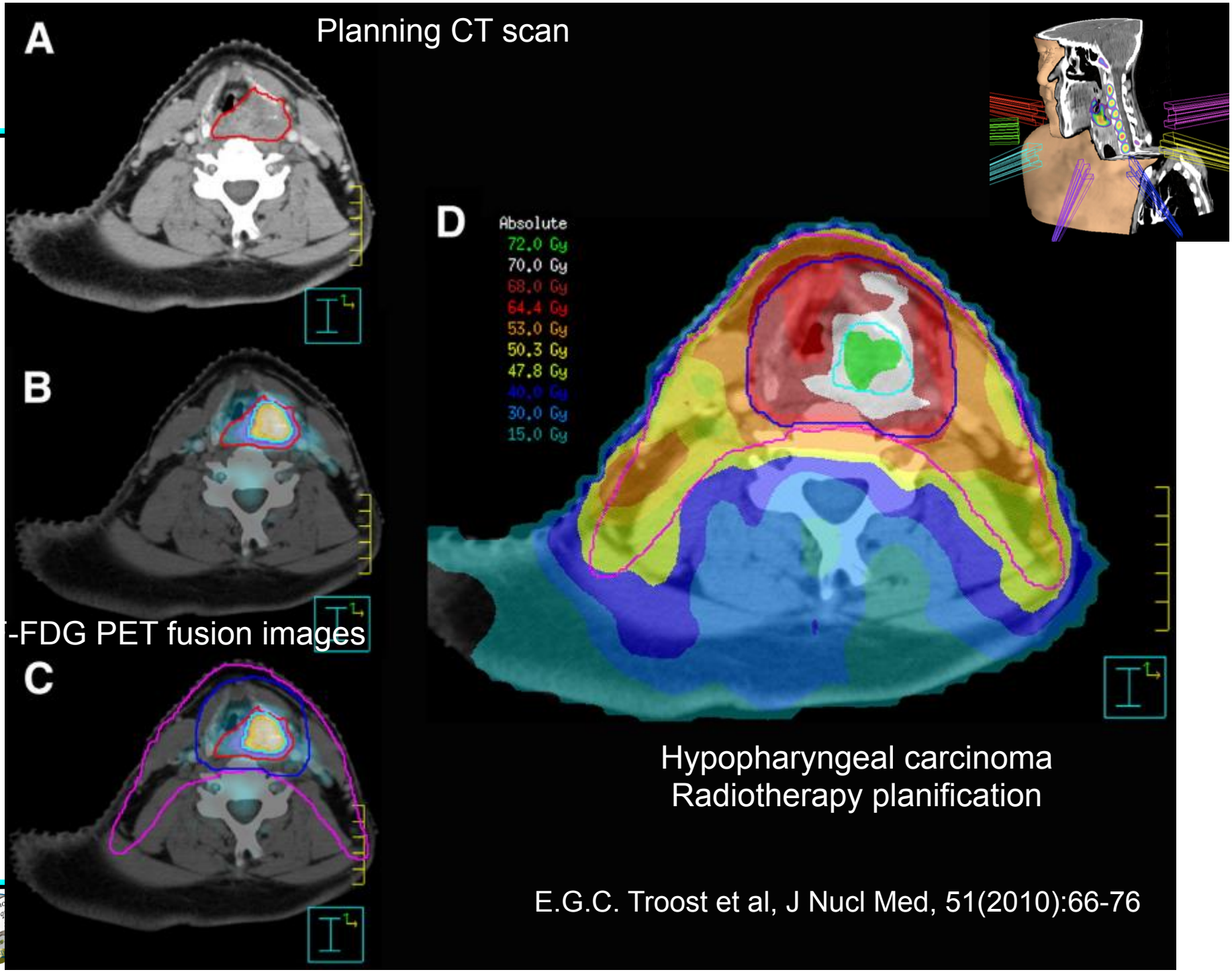
	UCM	UAM	UPM	URJC	UCIII	UAlcalá
Physics	11,90	12,78				
Biochemistry	12,32	12,55				8,17
Mathematics	11,71	12,10		11,54		
Biomedical Eng.			12,01	12,75		
Medicine	12,966	13,124		12,792		12,811

I want to point out that …

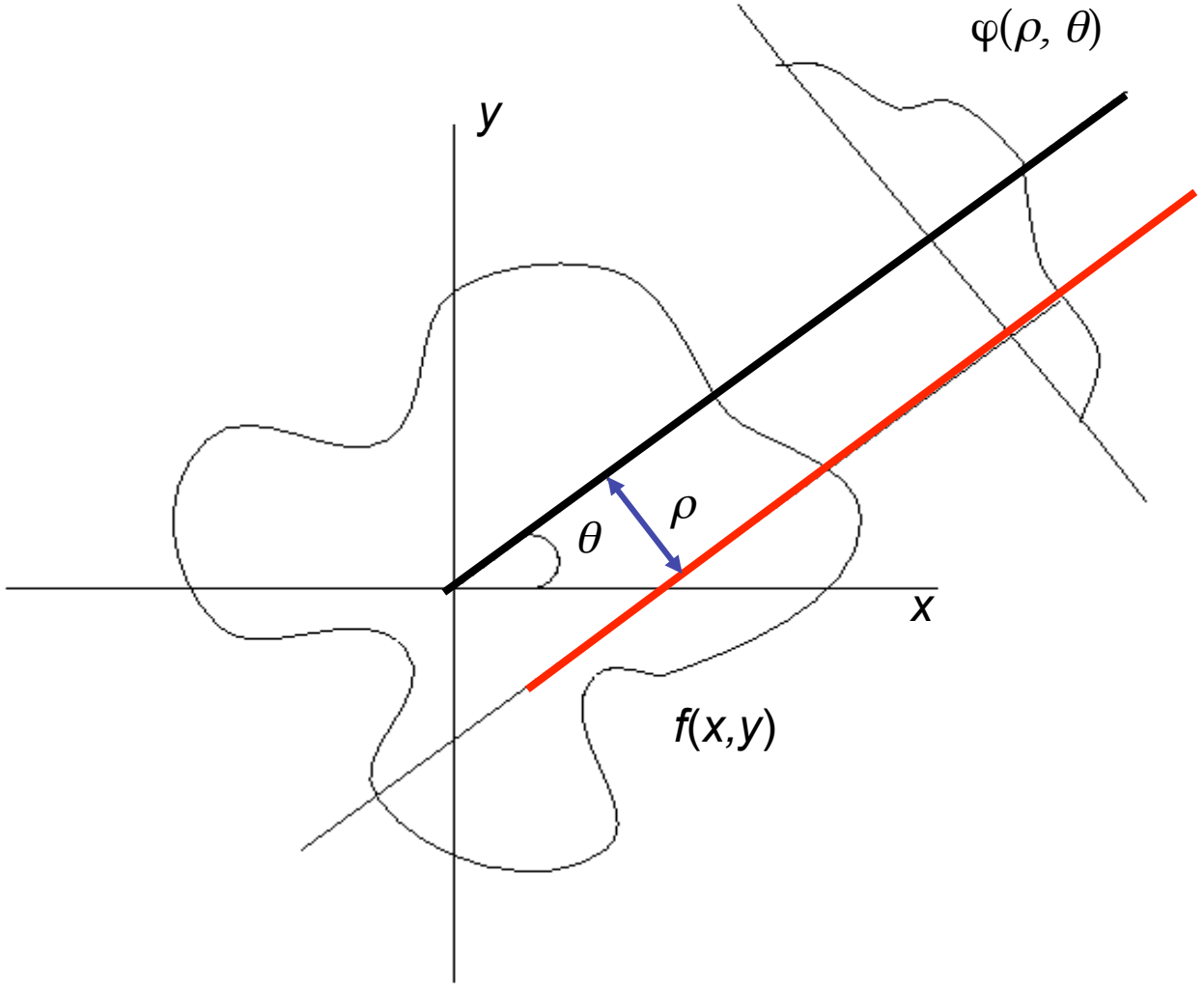
- Mathematics and Physics are base and tool in Medicine. You must believe me!!
- Multidisciplinarity is a common feature in modern sciences like (Jajaja) medicine
- It is useful, so
  - Something must change. New concepts
  - Common languaje among “species”
  - Harvard´s spirit
- This is not cheap nor profitable short-term time

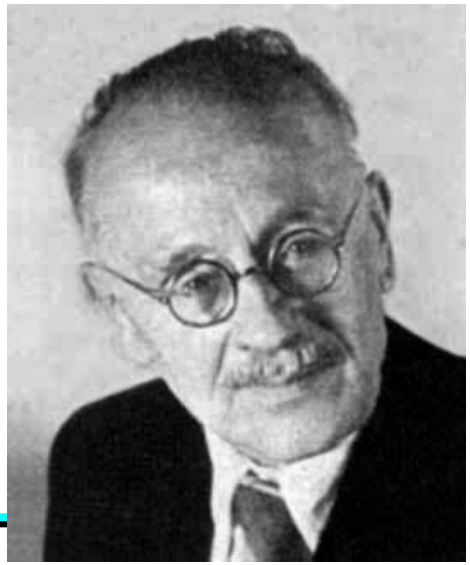
Where to find Mats&Physics in Medicine?




A
Planning CT scan
B
-FDG PET fusion images
C
D
Absolute
72.0 Gy
70.0 Gy
68.0 Gy
64.4 Gy
53.0 Gy
50.3 Gy
47.8 Gy
30.0 Gy
15.0 Gy
Hypopharyngeal carcinoma
Radiotherapy planification
E.G.C. Troost et al, J Nucl Med, 51(2010):66-76

Radon transform

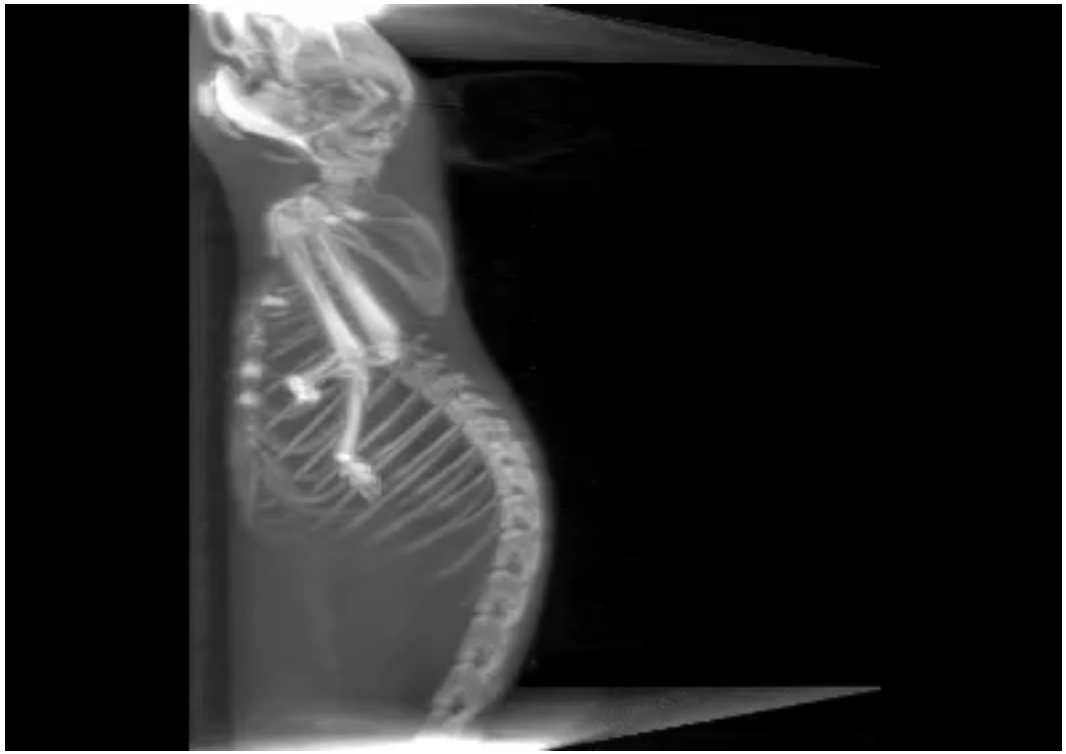




Math power! Projection-slice theorem

The projection-slice theorem or central slice theorem or Fourier slice theorem in two dimensions states that the results of the following two calculations are equal:

- Take a two-dimensional function f(*r*), project it onto a (one-dimensional) line, and do a Fourier transform of that projection.
- Take that same function, but do a two-dimensional Fourier transform first, and then slice it through its origin, which is parallel to the projection line.



LMAI-UNED, Tomografía Axial Computerizada de ratón,
MicroCT Suinsa de alta resolución 2004

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Dpto. Física Matemática y de Fluidos
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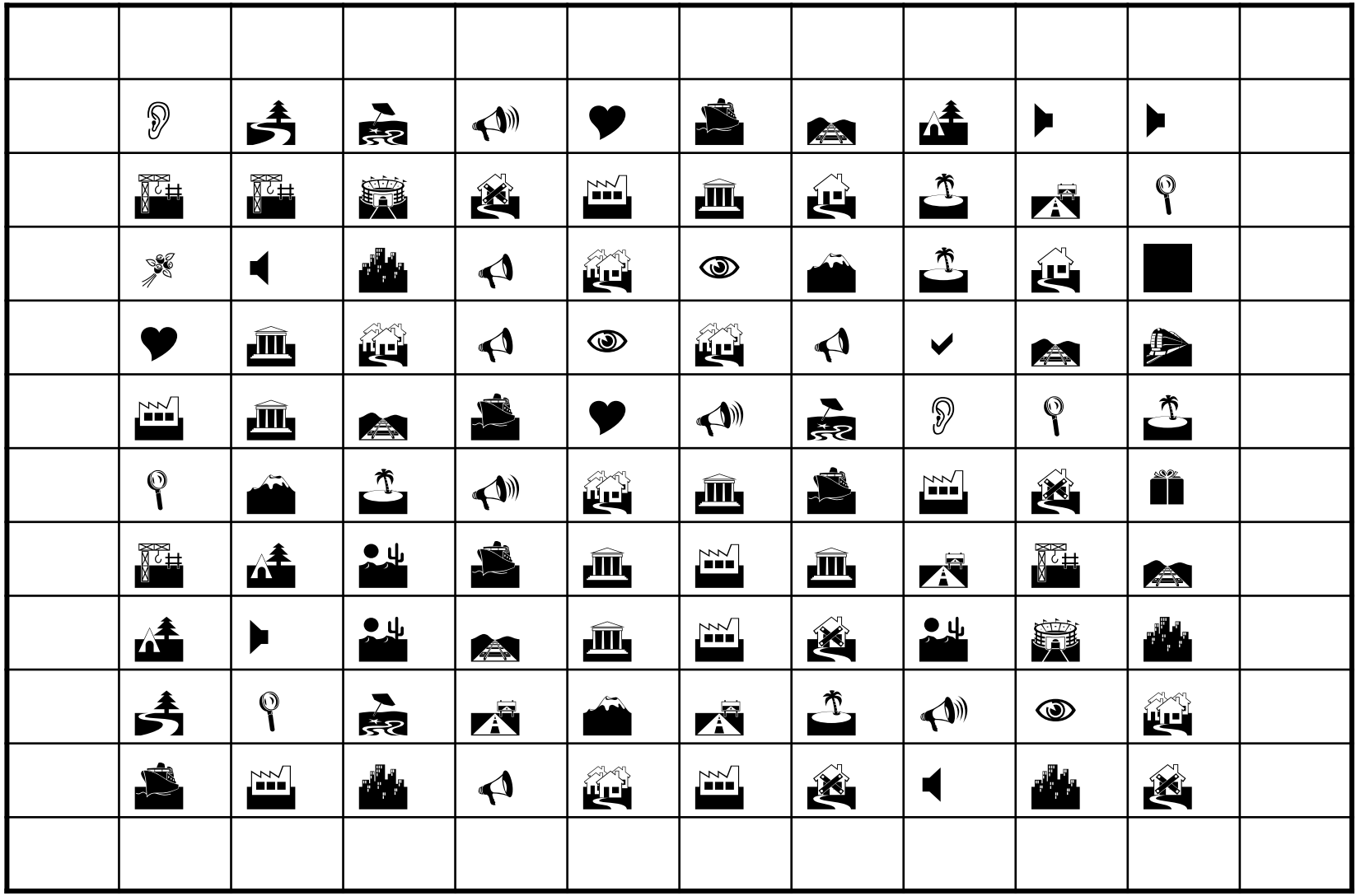
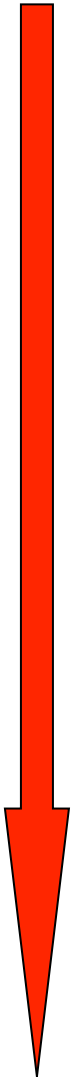
Basic Math: Strawberries game

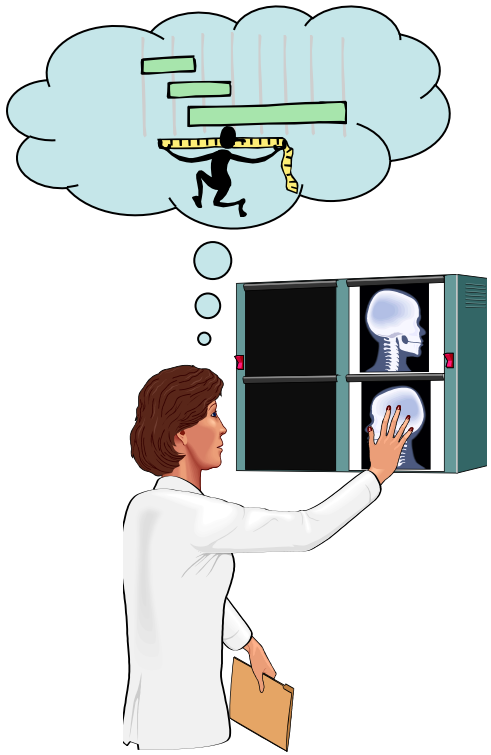


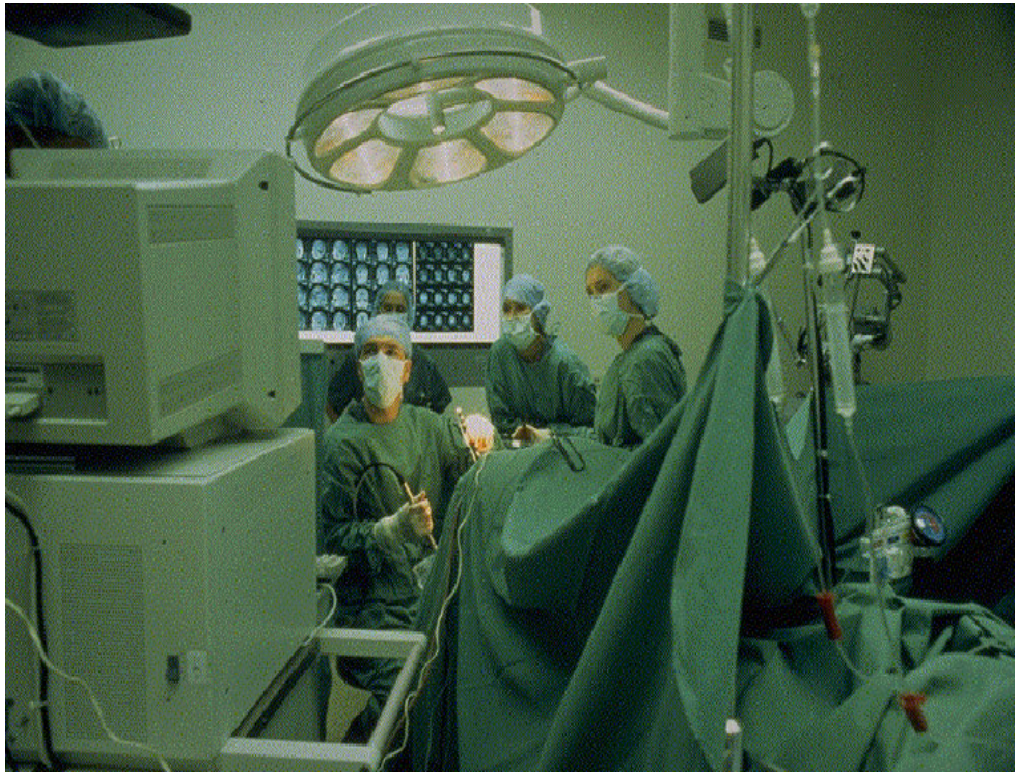
Basic Math: Strawberries game



12	58	57	6	12	34	18	35	23	98	12	12
33											33
27											27
23											23
67											67
52											52
87											87
67											67
65											65
69											69
22											22
12	58	57	6	12	34	18	35	23	98	12	12

De la lenteja al micrómetro: medir y más





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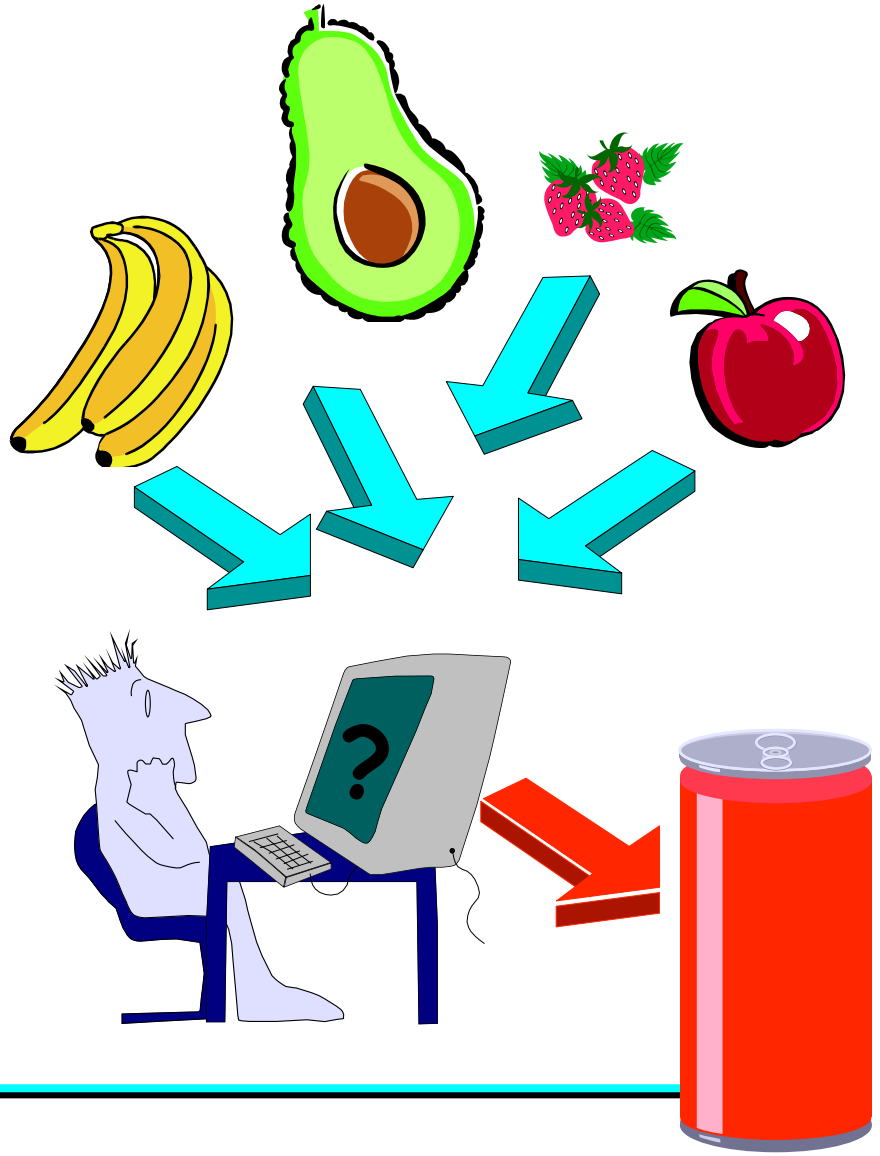
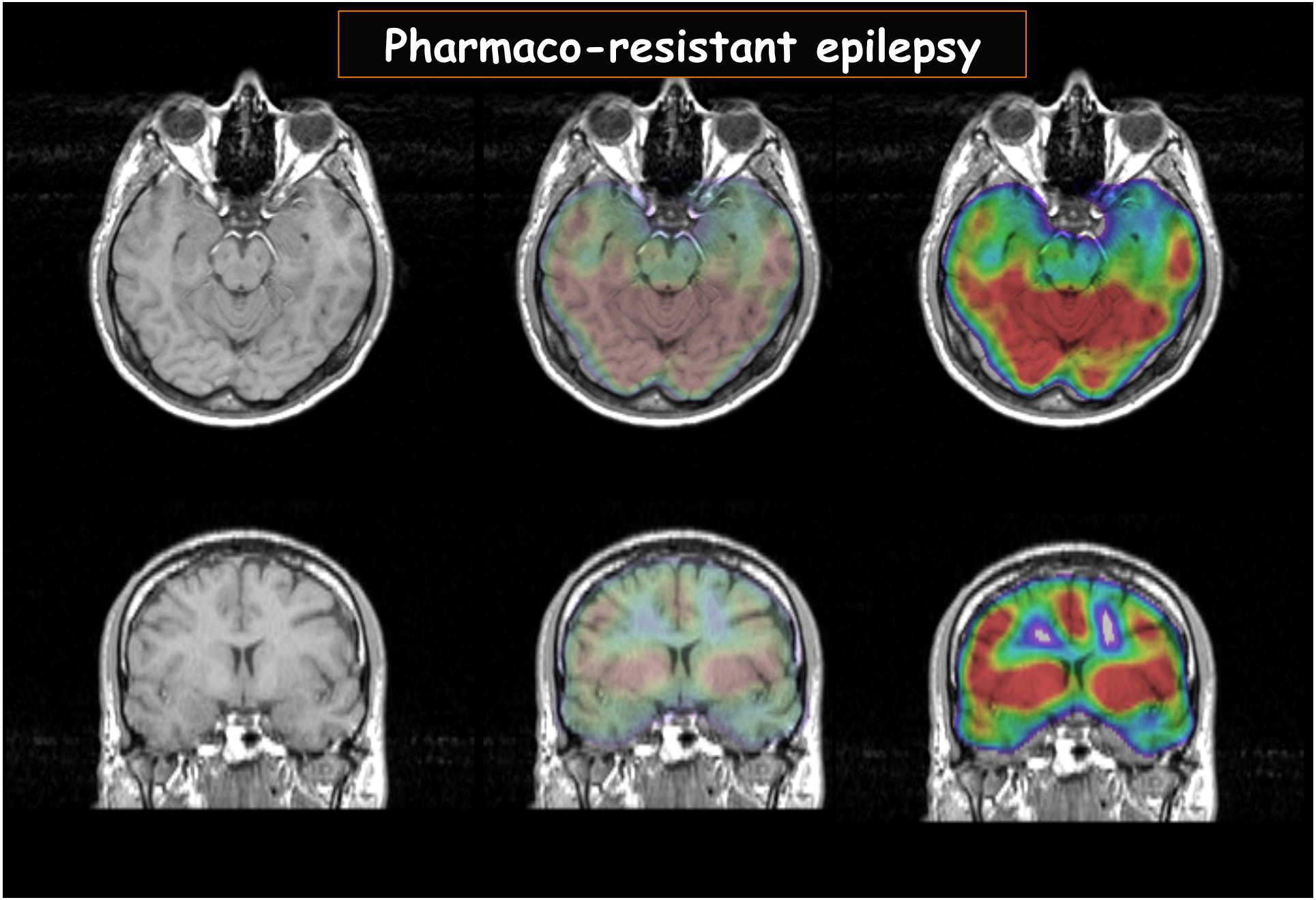
Medical image registration

- Image registration is the process of transforming different sets of data into one coordinate system. Data may be multiple photographs, data from different sensors, times, depths, or viewpoints.

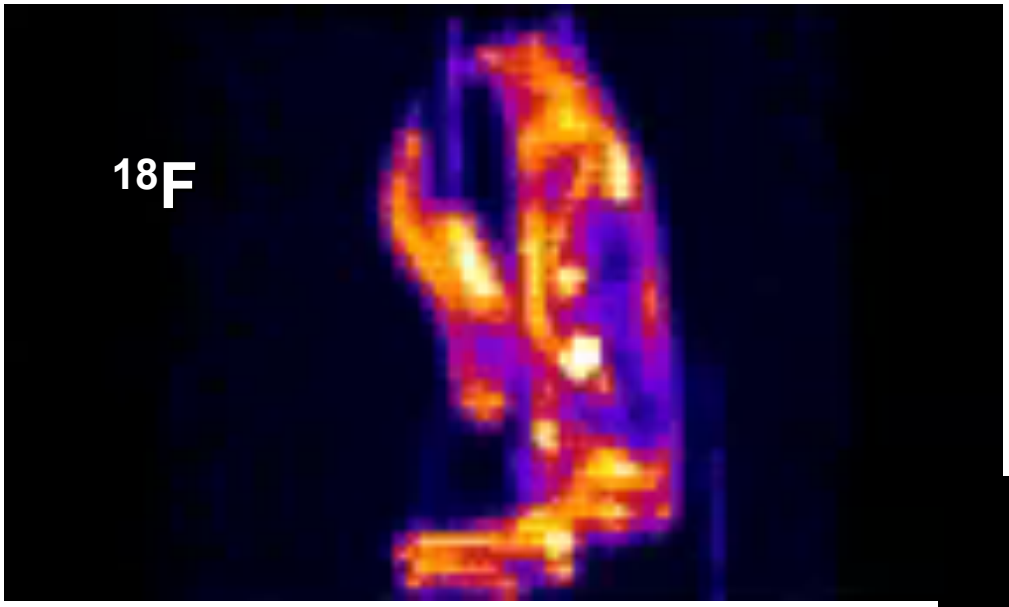
- Registration is necessary in order to be able to compare or integrate the data obtained from these different measurements.

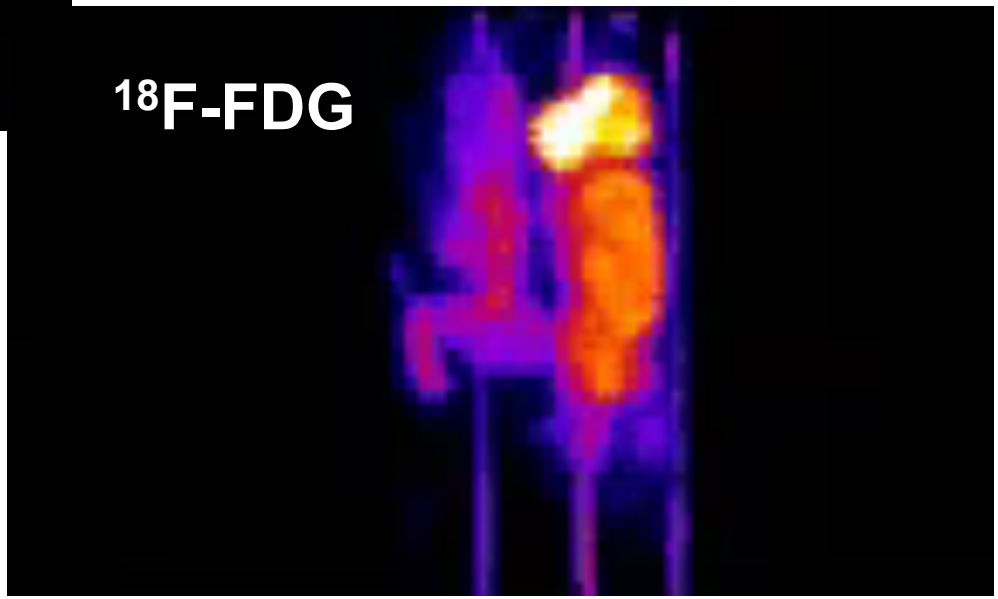


Pharmaco-resistant epilepsy



PET High Resolution



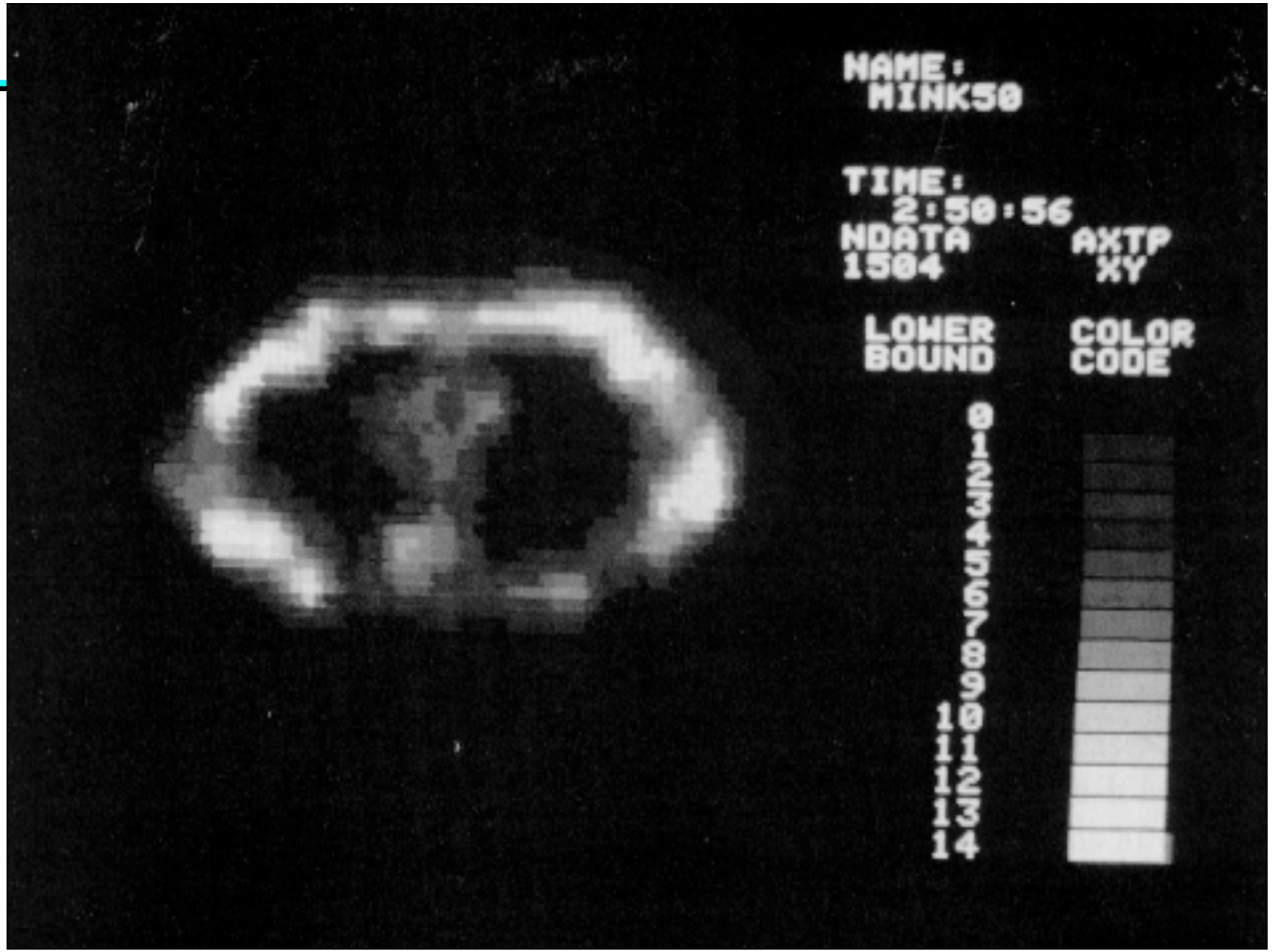


1977

R. Damadian
L. Minkoff
M. Goldsmith

1st MRI's body

Smithsonian Institute
Washington


NAME:
MINK50
TIME:
2:50:56
NDATA
1504
AXTP
XY
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BOUND
COLOR
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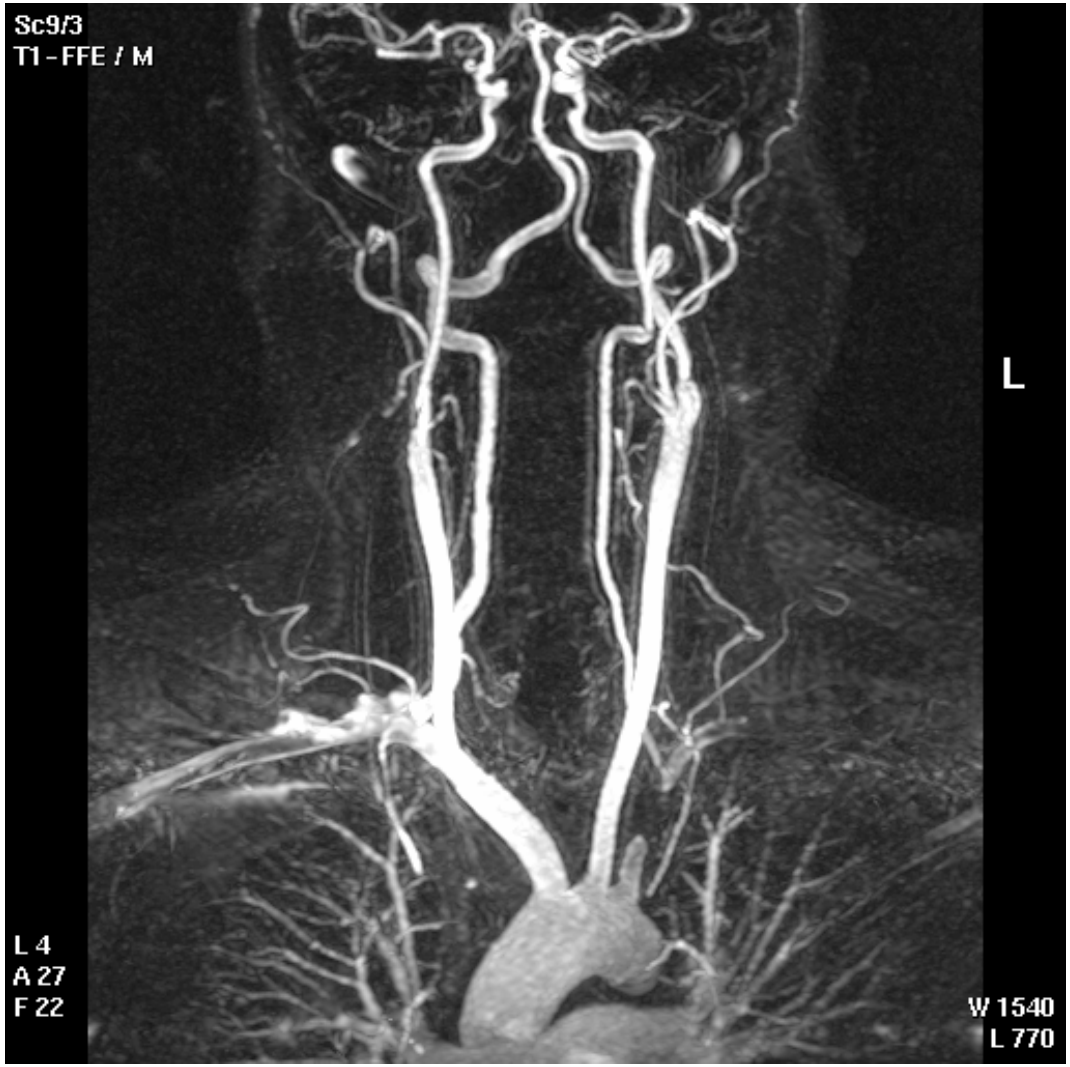
9
10
11
12
13
14

MRI

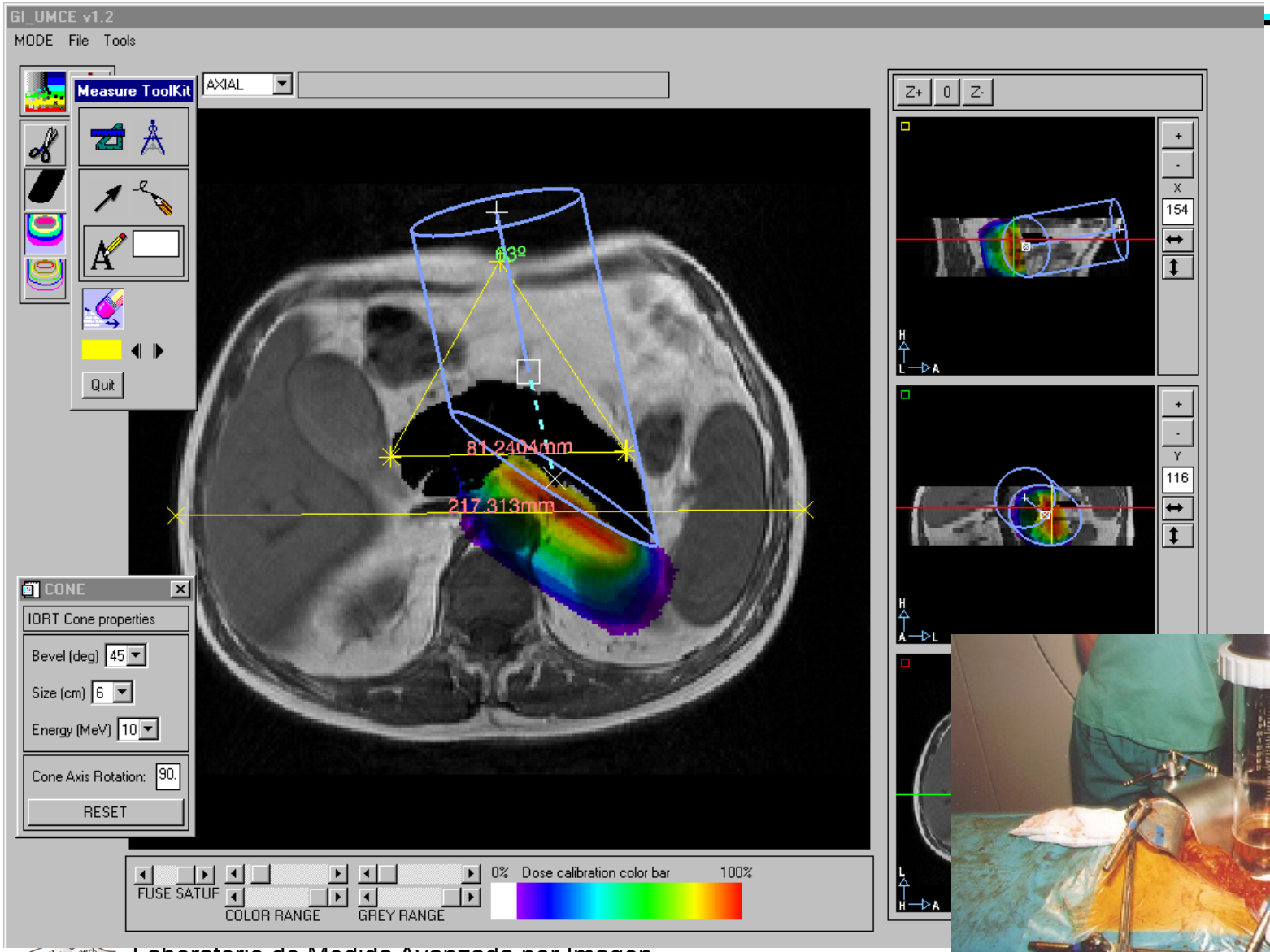
T1-FFE

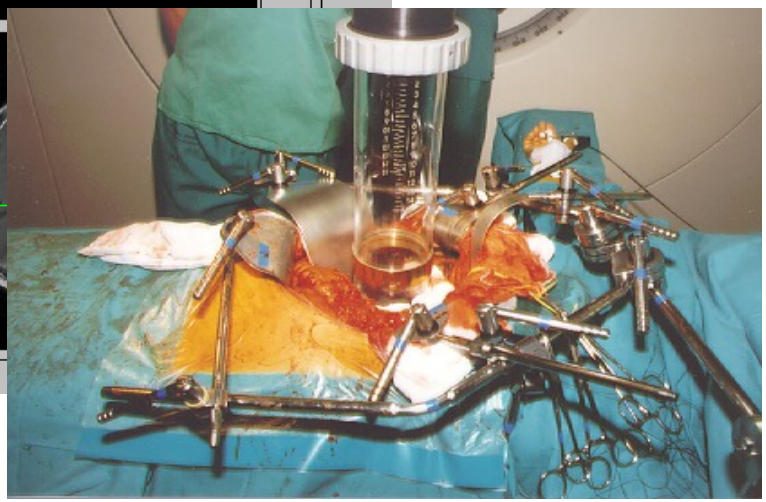
TR 140 ms
TE 4,5 ms
NEX 1
slices 45
thick 3 mm
FOV 300 mm
Acq.time 24 s



Robo de la subclávea

IORT





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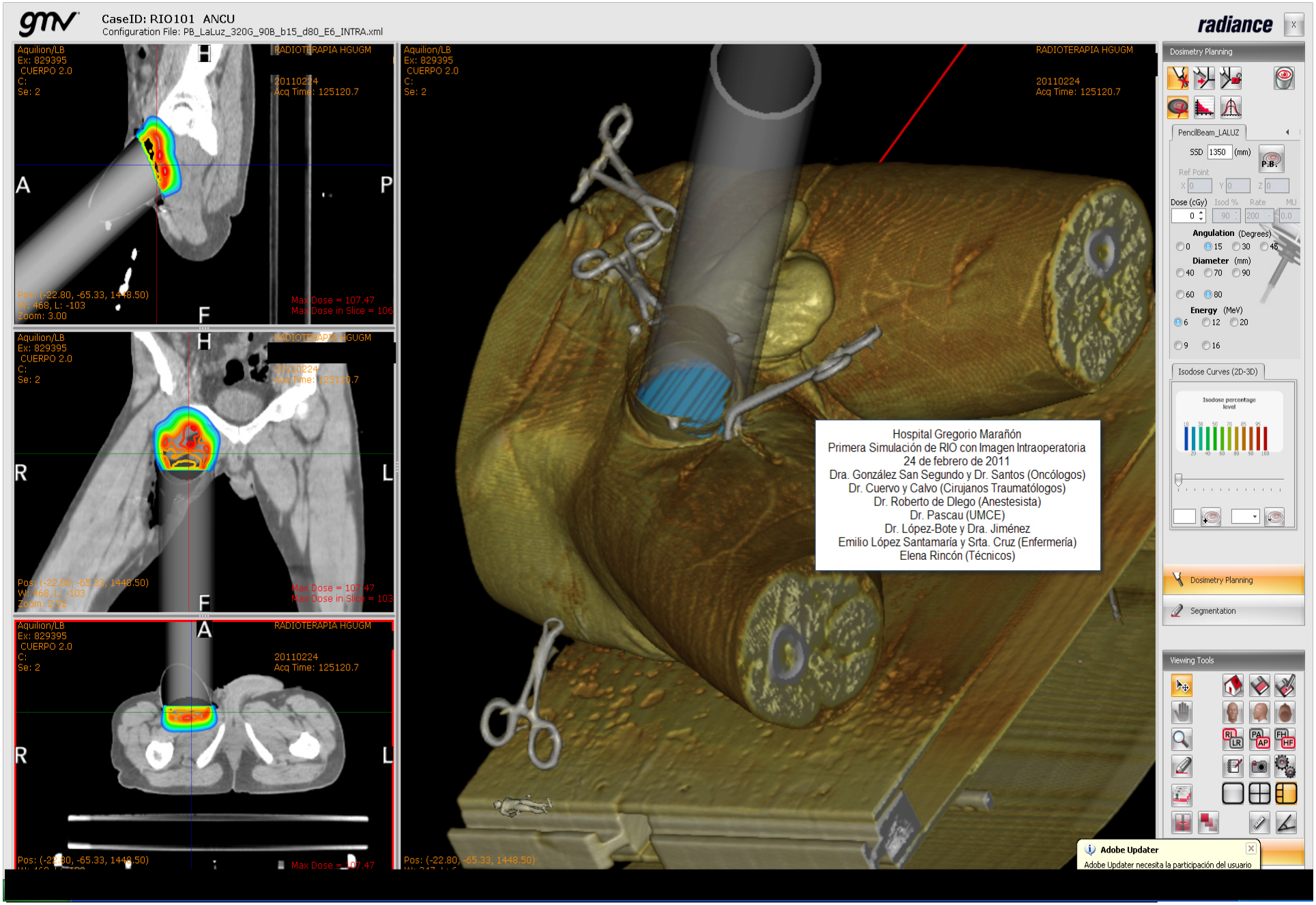

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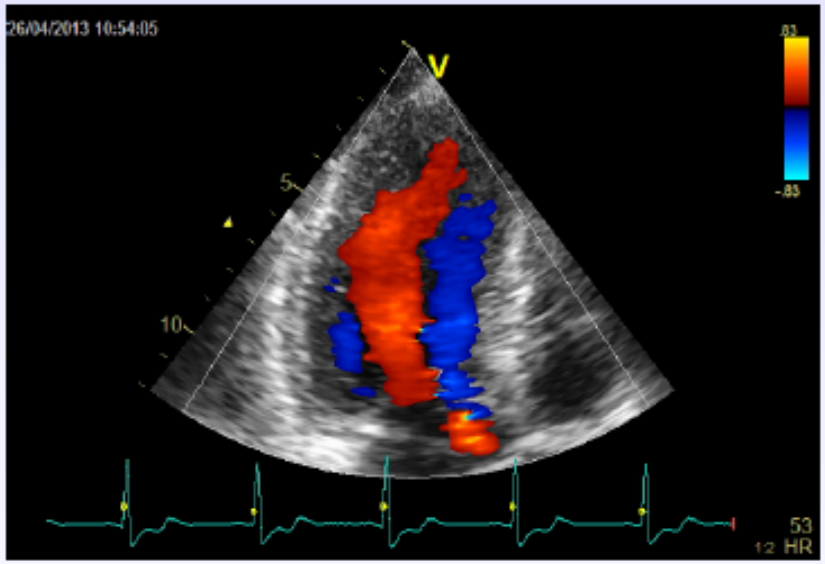
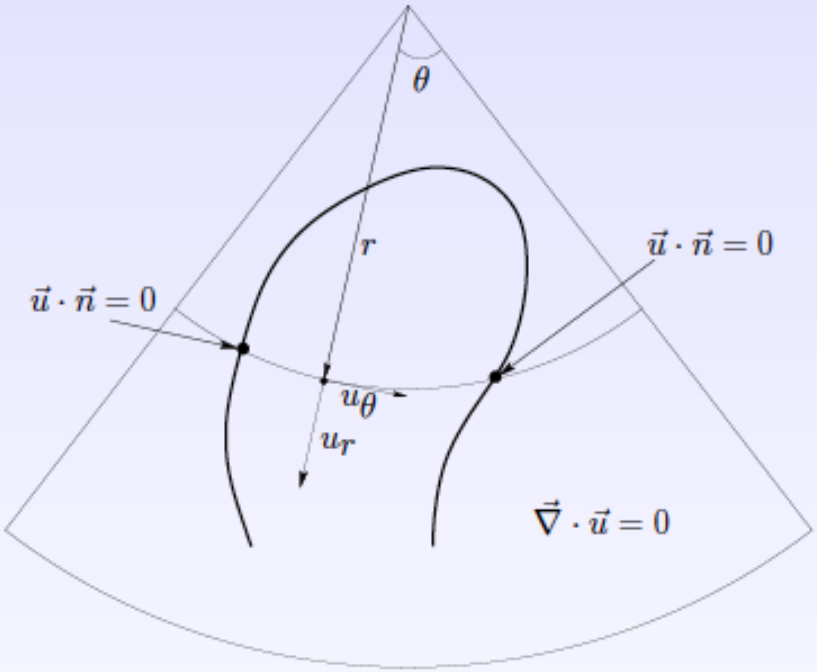
2D+t color Doppler velocimetry

- How to obtain the 2D velocity field from Doppler echocardiography?
- Hypothesis: Planar flow in the apical long axis view of the LV





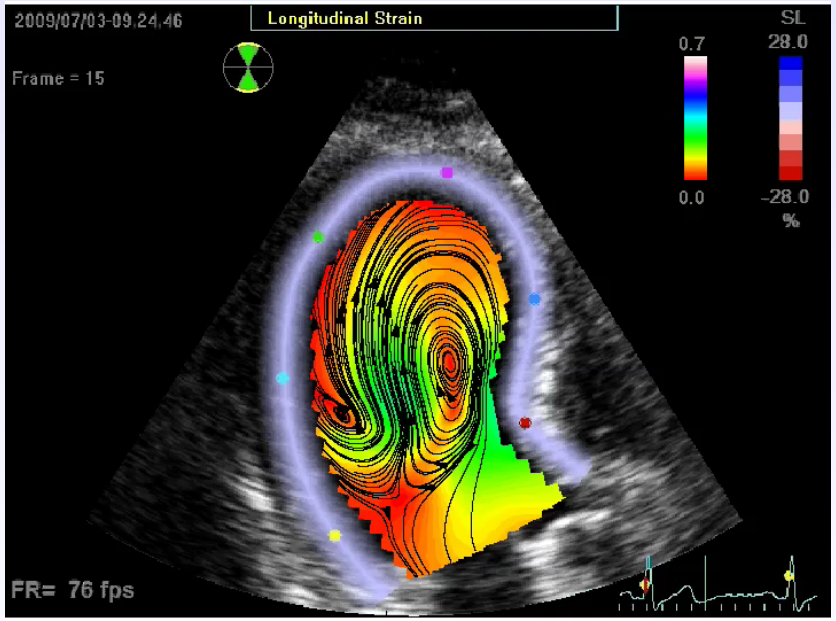
- Solution: choose linear combination of u_θ^1 and u_θ^2 that minimizes $|u_\theta^1 - u_\theta^2|$

D. García IEEE Trans Med Imaging. 2010

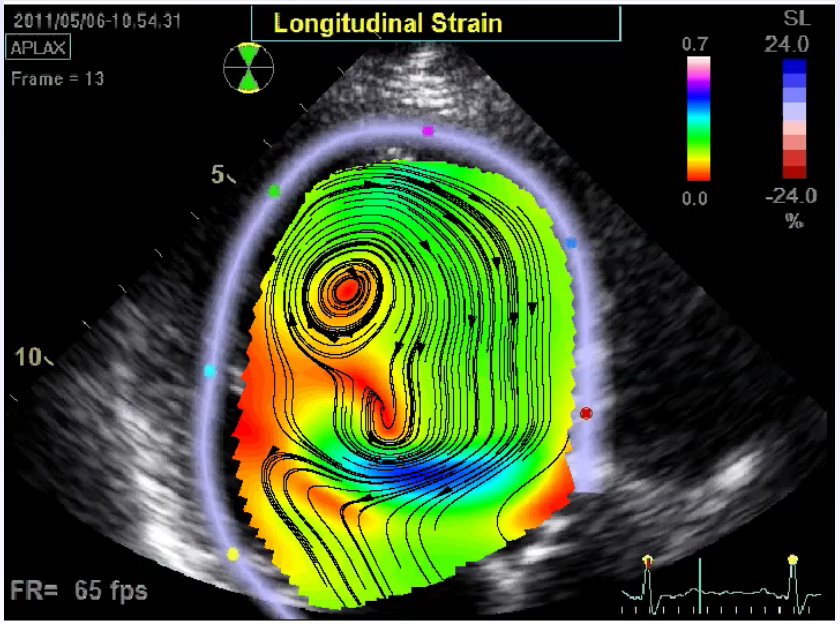
Clinical Setting

- The 2D+t color Doppler velocimetry captures the formation and evolution of the intraventricular vortex.

My heart (hopefully healthy!)

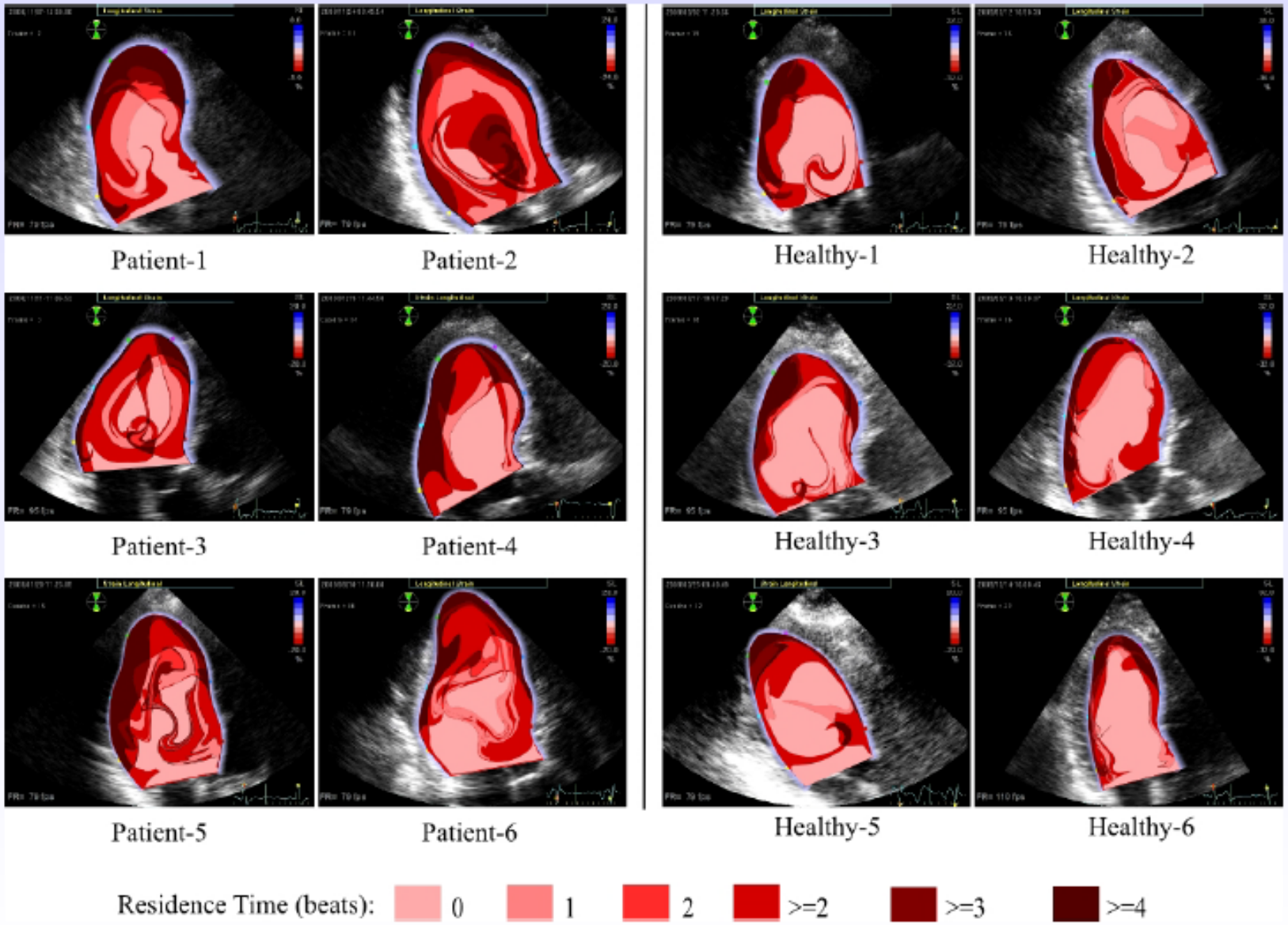


Severe Dilated cardiomyopathy

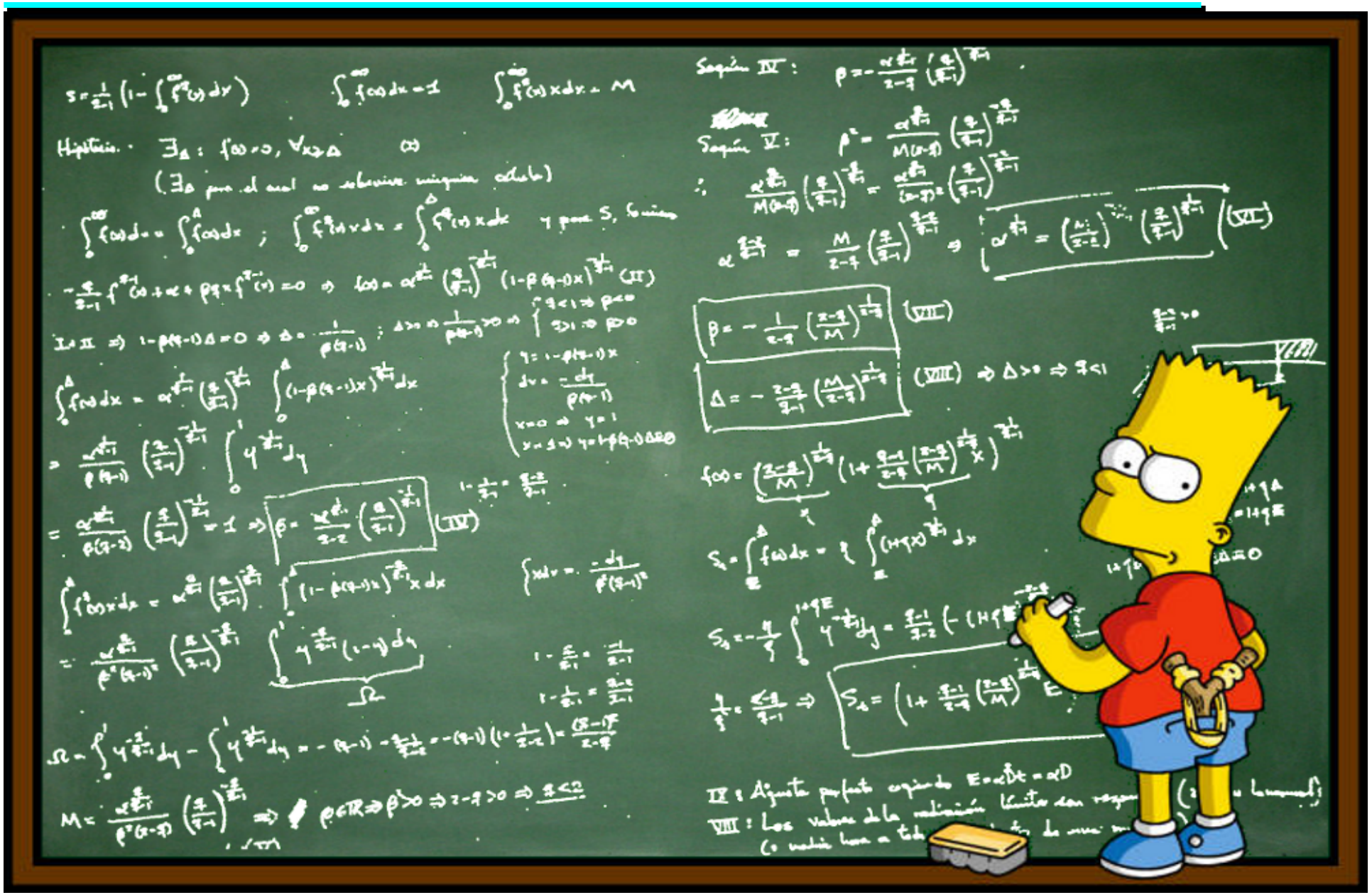


Vortex Contribution: Mixing

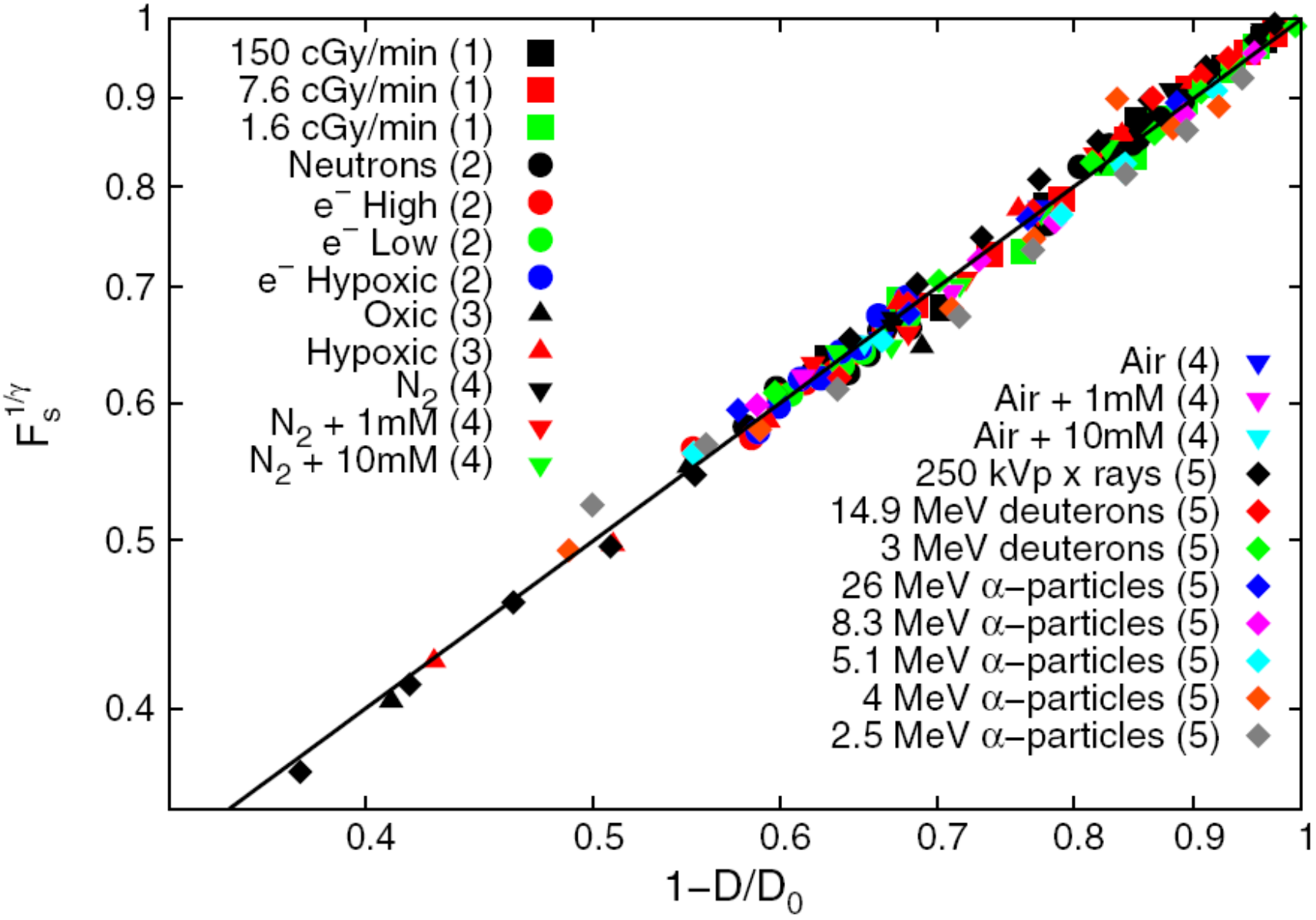
- NIDCM and Healthy



Radiobiología



$\varepsilon = -(D-D_0)/D_0$; $\mathrm{Log}(F_S) = \gamma \mathrm{Log}(\varepsilon)$



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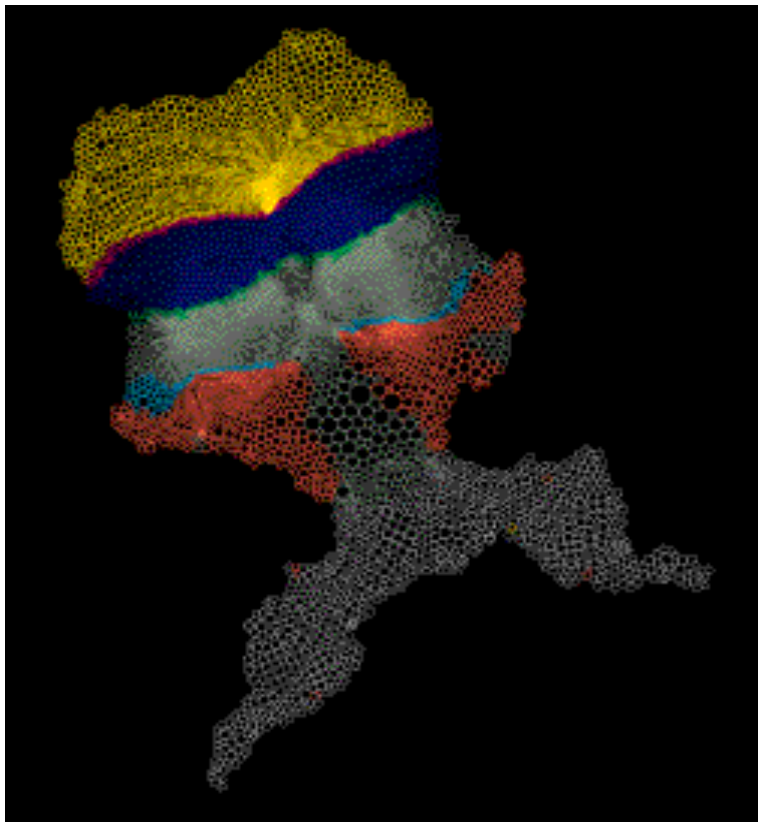
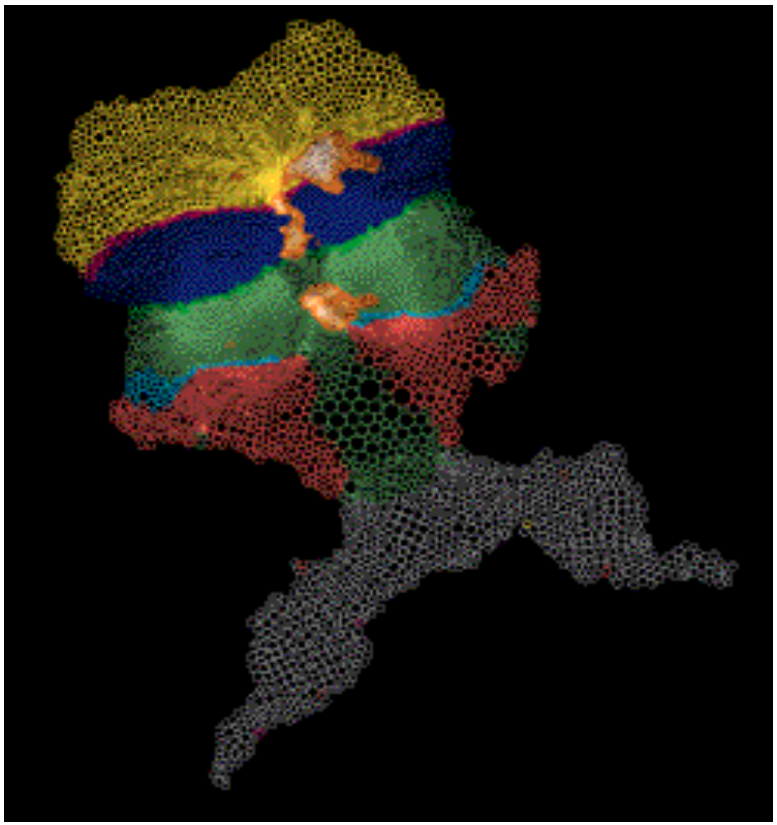
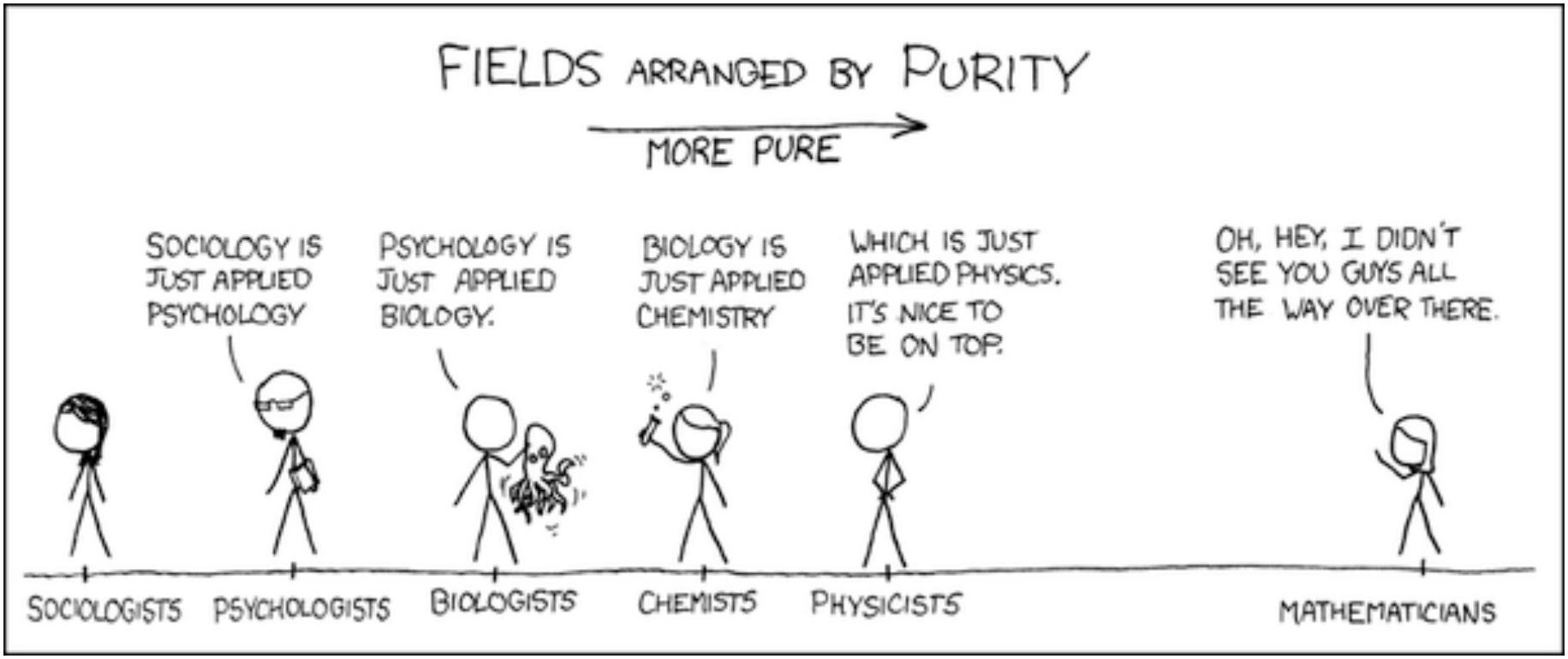
Euclidean Flat Map





So far and so close!



Maths, Physics and Medicine

- Maths and Physics
  - Both ahead of their time
  - Solve nonexistent problems
  - Physics links concepts with real things, mathematics does not need it.
- It was not new but was not applicable
  - Electronics (Quantum physics)
  - Computing (Mathematics)

Where can math help out?

- **Too big**--biosphere
- **Too slow**--macro evolution
- **Too remote in time**--early extinctions
- **Too complex**--brain, stock market
- **Too small**--molecular structure
- **Too fast**--photosynthesis
- **Too remote in space**--life at the extremes
- **Too dangerous or unethical**--epidemiology of infectious agents, war weapons and strategies

Joel Cohen, Rockefeller University

Interference areas in Medicine

- All you are able to think
  - Medical imaging
  - Oncology
  - Cardiology
  - CNS
  - Cellular mechanics
  - And many other unkonwn fields to me

Mathematics & Medicine

Imperial College London

Imperial celebrates Pride

New way to predict when electric cars and home batteries become cost effective

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Mathematics in Medicine

Medicine has become increasingly reliant on mathematics in recent years. Differential equations and statistics have long played a role, but recent medical advances have involved the use of mathematics in new and exciting ways, such as the role of geometry and topology in:

- modelling potential drug targets;
- predicting cardiac defibrillation;
- comparing human brains;
- screening treatments for harmful side effects.

Our goal is to highlight how mathematics – with an emphasis on these subdisciplines – supports both medical research and treatment, and to involve the broader public in discussions of the future of this research.

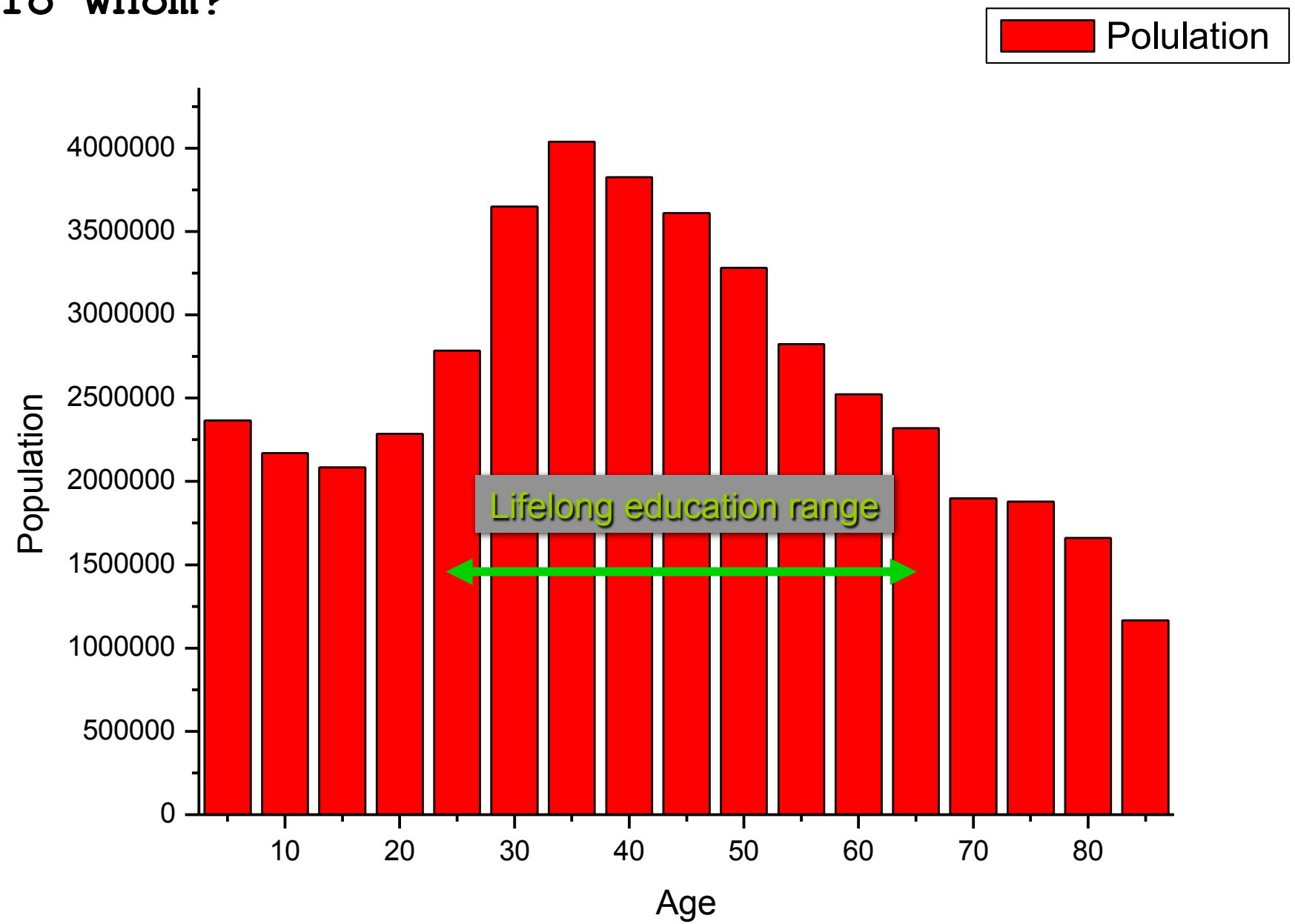
Gold-standard

- Medical Physics studies
- AAPM: An applied branch of physics concerned with the application of the concepts and methods of physics to the diagnosis and treatment of human disease. It is allied with medical electronics, bioengineering, and health physics.
- ACMP: It means that branch of physics that is associated with the practice of medicine. The term Medical Physics, as it is used here, includes radiological physics, therapeutic radiological physics, diagnostic imaging physics, medical nuclear physics and medical health physics.

- AAPM: American Association of Physicists in Medicine
- ACPM: American College of Medical Physicists

What?
Why?
Where?
How?
To whom?

To whom?

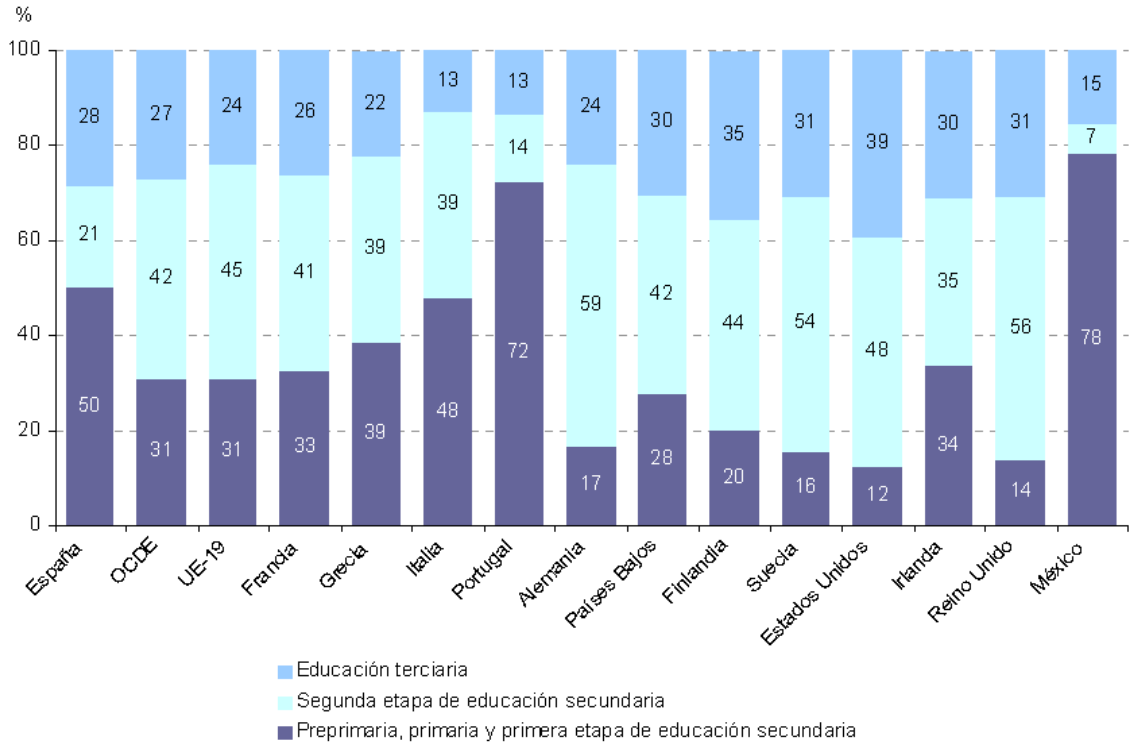

Polulation
Population
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
10
20
30
40
50
60
70
80
Age
Lifelong education range

More data

De los españoles de 25 a 64 años, un 28% posee titulación superior, pero el 50% sólo ha finalizado los estudios obligatorios.

Gráfico A1.1a (extracto de la Tabla A1.1a)

Nivel de formación de la población adulta (25–64 años) (2006).



Organization for Economic Co-operation and Development report, September 2008

Traditional vs distance learning student

- Plenty of time
- Studying in a groove
- Want to be told what they need to know
- Limited life experience
- Not in a position to pay full cost

- Limited time
- Highly motivated but "out of practice"
- Usually have specific learning needs
- Highly relevant life experiences to share
- May be able to pay full cost

Traditional vs distance learning

- Teacher is source of knowledge
- Learners receive knowledge
- Learners work by themselves
- Tests given to assess progress
- All learners do the same thing
- Teachers receive initial training
- Good learners identified

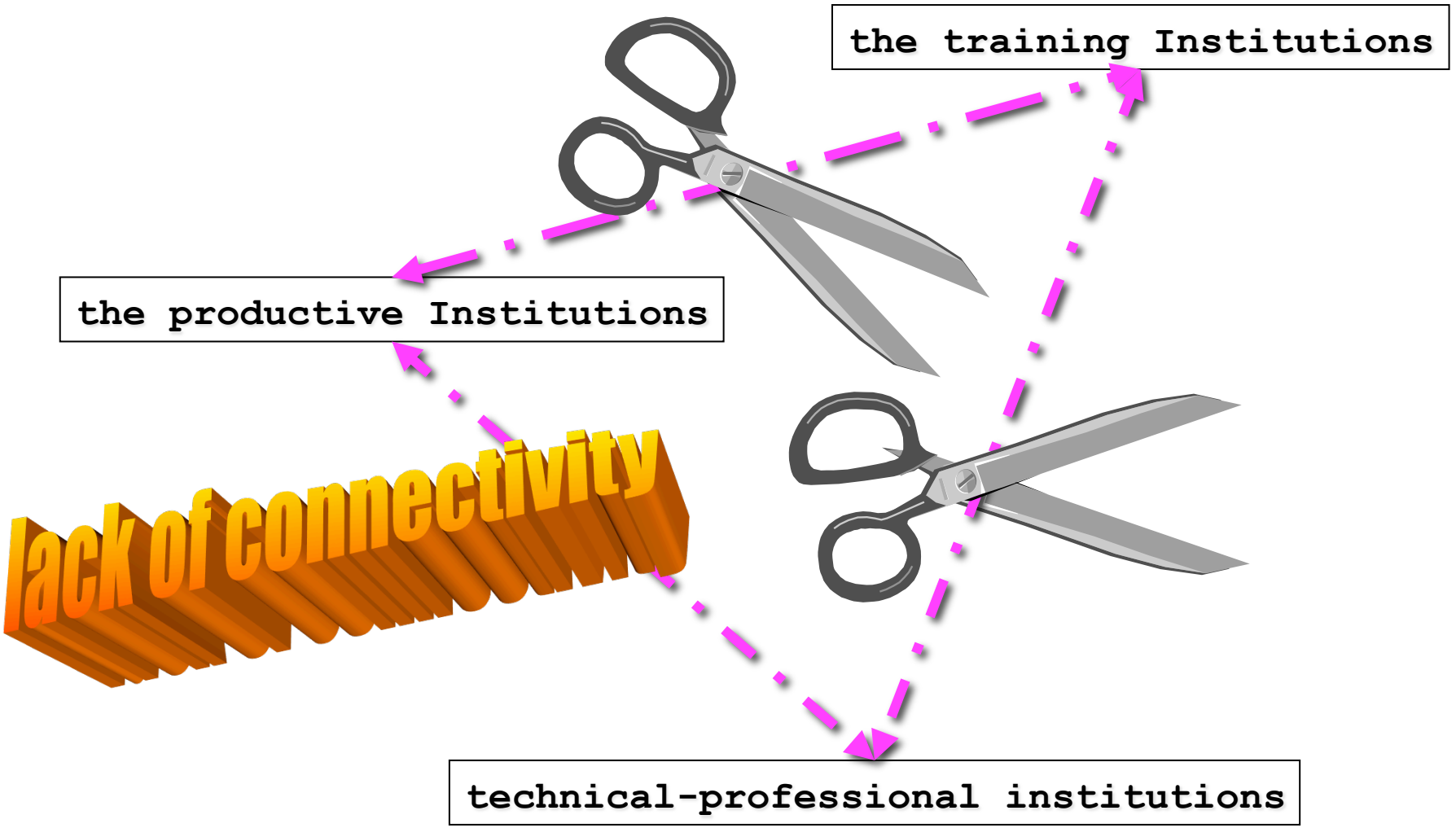
- Educators are guides to knowledge
- Discontinuity learning
- People learn by doing
- People learn in groups
- Assessments guide learning
- Individual learning plans
- Educators are lifelong learners
- Access to lifetime learning

Economic differences

- Traditional
  - most funding already committed
  - motivation is to improve quality of teaching
  - no new money
  - must work with existing system
- Distance learning
  - creating new business
  - motivation is to serve new markets
  - new students bring additional income
  - can work alongside existing system

	Undergraduate	Graduate
Course	Tens	Hundreds
Student	Thousands	Tens
Teacher	Tens	Tens
Student/Teacher rate	High	Below ten
Teacher specialization	Low-Medium MA, MSc, PhD	High-Very High PhD
Cost	Low	Very high

To take into account



Thinking on … Spain …

Lifelong formation in Europe
is twice than
lifelong formation in Spain

How is it possible to talk about
the communication/knowledge society
with
a 50% of scholar failure?

What?
Why?
Where?
How?
To whom?

Master en Tecnología e strumentación Biomédica: pasado y presente

JC Antoranz, M Desco⁺ y A Santos&*

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gen

Instituciones

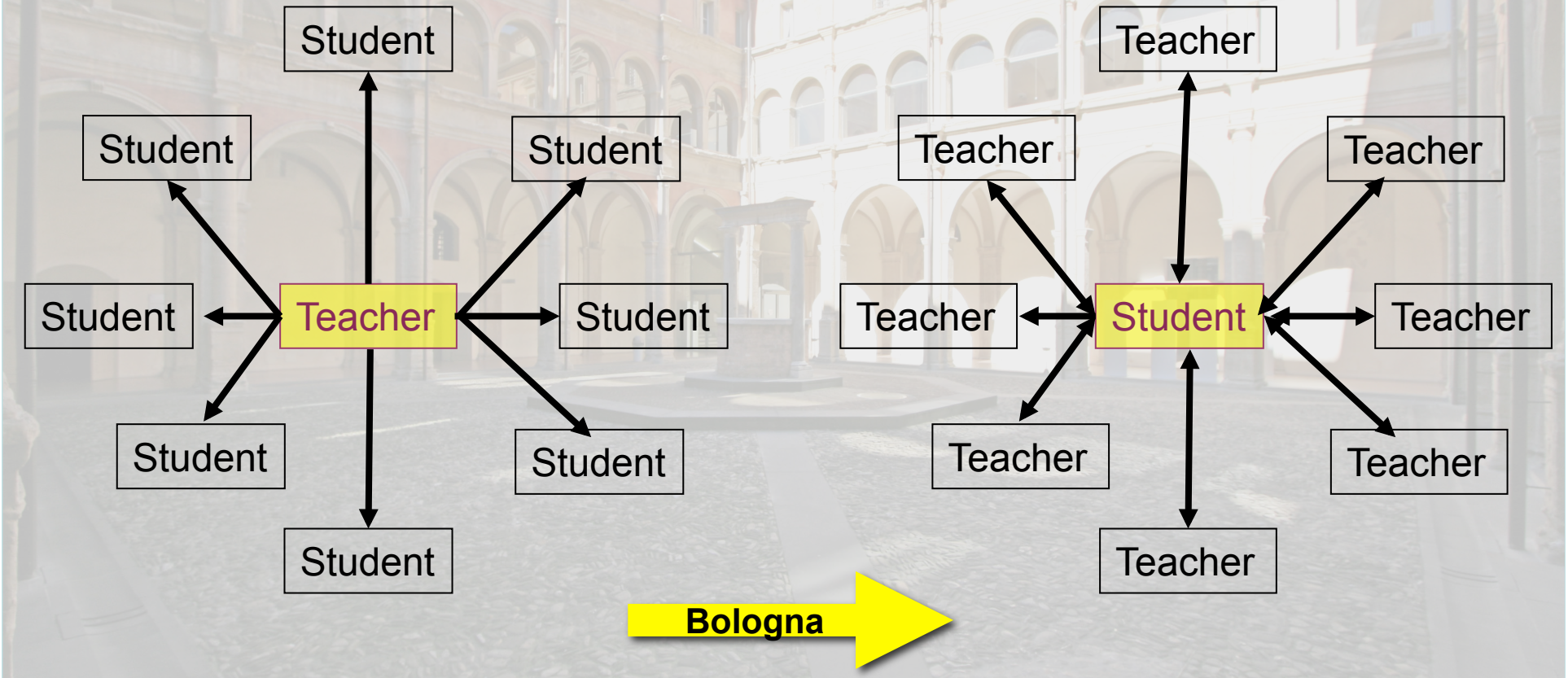
- UNED
- HGGM
- UPM
- Univ. Valladolid
- UPV
- UPC
- Univ. Miguel Hernández
- MSD
- Univ. Sevilla
- ONCE
- GesMédica
- BioEM de Alcalá
- Inst. Biomecánica de Valencia
- CNM
- Univ. Pompeu Fabra
- NIH
- UAM
- UCM
- Inst. Salud Carlos III
- Univ. Rey Juan Carlos

- 21 centros y más de 40 profesores

European Space for Higher Education (ESHE)

Evidence-based medicine

P4 Medicine: Predictive, Preventive, Personalized & Participatory



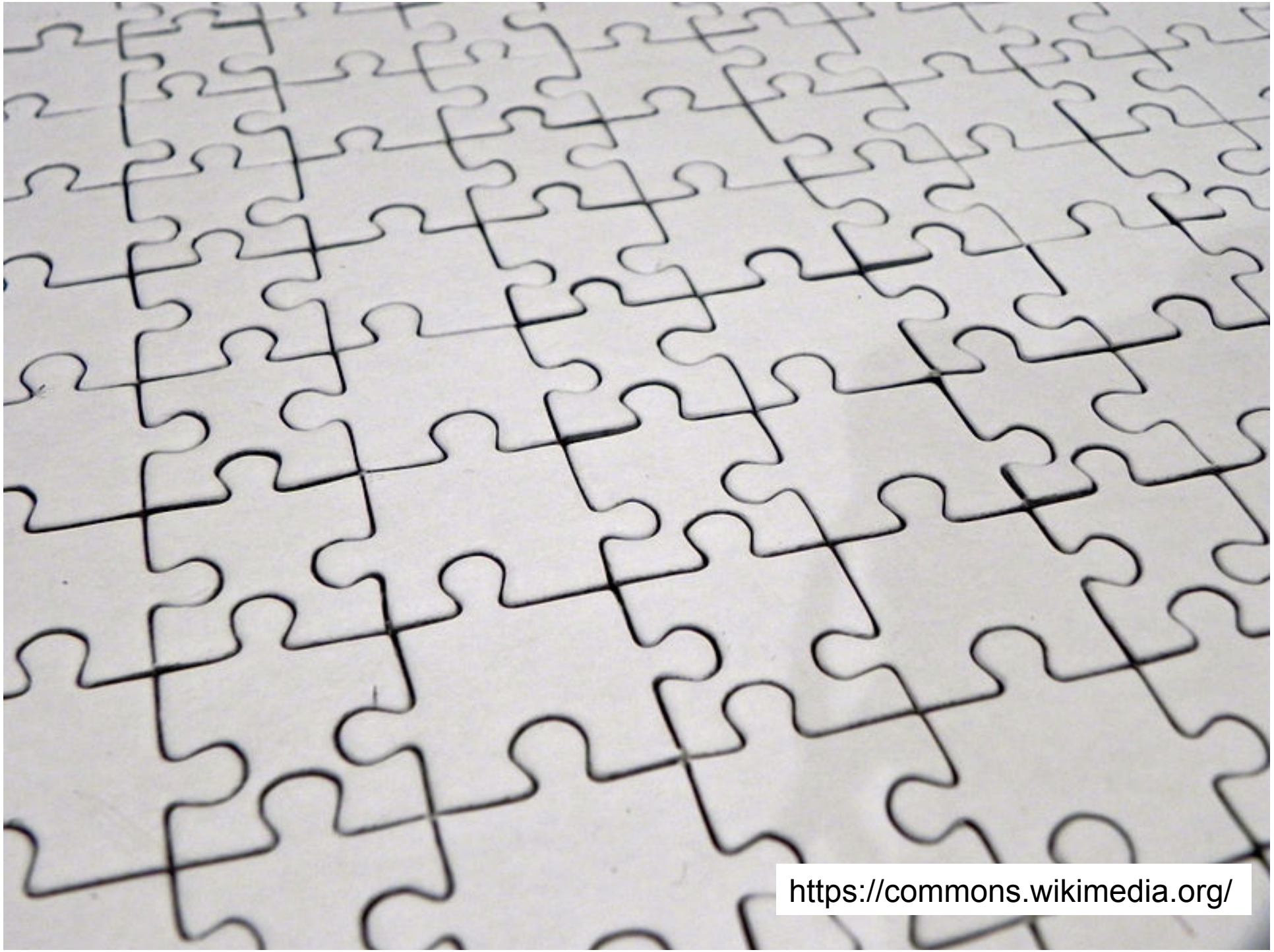
Egocentrism-geocentrism-like theory

Copernican-like theory

Copying Harvard & Oxford

- "*Only once … no more*" *(1985)**
- Old idea but new scenario
- Be needs not technology driven
- Apply Ockham's Razor
  - If you hear *hoof* beats, you should look for *horses*, not zebras
- Develop self-sustained models
- Create students!!
- The goal: To be the best

"Through this revolutionary restructuring of the traditional medical curriculum, HMS students acquire not only the core scientific, biomedical, and clinical expertise they need to become successful physicians but also the analytical tools, adaptability skills, and flexible attitudes they require to become lifelong learners."


https://commons.wikimedia.org/

Por Objetivos

miércoles, 19 de diciembre de 2007
8:52:40

Objetivo	Materia	Asignatura	Tema	Obj. Aprendizaje
Amplificadores: ganancia y ancho de banda				
	Física	Electrónica	El amplificador operacional (AO)	Conocimiento
	Física	Electrónica	Técnicas básicas de análisis de circuitos	Conocimiento
	Física	Electrónica	Amplificación con transistores	Conocimiento
Biología celular: DNA-RNA-proteina				
	Biología	Biología Celular	Información genética, codificación, expresión y regulación	Conocimiento
	Biología	Principios básicos de Bioquímica	Aspectos moleculares del cáncer	Conocimiento
	Física	Fisica Biomédica I	Electrobiología: efectos biológicos del campo magnético	Conocimiento
	Biología	Principios básicos de Bioquímica	Patología molecular y Terapia génica	Conocimiento
	Biología	Principios básicos de Bioquímica	Genoma	Conocimiento
Biomateriales				
	Física	Fisica Biomédica II	Biopolímeros y cinética enzimática: Fenómenos competitivos y cooperativos	Conocimiento
Biomecánica				
	Física	Fisica Biomédica I	Mecánica del múscilo cardiaco	Conocimiento
	Física	Fisica Biomédica I	Mecánica de la marcha humana	Conocimiento
	Física	Fisica Biomédica I	Estática	Conocimiento
Cargas en movimiento				

MP Master Features

- 120 ECTS* in four semesters
- Different paths depending on previous studies and objectives (CAC)
- 1rst & 2nd semesters to obtain a common base to face real medical physics studies
- Practices
  - Hospital (HGGM) and faculty (UC3M)
- One student one tutor (“personal tracking”)
- 1rst & 2nd semesters are selective

*European Credit Transfer and Accumulation System

Master on Medical Physics

Master on Medical Physics

Course	Medicine			Biology			Assoc. Degree			Physics			Chemistry			Mathematics			Engineering		
	A	R	P	A	R	P	A	R	P	A	R	P	A	R	P	A	R	P	A	R	P
Math. Medical Physics I																					
Math. Medical Physics II																					
Modern Physics																					
Atomic & Nuclear Physics																					
Optics & Electromagnetism																					
Numerical Methods																					
Mathematical Physics																					
Cellular Biology																					
Physiology																					
Anatomophysiopathology I																					
Biochemistry																					
Anatomophysiopathology II																					
Adaptive ECTS	42	42	42	42	42	42	54	54	54	36	36	36	54	54	54	48	48	48	54	54	54
Biomedical Physics I																					
Biomedical Physics II																					
Medical Imaging I																					
Medical Imaging II																					
Physics of Fluids																					
Image Processing																					
Interaction of radiation & matter																					
Radiation Protection																					
Biological systems (B.S.) modeling																					
Numerical solutions of B.S. models																					
Medical Instrumentation																					
Decision Theory in Medicine																					
Biostatistics																					
Applied Electronics																					
Master dissertation																					

Profile Codes
A: Academic
R: Research
P: Professional

Color codes
- Course not allowed for a given profile
- Optional course (6 ECTS)
- Basic course 3rd & 4th semesters (6 ECTS)
- Basic course 1st & 2nd semesters (6 ECTS)
- Master dissertation (Research profile with 18 ECTS)
- Master dissertation (Academic & Professional profiles with 6 ECTS)

Medicine-Technology-Physics

- 4+2 (6 Medicine) years formation
- Knowledge expansion (+x2,'73-'78,'03-'08, +x3, '09-'15)
- (*)OMICS era starts
  - Genomics, Proteomics, Transcriptomics (set of all messenger RNA (mRNA) molecules produced in one/population of cells)
  - Cellulomics
    - Xenotransplant, Cellular reproduction, Tissue and organs engineering
  - Metabolomics
- Medical Imaging
- Nanomedicine
- New technologies
- Knowledge gap is, at least, a linear function of time

*omics informally refers to a field of study in biology ending in the suffix -omics

And our students are …

- Coming from:
  - 65% “Hard Science”
  - 35% “Soft Science”
- Working on
  - 45% related to MP
  - 55% not related to
- Unemployed
  - 6% unemployed
  - 0,5% retired

Virtual courses: aLF

- aLF platform
  - UNED own e-learning tool
  - community oriented design
- Measurements
  - access and login time logging
  - ¿related to success?
    - AI index

$$AI = \frac{\text{Total access time}}{\frac{\text{Number of visited documents}}{\text{Number of sessions}} - 3}$$

Activity-interest index

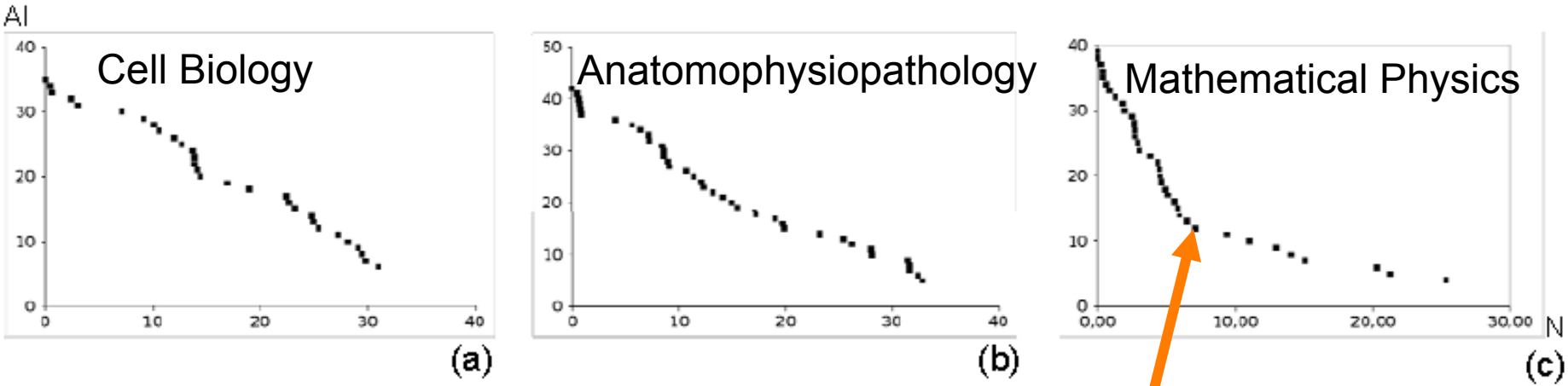


Figure 1: Activity-interest index (AI) and final marks for the three more populated subjects of the CAC. Upper row (a-c) AI accumulated histogram: number of students (ordinates) having AI larger than that that given by the abscissas.

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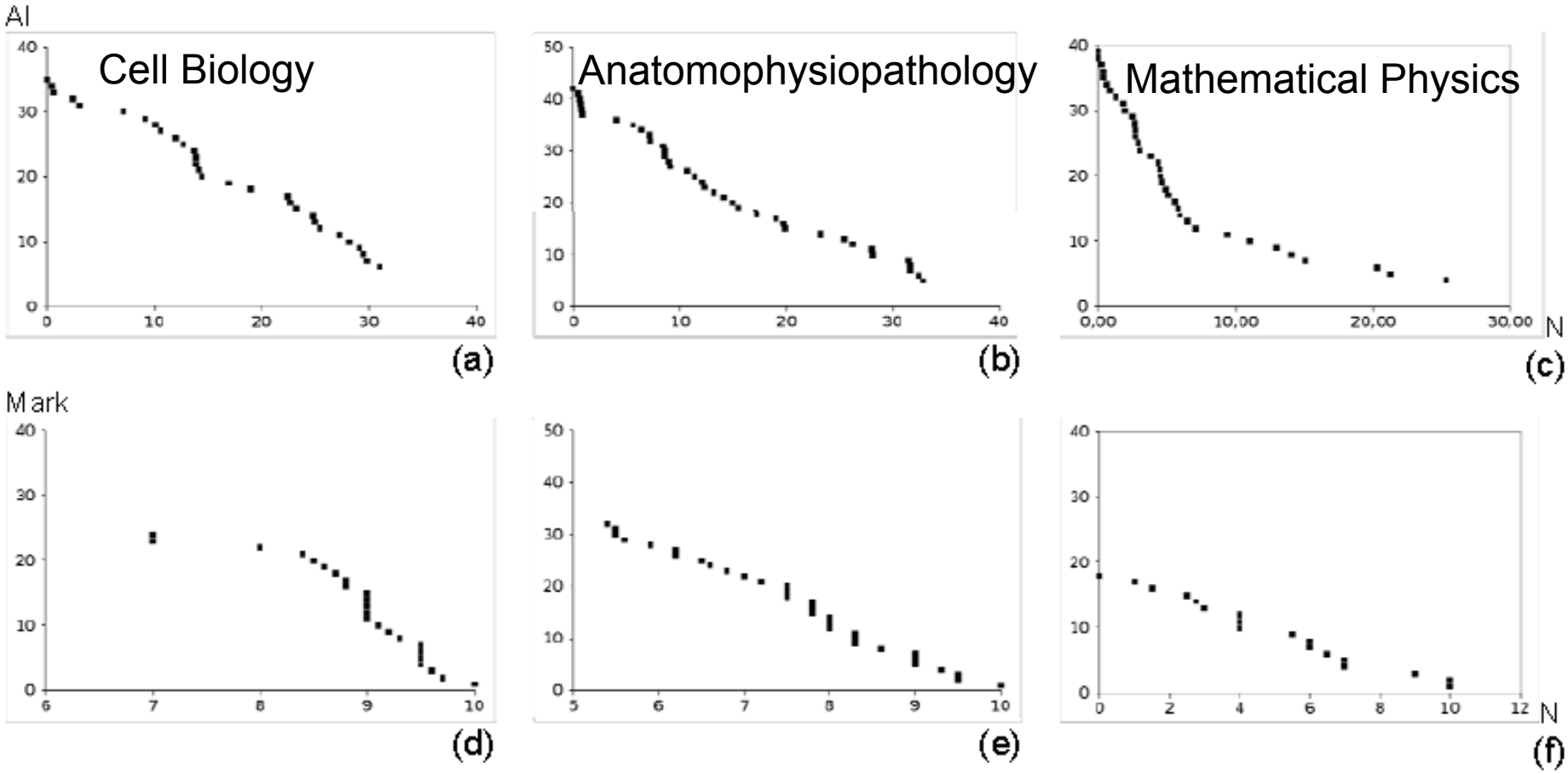
Activity-interest index



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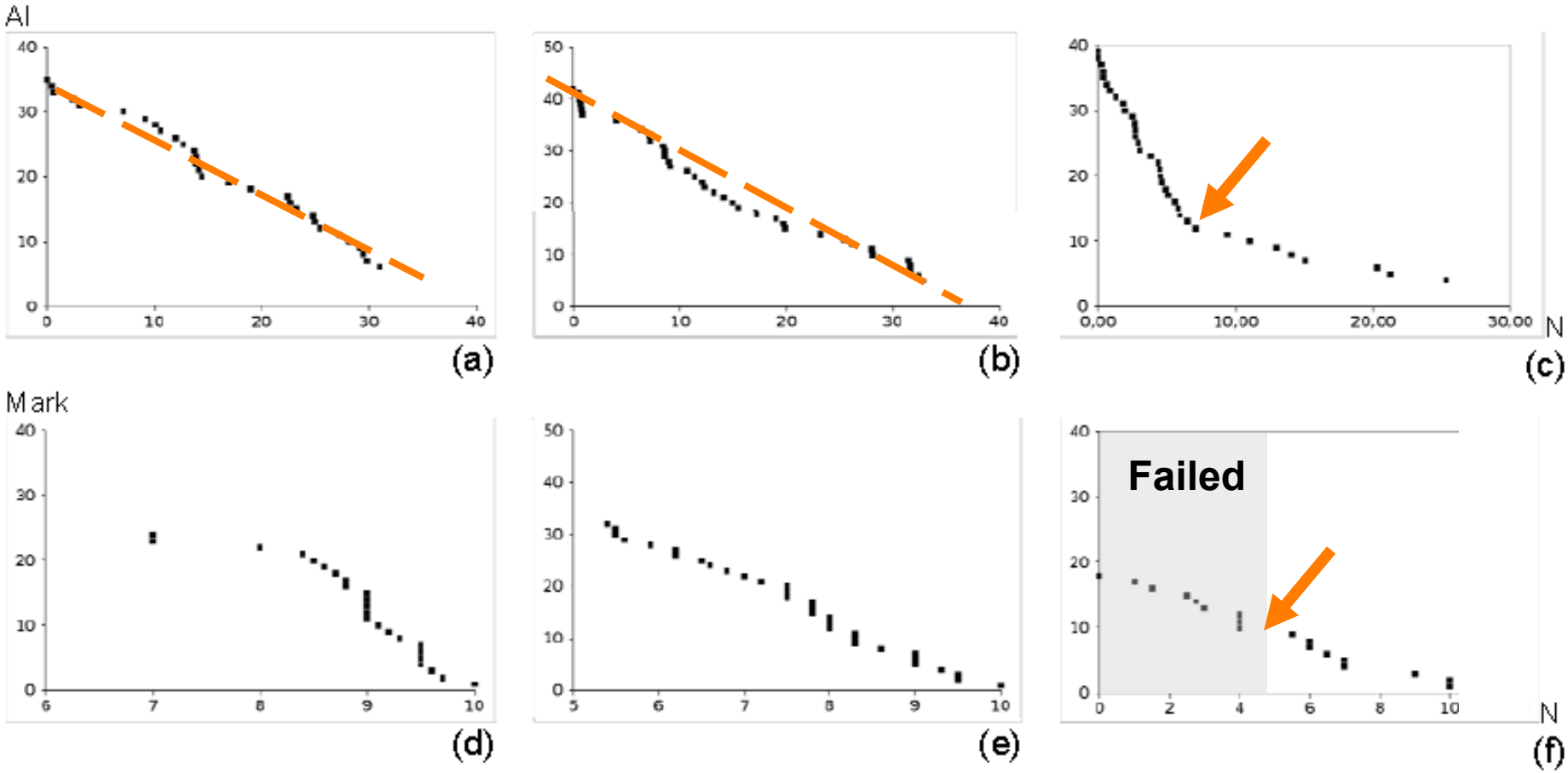

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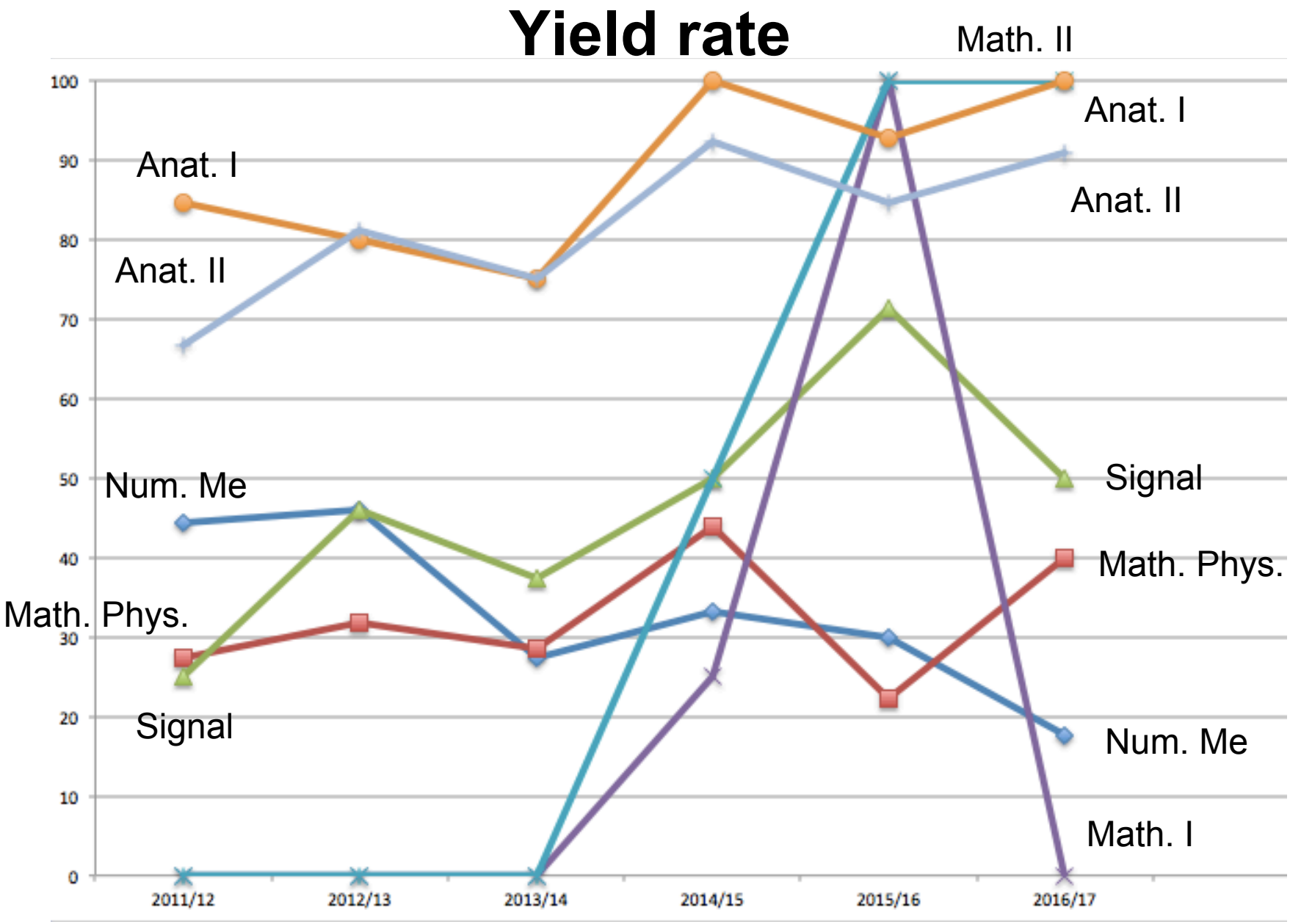
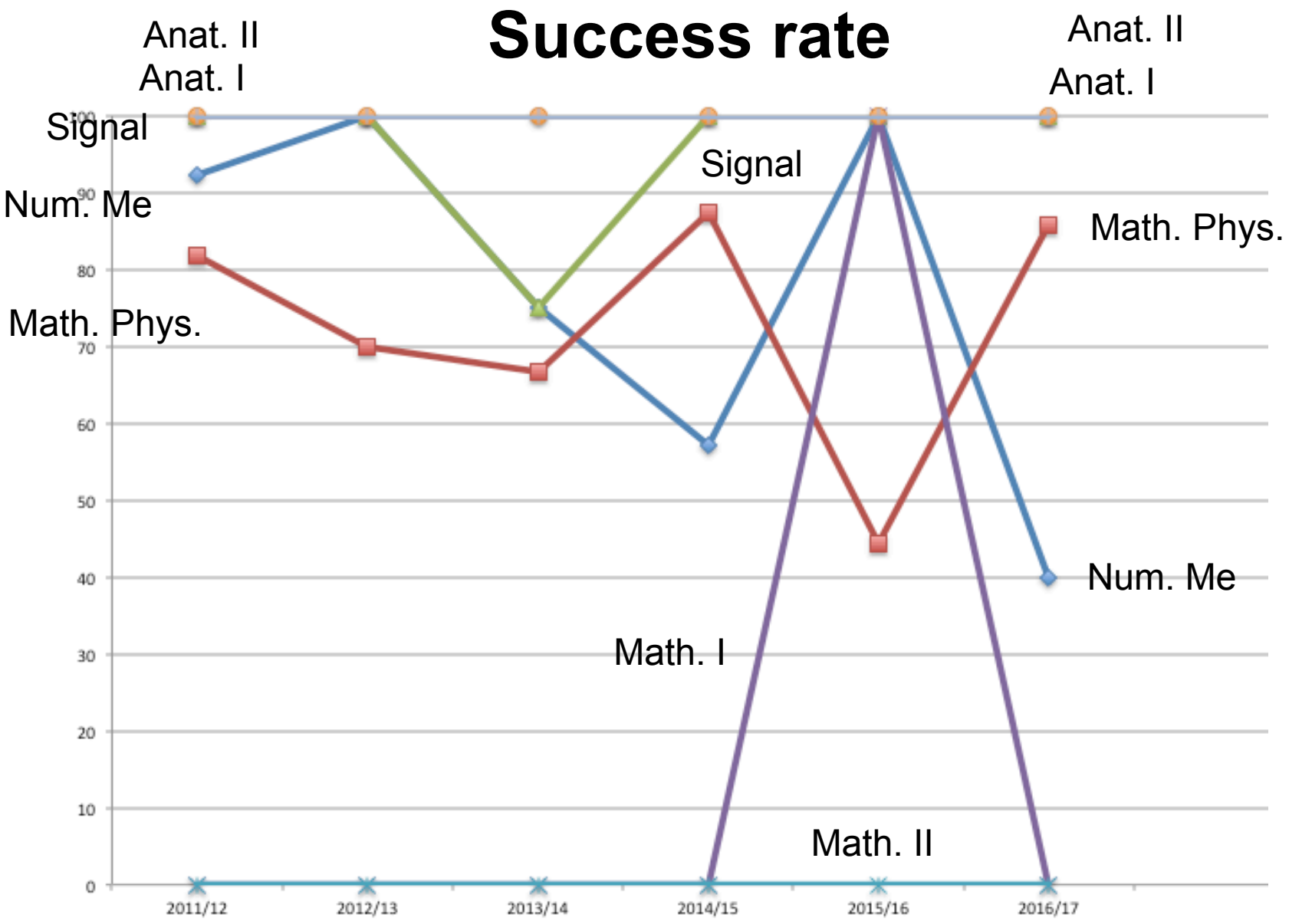
Master results

- Dropout rate is 58%
- Average residence time in the master's degree is 5.5 years

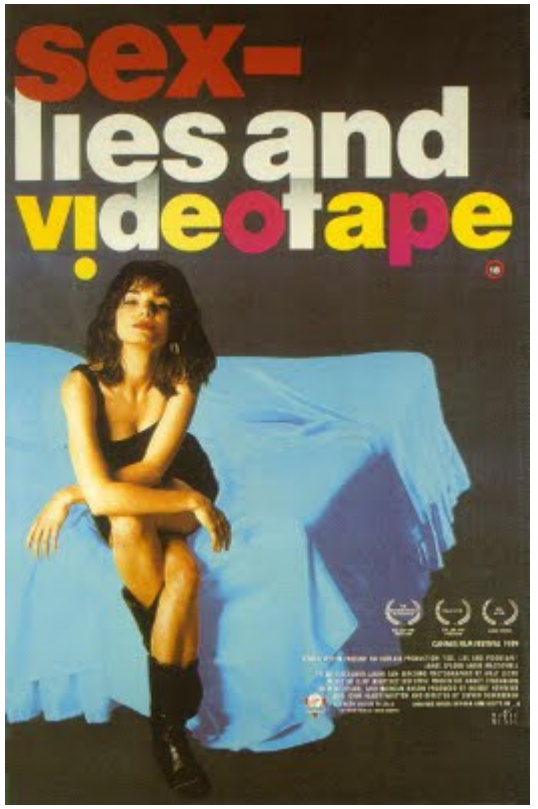
	Number of graduates	Average mark	Average success rate%
2010/11	3	-	-
2011/12	3	8,04	95,86
2012/13	1	8,07	98,19
2013/14	3	8.07	93,14
2014/15	6	8,0	95,45
2015/16	6	8,05	93,60
2016/17	4	7,98	93,69
2017/18	1		


Yield rate
Math. II
Anat. I
Anat. I
Anat. II
Anat. II
Num. Me
Signal
Math. Phys.
Math. Phys.
Signal
Num. Me
Math. I
100
90
80
70
60
50
40
30
20
10
0
2011/12
2012/13
2013/14
2014/15
2015/16
2016/17


Success rate
Anat. II
Anat. I
Signal
Num. Me
Math. Phys.
Math. I
Math. II
Anat. II
Anat. I
Signal
Math. Phys.
Num. Me
100
90
80
70
60
50
40
30
20
10
0
2011/12
2012/13
2013/14
2014/15
2015/16
2016/17

But … “Sex, lies and videotapes”

- 30 ECTS*30 hours=
  - 900 hours/semester
- 1 semester ⇔ 180 days
- 180*5/7= 128 work days
- 900/128⇔7 hours/ day
- Really 4 months ⇔
  - 10 hours/day



And our conclusions

- Our broad open MP Master has attracted the attention of a broader audience due to the Curricular Adaptation Course (CAC)
- Initial formation is a key point, something inherited from our former master on Bioengineering and Medical Technologies
- The e-learning platform or the time dedicated by the average student do not correlate with the assimilation of the new information

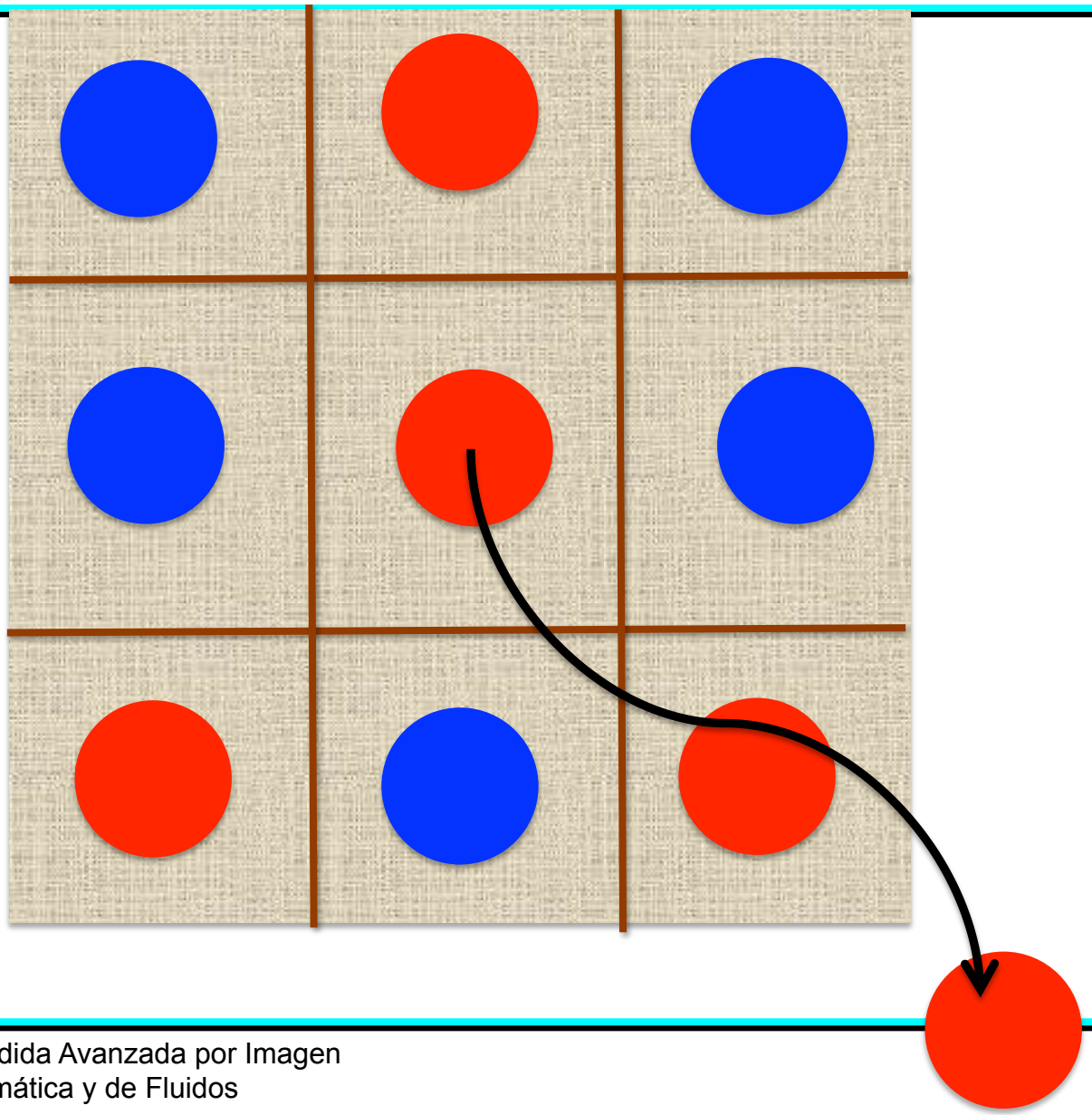
And our conclusions

- The former curriculum does correlate, even in the case of our complementary CAC, where the students coming from more technical disciplines outperform those from health and biological areas
- It is connected to the higher average success in bio-health subjects (nearly 100% success) compared to technical subjects (nearly 50% success)


Yes!
We can do it;
anything,
anywhere,
any time.


Doctor, doctor, during the last week I've not been able to sleep, nor eat, nor drink. What do you think it happens to me?
I think that you are sleepy, hungry and thirsty.
True but useless

Think outside the box, please!



Thank you for your attention