(MICRO-)GRAVITY RESEARCH IN LIFE and PHYSICAL SCIENCE

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DESC : Dutch Experiment Support Center
Dept. Cranial-Facial Surgery / Dept. Oral Cell Biology
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European Erasmus course : "Evolution of the biosphere : Origins of Life - Life in Space"
09:00-10:30, 25-8-2014, Observatoire Océanologique de Banyuls, France

1

The European Low Gravity Research Association, ELGRA, is a non-profit international society of multidisciplinary character founded in 1979 in London/UK. ELGRA is devoted to the promotion of research under low gravity conditions in Europe. The organization provides a platform for all scientists interested in life and physical sciences in space. Moreover, the aim of the association is to represent and strengthen the scientific community of low gravity research. ELGRA is also devoted to the involvement of young people in research under low gravity by educational programs. ELGRA tries to achieve its goals by:

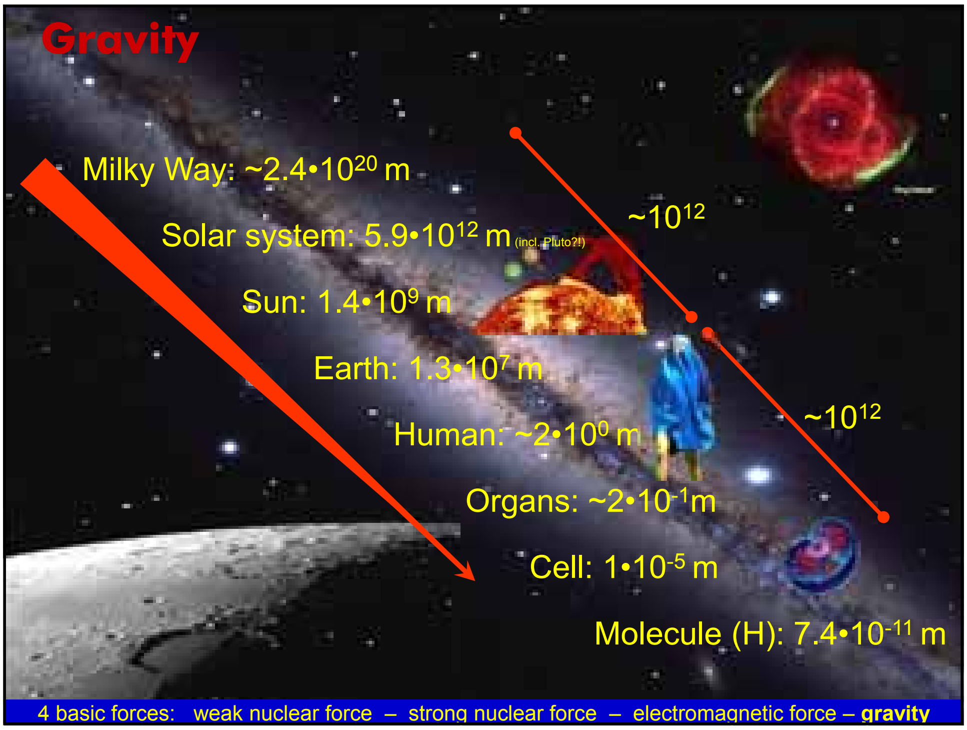
- ✓ Organizing scientific symposia and courses. (Next biennial Symposium and General Assembly is in Vatican City, Rome, 11-15 Sept. 2013)
- ✓ Spreading information among European and national authorities as well as industries
- ✓ Develop and advocate and secure the use of gravity related research on national and international platforms.
- ✓ Supporting students and young scientists at scientific meetings.

Membership is open to individuals as well as corporate bodies, i.e. scientific institutions or companies, engaged in science under low gravity conditions.

ELGRA offers three different types of membership:

- The SELGRA student ELGRA society / membership : Open to any student expressing an interest in the field. There is **no fee** for student membership. [https://www.facebook.com/SELGRA]
- A regular member : Open to individuals or publicly-funded scientific institutions
- A supporting membership : Open to individuals, institutions and companies


ESA – ELGRA education activities
"Fly Your Thesis"
European Parabolic Flight
"Spin Your Thesis"
Hyper-g : special announcement
"Drop Your Thesis"
Bremen & Madrid drop towers
See also ESA session tomorrow
esa
5


Gravity
Milky Way: ~2.4•10^20 m
Solar system: 5.9•10^12 m (incl. Pluto?!)
Sun: 1.4•10^9 m
Earth: 1.3•10^7 m
Human: ~2•10^0 m
Organs: ~2•10^-1 m
Cell: 1•10^-5 m
Molecule (H): 7.4•10^-11 m
~10^12
~10^12
4 basic forces: weak nuclear force – strong nuclear force – electromagnetic force – gravity

Gravity

Galileo Galilei (1564-1642)

Isaac Newton (1642-1727)
'Principia'

Newton's 2nd law: F = m × a

F mostly refer to as ***weight*** (F = m × g)

In our universe, zero gravity exists only in theoretical terms, since there is mass in outer space hence, gravity gradients, as shown by Newton's 'universal law of gravitation'.

$$F_G = G\ (mM / r^2)$$

F_G = the gravitational force
G = the gravitational constant (=6.67×10^{-11} $Nm2/kg^2$)
m = mass of object
M = mass of the Earth
r = distance between the centre of the two masses m and M

g = 0 or 0g

Always:
- µg
- (better) near weightlessness

(Hyper) Gravity (Weight) and Living Systems

Galileo: "Man can not build a house, nor nature can construct an animal beyond a certain size without altering the design or material"

First HG studies by Knight in 1806 using modified water wheel: Plants' show positive and negative geotropism of roots and shoots

Gravity and Terrestrial Life

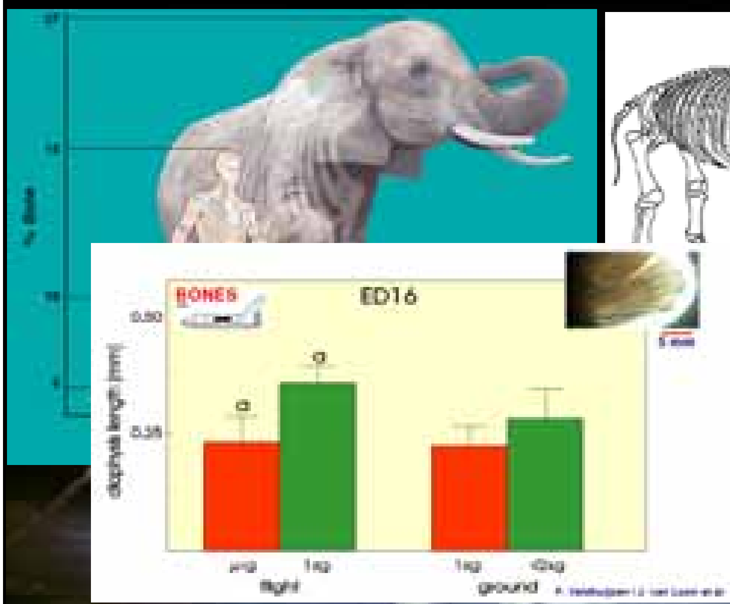
Fossil fish bridges evolutionary gap between animals of land and sea. (*Zina Deretsky, National Science Foundation, 2006)*

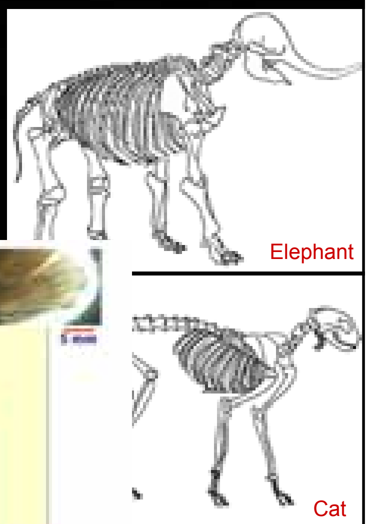
"The skeleton of Tiktaalik indicates that it could support its body under the force of gravity whether in very shallow water or on land," (Farish Jenkins, Harvard Univ.)

Shubin et al., Nature, 2006

9

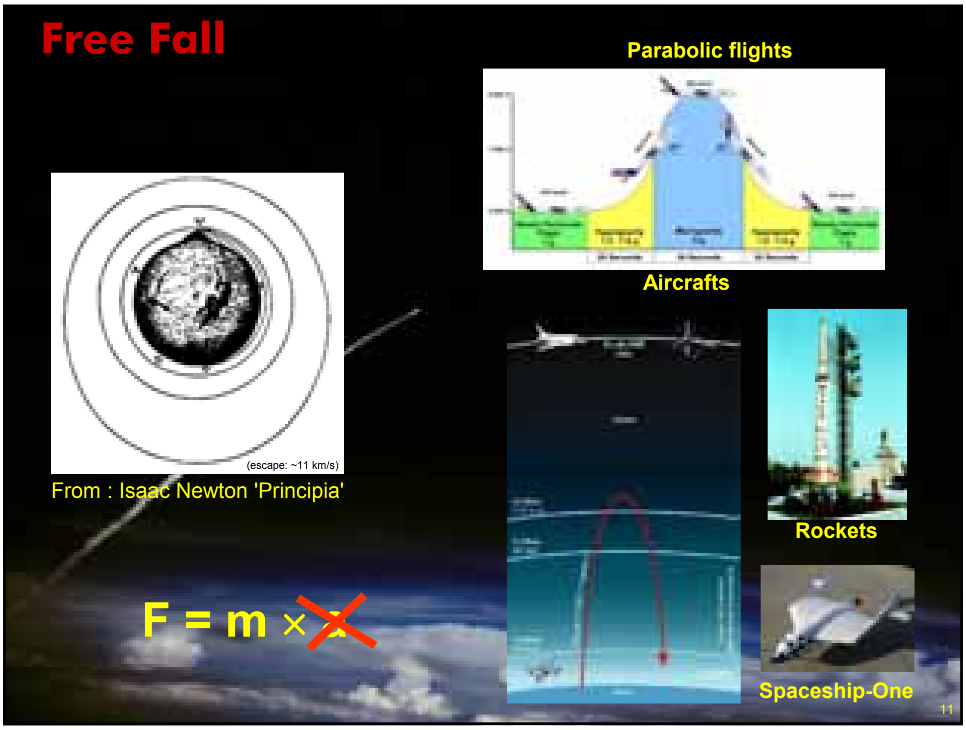
Gravity and Terrestrial Life – 2

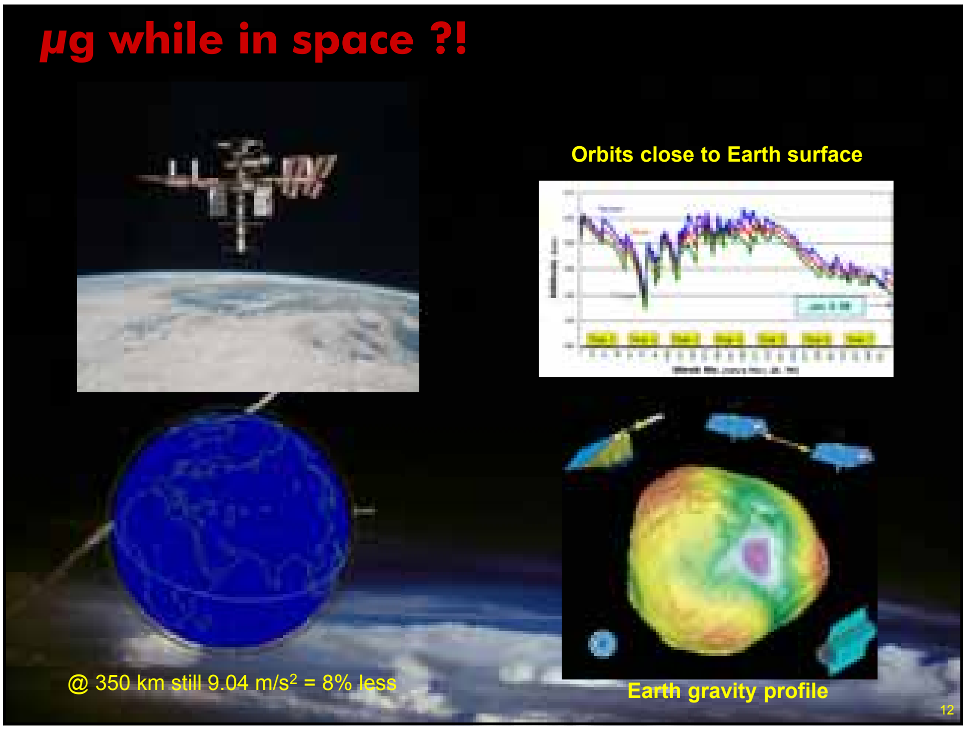


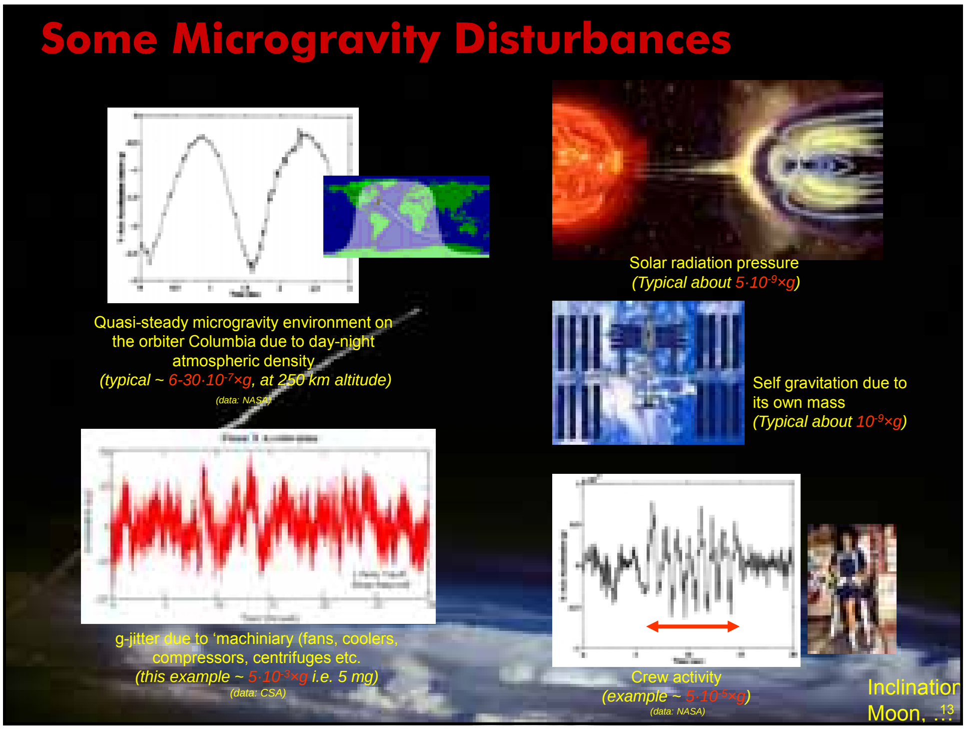


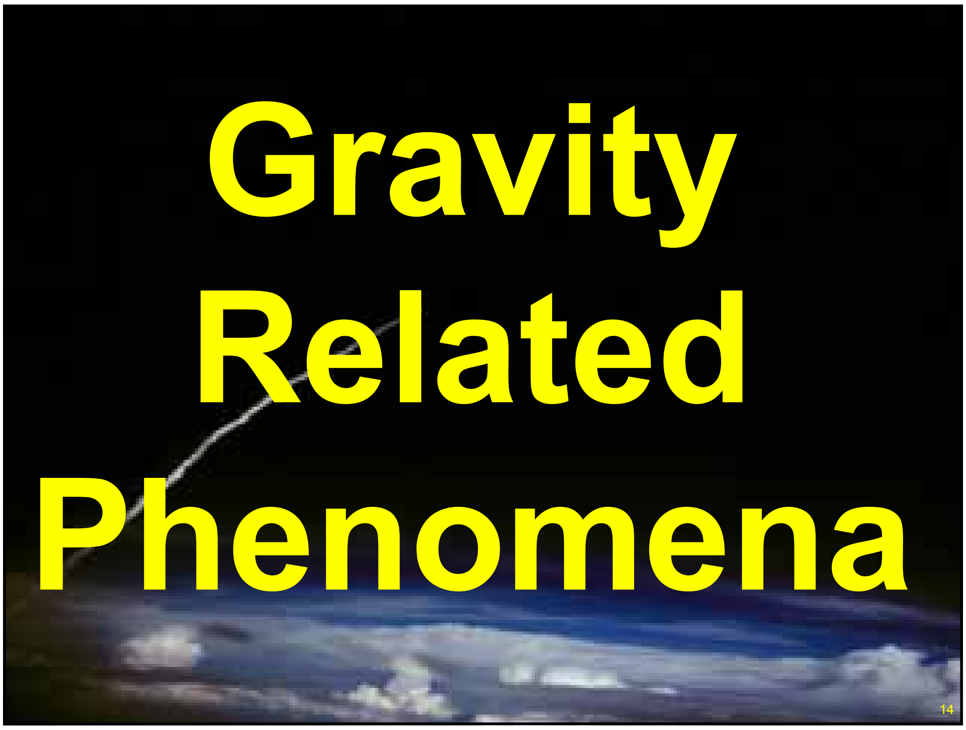
R. Marco et al. 2003

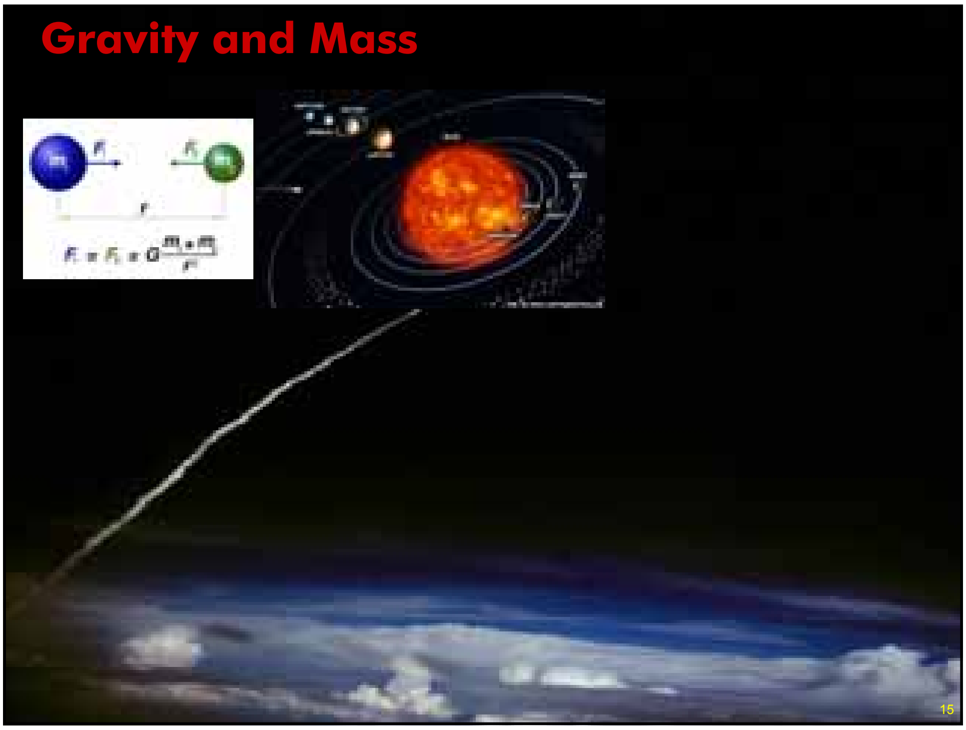
10

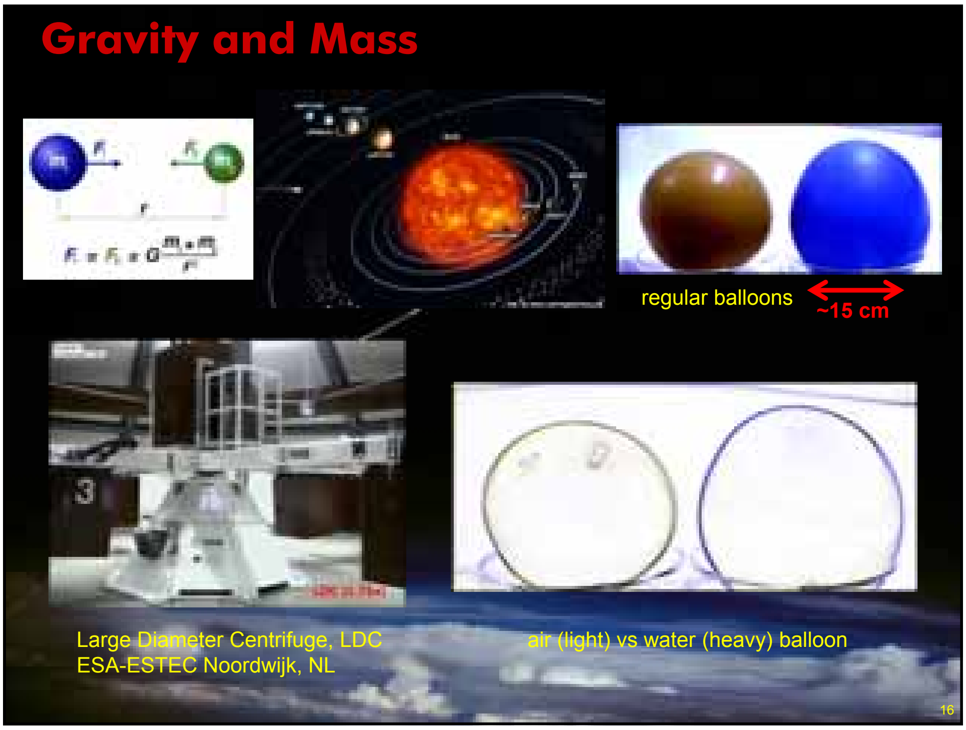

Free Fall
Parabolic flights
Aircrafts
(escape: ~11 km/s)
From : Isaac Newton 'Principia'
Rockets
F = m × a
Spaceship-One
11


μg while in space ?!
Orbits close to Earth surface
@ 350 km still 9.04 m/s² = 8% less
Earth gravity profile
12


Some Microgravity Disturbances
Solar radiation pressure
(Typical about 5·10⁻⁹×g)
Quasi-steady microgravity environment on the orbiter Columbia due to day-night atmospheric density
(typical ~ 6-30·10⁻⁷×g, at 250 km altitude)
(data: NASA)
Self gravitation due to its own mass
(Typical about 10⁻⁹×g)
g-jitter due to 'machiniary (fans, coolers, compressors, centrifuges etc.
(this example ~ 5·10⁻³×g i.e. 5 mg)
(data: CSA)
Crew activity
(example ~ 5·10⁻⁵×g)
(data: NASA)
Inclination
Moon, ...
13


Gravity Related Phenomena
14


Gravity and Mass
15


Gravity and Mass
regular balloons
~15 cm
Large Diameter Centrifuge, LDC
ESA-ESTEC Noordwijk, NL
air (light) vs water (heavy) balloon
16

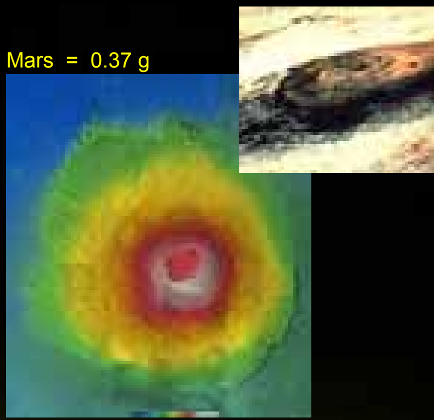
Gravity and Geology

Earth = 1 g

Mount Everest : 8.85 km

× 3 =

Mars = 0.37 g



Mount Olympus : ~ 26 km

The central edifice stands 27 kilometers high above the mean surface level of Mars this is about three times the elevation of Mount Everest above sea level and 2.6 times the height of Mauna Kea above its base. It is 550 km (342 miles) in width, flanked by steep cliffs.

Sedimentation

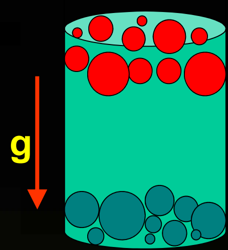
$$F_S = mg - F_B - F_F$$

$$F_S = mg - (\rho f V g) - (6\pi r \eta v)$$

Where:
m = mass of the object (kg)
g = the gravity acceleration (m/s^2)
FB = buoyant force (see below) = $\rho f V g$
ρf = specific density of the fluid (g/cm^3)
V = volume of the displaced fluid (= volume of the object) (m^3)
F_F = frictional force = kv

k = the Stokes equation: 6πrη□ (□for a spherical object)

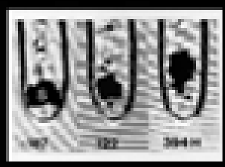
Where:
r = radius of the object (m)
η = viscosity constant (N·s/m^2 or, Pa·s)
v□= object's velocity relative to the fluid (m/s)



By definition, sedimentation force (F_S) is the downward force of weight due to linear acceleration (mg) minus buoyancy (F_B) minus frictional forces opposing downward motion (F_F).

Sedimentation Examples

Physical Science | **Life Science** | **Technology**



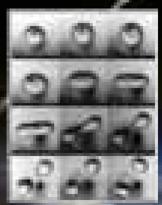
µg

Dusty plasmas (G. Kroese, TU/e, NL)

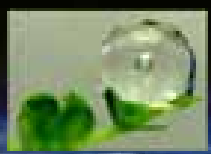
Agglutination (D. Petit, NASA)

Chara Rhizoids (Buchen, Braun & Sievers)

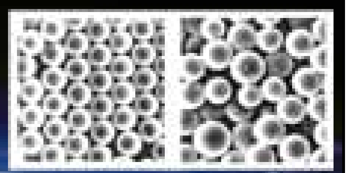
Fuel tank ("Sloshsat" NLR)



Water drop in air (USML-1: NASA JPL)



Water drop on leaf (Mir)



µg 1g

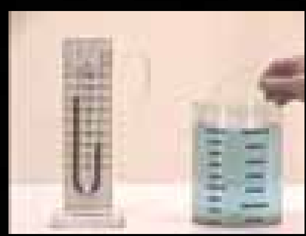
Latex spheres (data: NASA)

19

Hydrostatic pressure

P = F/A

= ρAgh/A



Where:

P = pressure (Pa)
F = force (N)
A = surface area (m²)
ρ = density of the liquid or gas (g/cm³)
***g* = unit gravity (m/s²)**
h = height of the liquid (or gas) column (m)

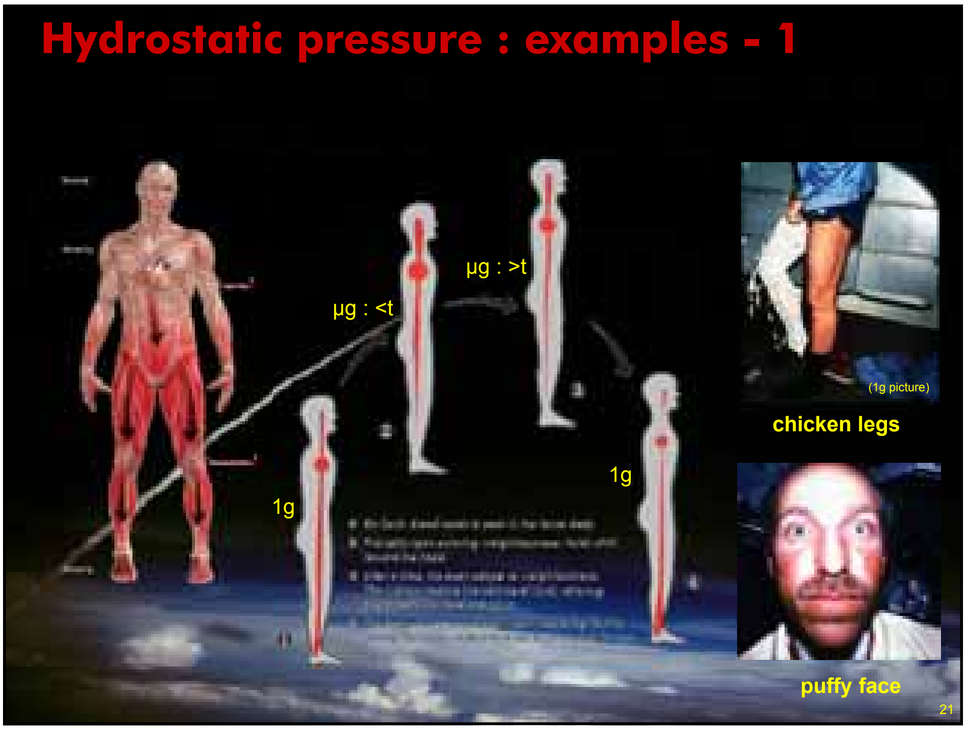
Normally, the pressure exerted by a fluid column is additional to atmospheric pressure. The total pressure would be:

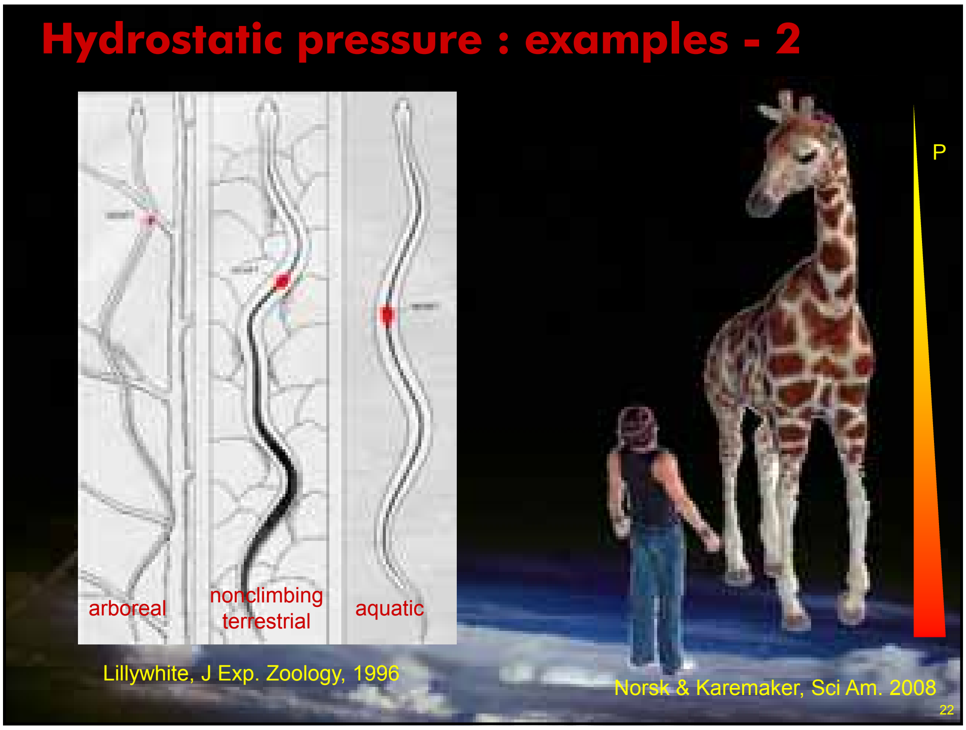
$P_{tot} = \rho g h + P_o$

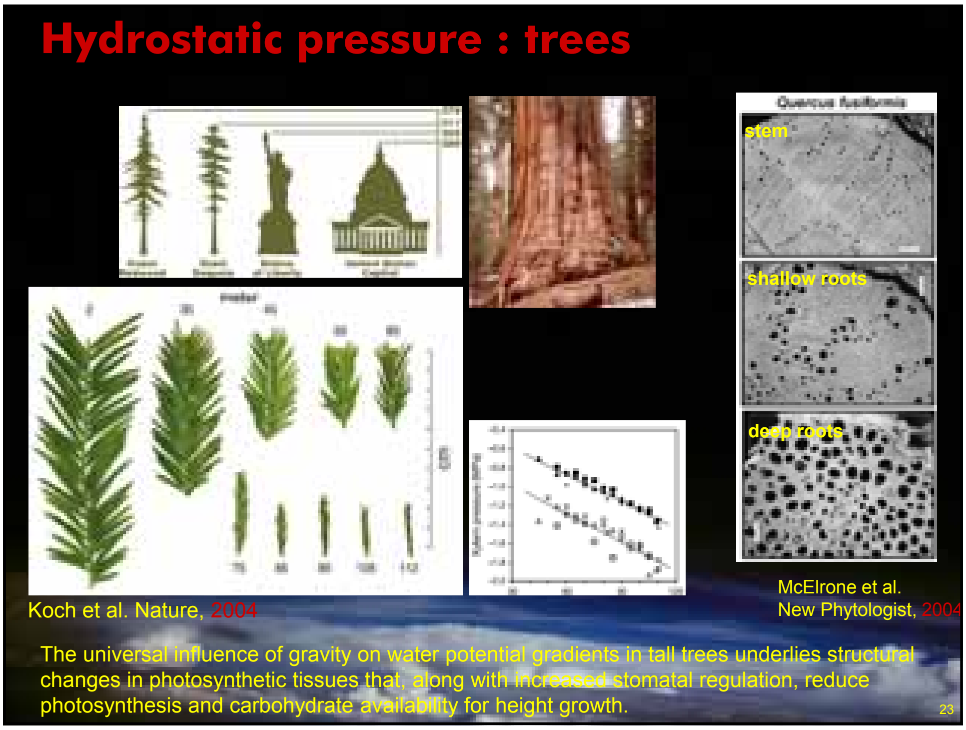
Where:
P_o = atmospheric pressure (Pa)

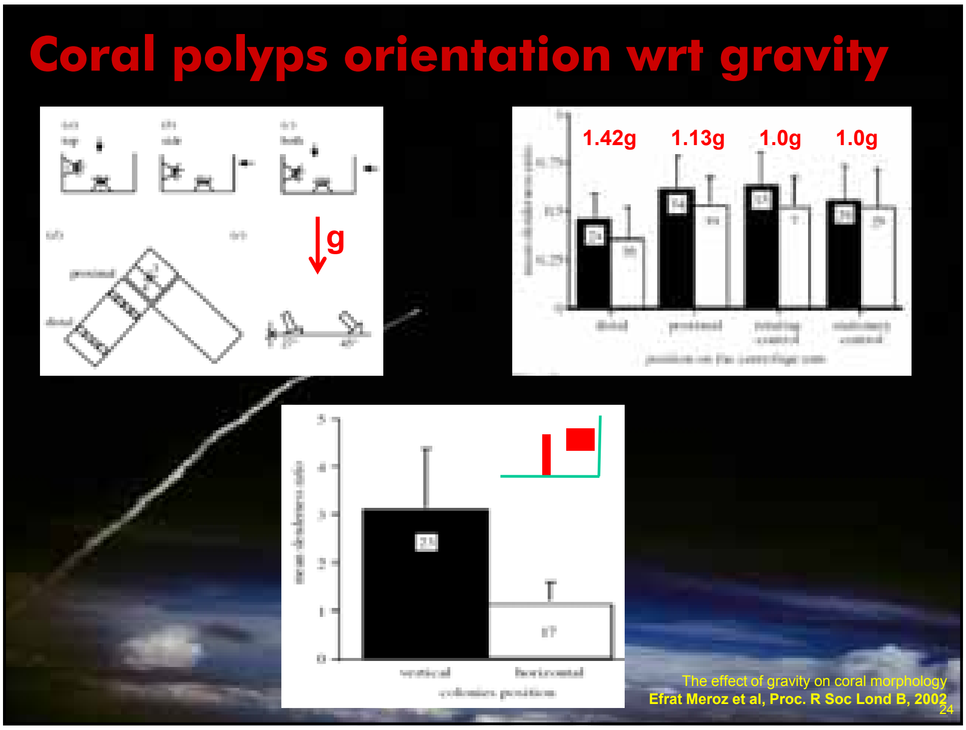
Hydrostatic pressure is linearly proportional to *g*. Under pure weightlessness conditions, hydrostatic pressure due to weight is zero.

20

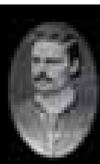

Hydrostatic pressure : examples - 1
µg : <t
µg : >t
1g
1g
(1g picture)
chicken legs
puffy face
21


Hydrostatic pressure : examples - 2
arboreal
nonclimbing terrestrial
aquatic
Lillywhite, J Exp. Zoology, 1996
P
Norsk & Karemaker, Sci Am. 2008
22


Hydrostatic pressure : trees
Quercus fusiformis
stem
shallow roots
deep roots
Koch et al. Nature, 2004
McElrone et al.
New Phytologist, 2004
The universal influence of gravity on water potential gradients in tall trees underlies structural changes in photosynthetic tissues that, along with increased stomatal regulation, reduce photosynthesis and carbohydrate availability for height growth.
23


Coral polyps orientation wrt gravity
g
1.42g
1.13g
1.0g
1.0g
The effect of gravity on coral morphology
Efrat Meroz et al, Proc. R Soc Lond B, 2002
24

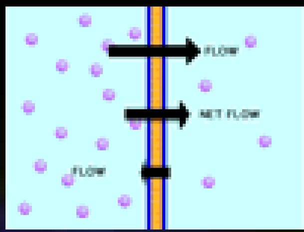
Diffusion



Adolf Fick
(1829-1901)

Fick's law: $\Delta N / \Delta t = -DA \times (\Delta C / \Delta x2)$

Where:
ΔN = number of diffusing molecules (n)
Δt = time needed for diffusion (s)
A = surface area on which diffusion takes place (m^2)
ΔC = (C_1-C_2) concentration difference at 2 locations within the surface area
Δx = distance between C1 and C2 (m)
D = the diffusion coefficient for a particular substance
D = $(kT/4\pi\eta r)$
Where:
k = Bolzmann constant (JK^{-1})
T = temperature (K)
r = radius of diffusing molecule (assumed spherical) (m)
= for a spherical particle $r = (3M/4\pi\rho N_A)^{1/3}$
Where:
M = mass per mole
ρ = density of the molecule (kg/l)
NA = Avogadro's number (mol-1)
η = viscosity constant (Ns/m^2 = Pa•s)



25

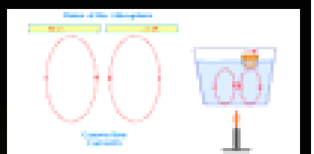
Convection

The general equation for convection: $q_c = \bar{h}_c A \Delta T$

Where:
q = the amount of heat transferred by convection
h_c = the average convection heat transfer coefficient
A = heat transfer area
ΔT = the difference between the surface temperature T_s and the ambient temperature of the fluid T_∞ far from the surface

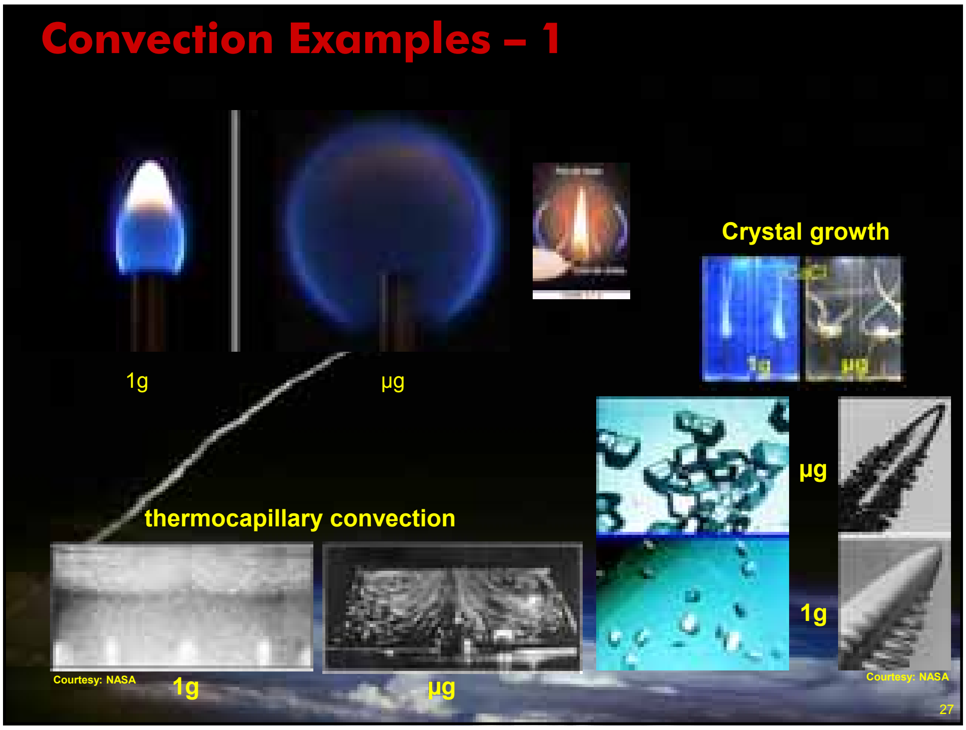
Natural convection:

$$Gr = \frac{g\beta(T - T_\infty)L^3}{V^3}$$

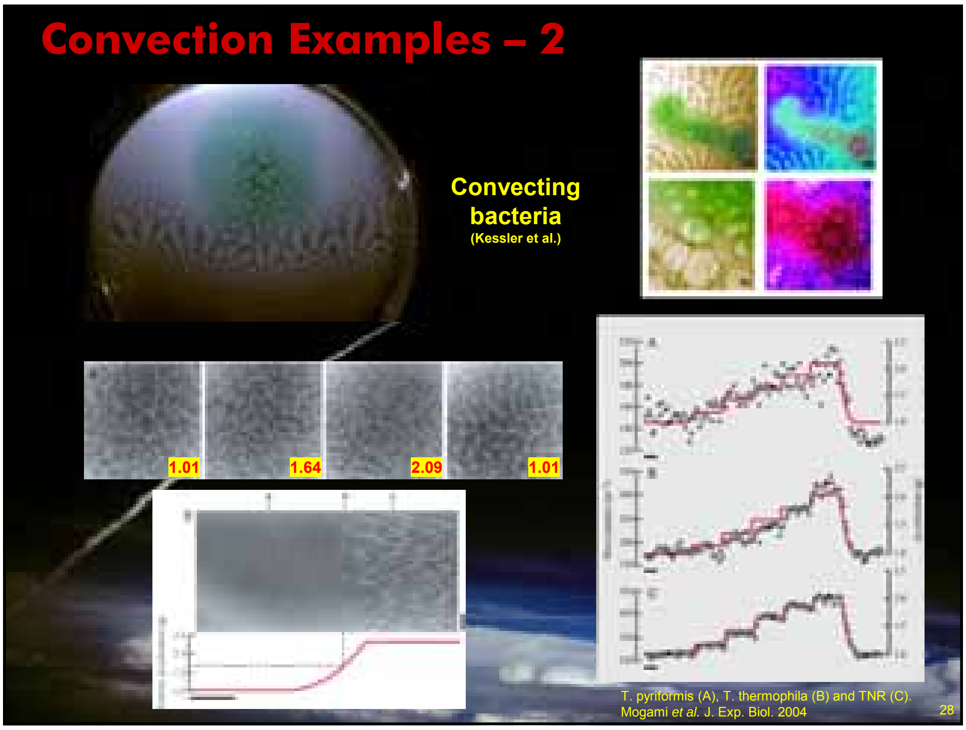


Where:
Gr = Grashof (Gr) number
g = acceleration due to gravity
β = the coefficient of expansion
($T - T_\infty$) = the temperature difference
L = the characteristic length
υ = the kinematic viscosity

26



Convection Examples – 1
1g
µg
Crystal growth
µg
1g
thermocapillary convection
Courtesy: NASA
1g
µg
Courtesy: NASA
27



Convection Examples – 2
Convecting bacteria
(Kessler et al.)
1.01
1.64
2.09
1.01
T. pyriformis (A), T. thermophila (B) and TNR (C).
Mogami et al. J. Exp. Biol. 2004
28

Diffusion vs. Convection

Einstein's mean-square or 'random-walk', x^2, diffusion distance. The diffusion constant of K^+ ions in water is: D = 0.001 mm^2/s
K+ ion in water; a one dimensional **5 mm** displacement by diffusion, it would take:

$t = x^2/D$
$t = 25/0.001 = 25000$ s = 6.9 h

Where:
x = displacement distance (mm)
D = diffusion constant (mm^2/s)

Convection currents that result from density differences generate large mixing capacity.

spherical particle : radius r = 0.1 mm in water (ρ = 1 g/cm^3, η = 0.01 poise)
specific gravity of the particle is 1 % more than water (ρ = 1.01 g/cm^3).

The Stokes equation for friction, F, would be;

$F = 6\pi r \eta v = 4/3 \pi r^3 (\rho_{water} - \rho) g$

$v = 2/9\ \eta\ (\rho_{water} - \rho)\ r^2 g$

v = 0.2 mm/s

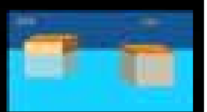
Where:
r = radius of particle (m)
η = viscosity constant (Pa·s)
v = velocity (m/s)
g = acceleration
ρ = density of particle (g/cm^3)

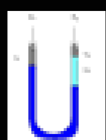
Within 6.9 h this particle would have travelled nearly **5 meters**. In this example the convection process is nearly **1000 times faster** as compared to diffusion

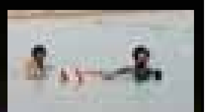
29

Buoyancy

$$F_{B,\,net} = mg + F_1 - F_2$$



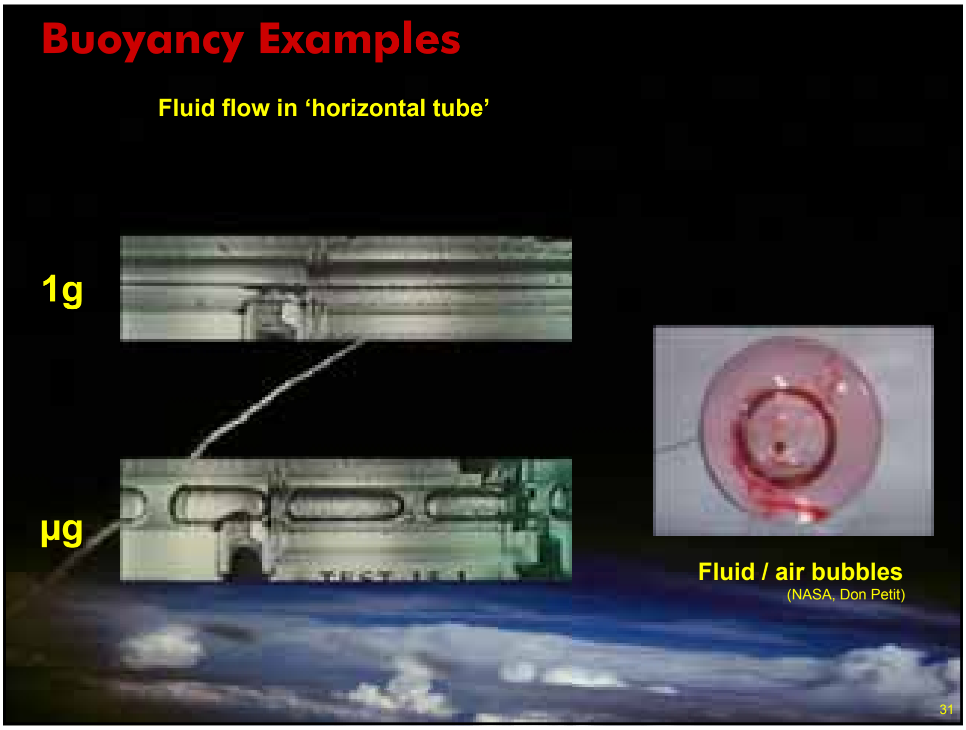




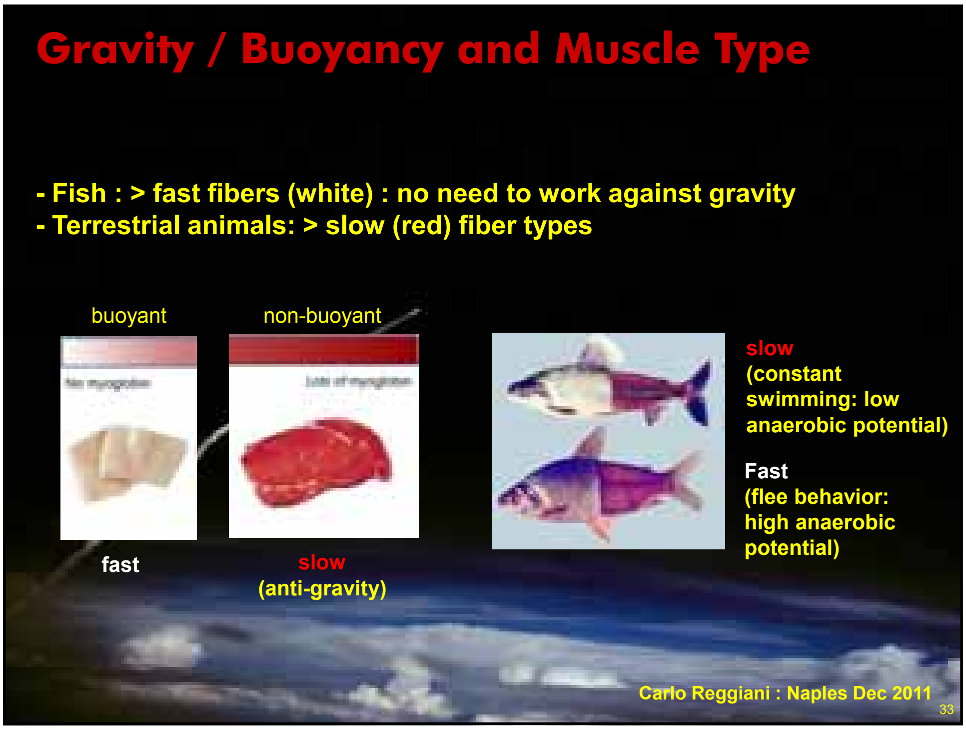
Where:
mg = downwards force due to the object's weight
F_1 = downwards force due to the fluid on top of the object
$= \rho_f g h_1 A$
F_2 = upwards force due to buoyancy
$= \rho_f g h_2 A$

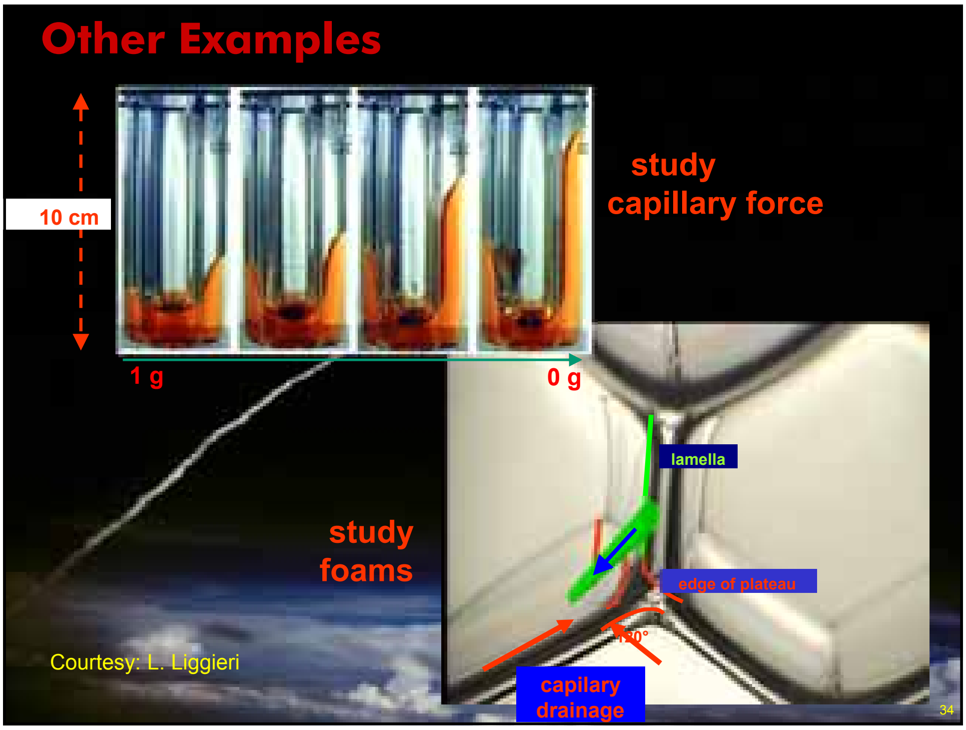
Where:
m = mass of the object (kg)
ρ_f = density of the fluid (g/cm^3)
g = the (gravity) acceleration (m/s^2)
h_1 = height of the fluid column above the object (m)
h_2 = height of fluid column from surface of the fluid to bottom of the object (m)
A = surface area (of a cylinder or cube) (m^2)

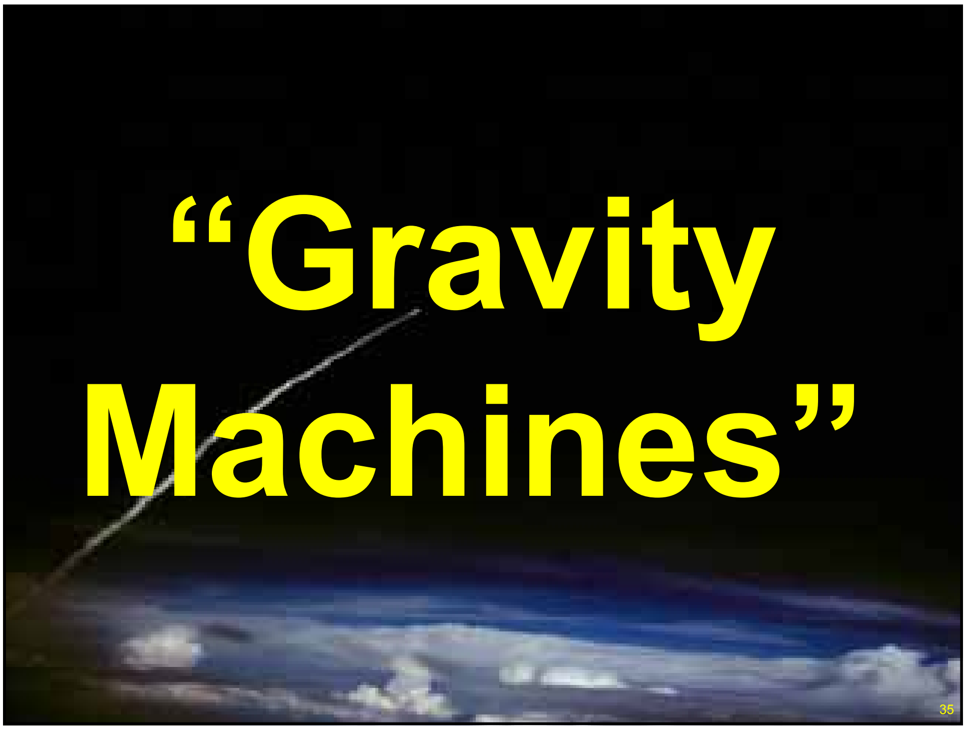
30

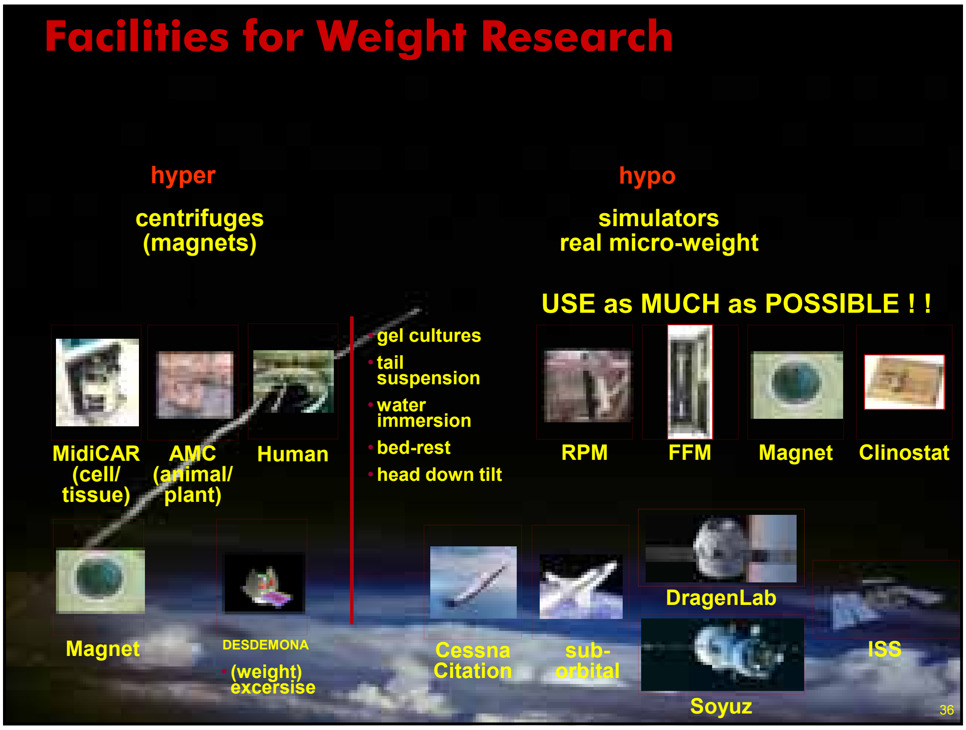

Buoyancy Examples
Fluid flow in ‘horizontal tube’
1g
µg
Fluid / air bubbles
(NASA, Don Petit)
31


Solar storm 2012
Brno, CZ)

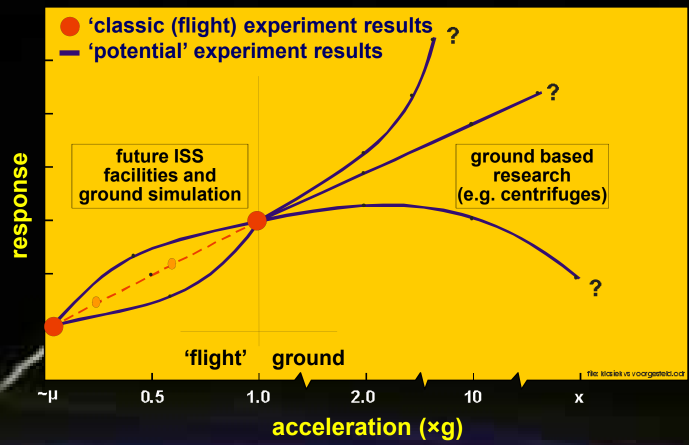

Gravity / Buoyancy and Muscle Type
- Fish : > fast fibers (white) : no need to work against gravity
- Terrestrial animals: > slow (red) fiber types
buoyant
non-buoyant
fast
slow
(anti-gravity)
slow
(constant swimming: low anaerobic potential)
Fast
(flee behavior: high anaerobic potential)
Carlo Reggiani : Naples Dec 2011
33


Other Examples
10 cm
1 g
0 g
study
capillary force
lamella
edge of plateau
study
foams
capilary
drainage
Courtesy: L. Liggieri
34


"Gravity Machines"
35


Facilities for Weight Research
hyper
centrifuges
(magnets)
hypo
simulators
real micro-weight
USE as MUCH as POSSIBLE ! !
gel cultures
tail suspension
water immersion
bed-rest
head down tilt
MidiCAR (cell/ tissue)
AMC (animal/ plant)
Human
RPM
FFM
Magnet
Clinostat
Magnet
DESDEMONA
(weight) excersise
Cessna Citation
sub-orbital
DragenLab
Soyuz
ISS
36

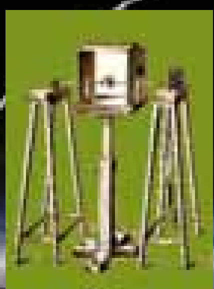
Current vs. Future Spaceflight Research



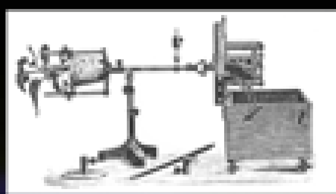
Schematic presentation of potential experiment opportunities compared to 'classic' experiment setups. Novel space station facilities as well as ground simulations and centrifuges may be applied to study the role of weight (accelerations) on various living and non-living samples.

'Classical' Clinostat

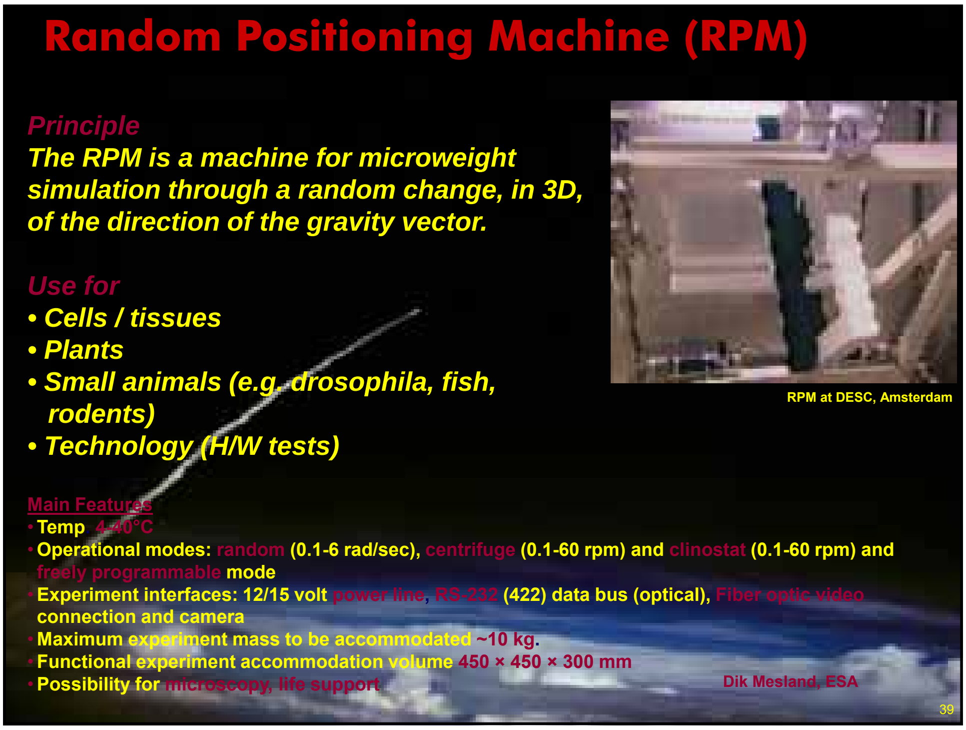
A Clinostat as Invented by J. v. SACHS. A clockwork (at the right side of the picture) has weights and a pendulum that start a slow movement of the axis. A mounting is fixed at the axis inside a protecting case (dark chamber), upon which a fungus is growing (*Phycomycetes*). The middle part of the axis is enclosed by a glass case that is standing upon a water-filled dish that helps to keep the air in the surrounding of the test object humid (J. v. SACHS, 1887).

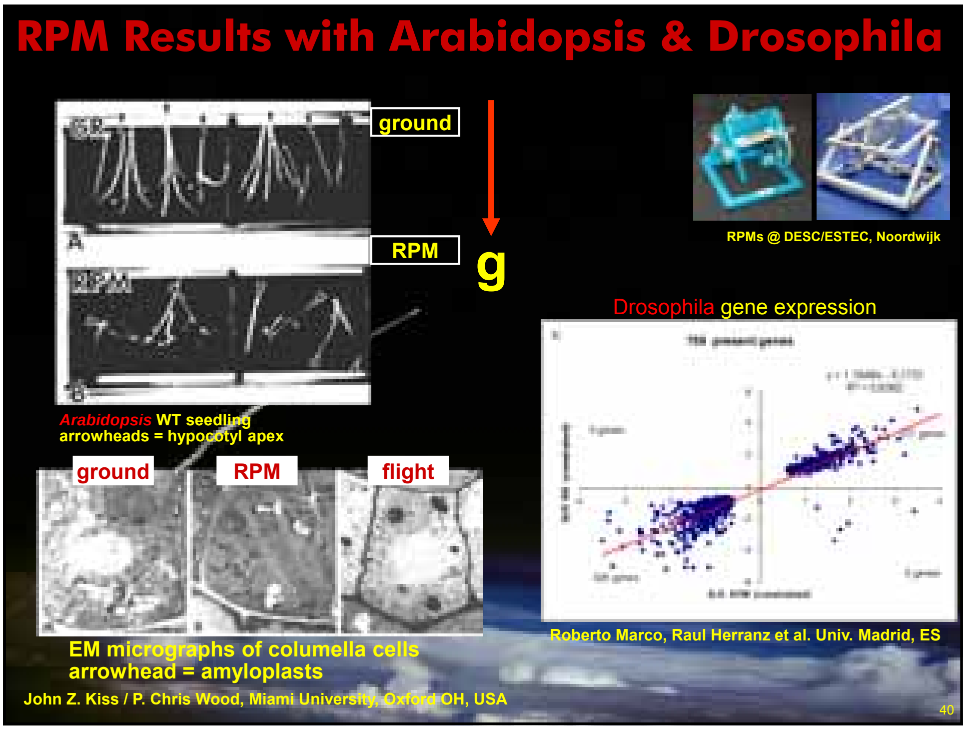


Sachs 1887

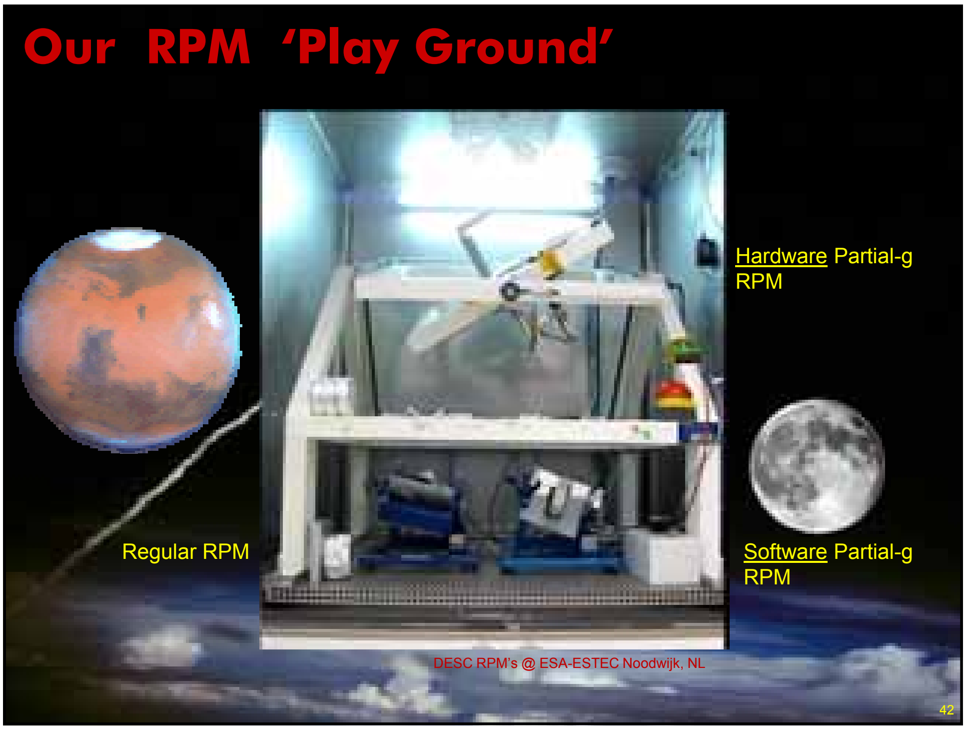


Pfeffer ~ 1892

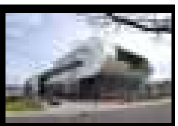

Random Positioning Machine (RPM)
Principle
The RPM is a machine for microweight simulation through a random change, in 3D, of the direction of the gravity vector.
Use for
• Cells / tissues
• Plants
• Small animals (e.g. drosophila, fish, rodents)
• Technology (H/W tests)
RPM at DESC, Amsterdam
Main Features
• Temp 4-40°C
• Operational modes: random (0.1-6 rad/sec), centrifuge (0.1-60 rpm) and clinostat (0.1-60 rpm) and freely programmable mode
• Experiment interfaces: 12/15 volt power line, RS-232 (422) data bus (optical), Fiber optic video connection and camera
• Maximum experiment mass to be accommodated ~10 kg.
• Functional experiment accommodation volume 450 × 450 × 300 mm
• Possibility for microscopy, life support
Dik Mesland, ESA
39


RPM Results with Arabidopsis & Drosophila
ground
RPM
g
Arabidopsis WT seedling
arrowheads = hypocotyl apex
ground
RPM
flight
EM micrographs of columella cells
arrowhead = amyloplasts
John Z. Kiss / P. Chris Wood, Miami University, Oxford OH, USA
RPMs @ DESC/ESTEC, Noordwijk
Drosophila gene expression
Roberto Marco, Raul Herranz et al. Univ. Madrid, ES
40


Random Positioning & Art . .
Giordano Bruno,
burned at the stake
in Rome, in 1600
Work from: Christian Waldvogel, Zurich, CH. 2013
41


Our RPM 'Play Ground'
Hardware Partial-g
RPM
Regular RPM
Software Partial-g
RPM
DESC RPM's @ ESA-ESTEC Noodwijk, NL
42

Levitation Magnet



HMFL, Nijmegen, NL

Principle

Magnetic levitation is possible for biological materials based their, quantum phenomenon, diamagnetic properties. Gravity is cancelled out on the level of individual atoms and molecules.

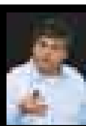
Bitter Magnet at the HMFL, Univ. Nijmegen, NL.

Main Features

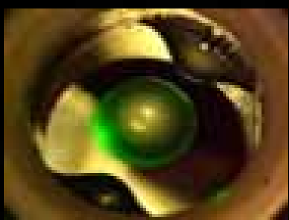
- **Sample area for homogeneous levitation : cylinder volume with diameter of ~ 20 mm and height of ~ 10 mm**
- **Experiment area: cylinder diameter of 32 mm, height ~ 1000 mm**
- **Operations at room temperature but adjustable**
- **Possibility for dedicated gas atmosphere**
- **Maximum levitation times 5-6 hours**
- **Homogeneity of levitation ~ 10%**

M.V. Berry, Andre K. Geim. Eur.J. Phys. 18, 307, 1997. 43

Levitation Magnet -2

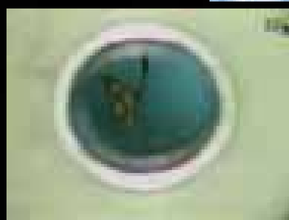


Andre Geim
Nobel Physics 2011



Inorganic

Plant



Animal

Levitation: $F_z = F_{magnetic} + F_{gravity} = 0 \Rightarrow B_z B_z' = \frac{\rho}{\chi}\mu_0 g$

magnetic field — magnetic permeability of vacuum — magnetic field gradient — magnetic susceptibility

M.V. Berry & A.K. Geim
Eur. J. Phys. 1997

44


Ground Simulation in Human Physiology
Haed Down Tilt (HDT)
ESA/CNES
Tilt Table
Karemaker, AMC, Amsterdam
Treadmill + LBMP
NASA
LBMP + HDT
Dry
Immersion
45


BREAK
46

Some Cell Mechano-Biology: Mechanomics, Physicomics

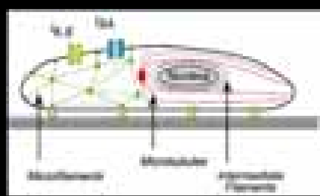
47

Gravitational Cell Biology

Direct / primary effects of gravity acceleration onto a cell

apply or remove a mechanical load

mechanotransduction

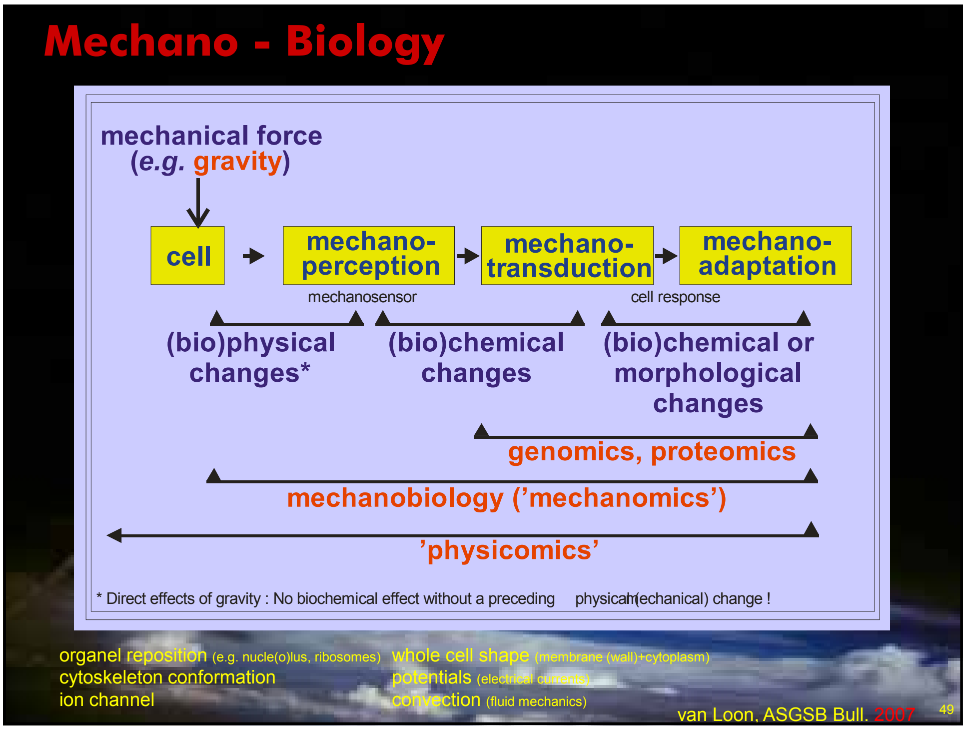


biochemical messengers → changes in structural, mechanical and functional properties → adaptation or injury

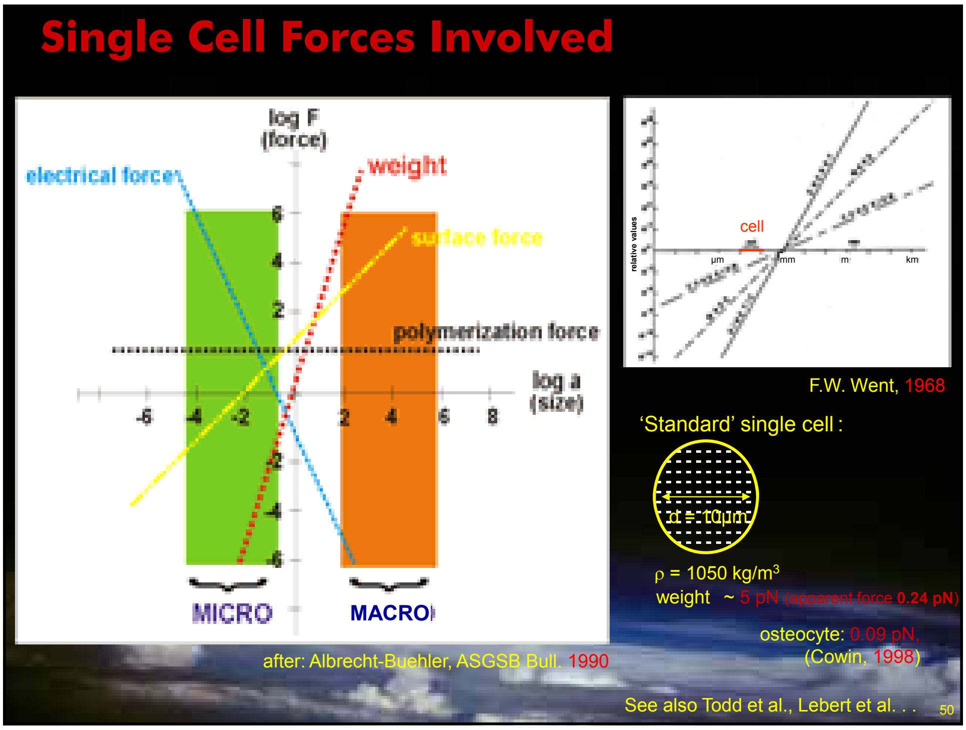
gene expression
protein synthesis

A cellular response to mechanical loads requires 'mechanosensors' and 'mechanotransducers'.

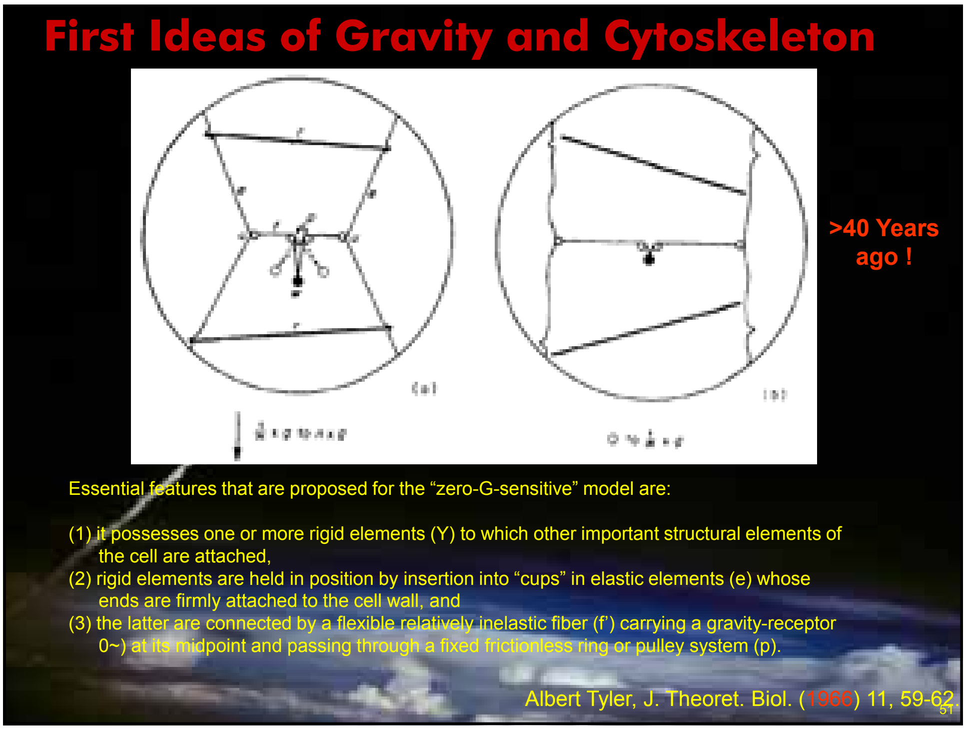
48

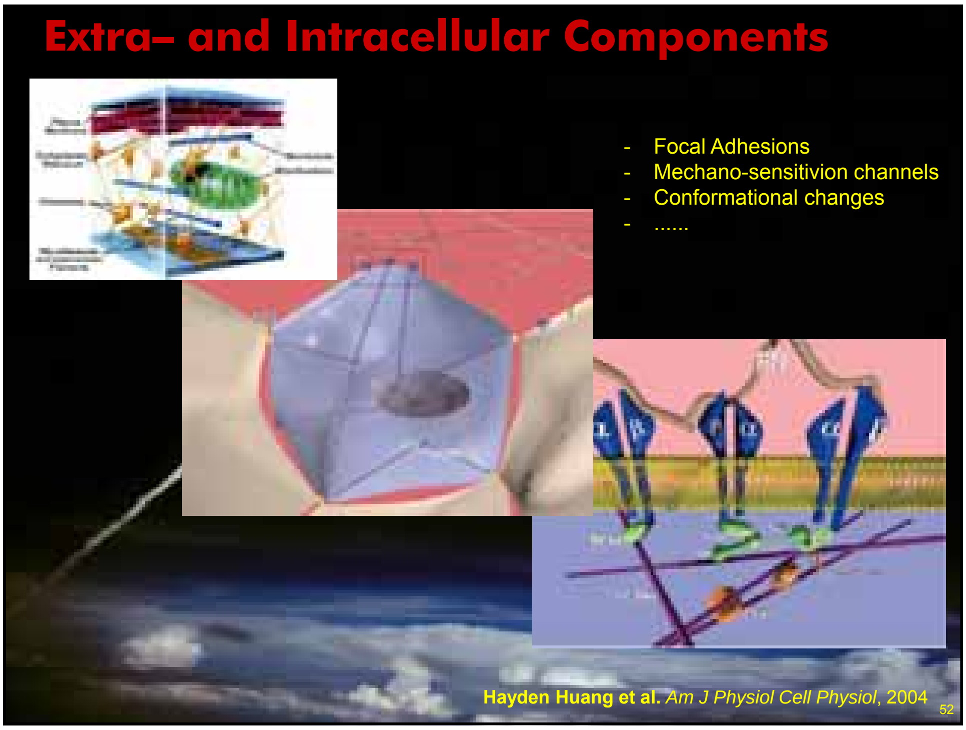


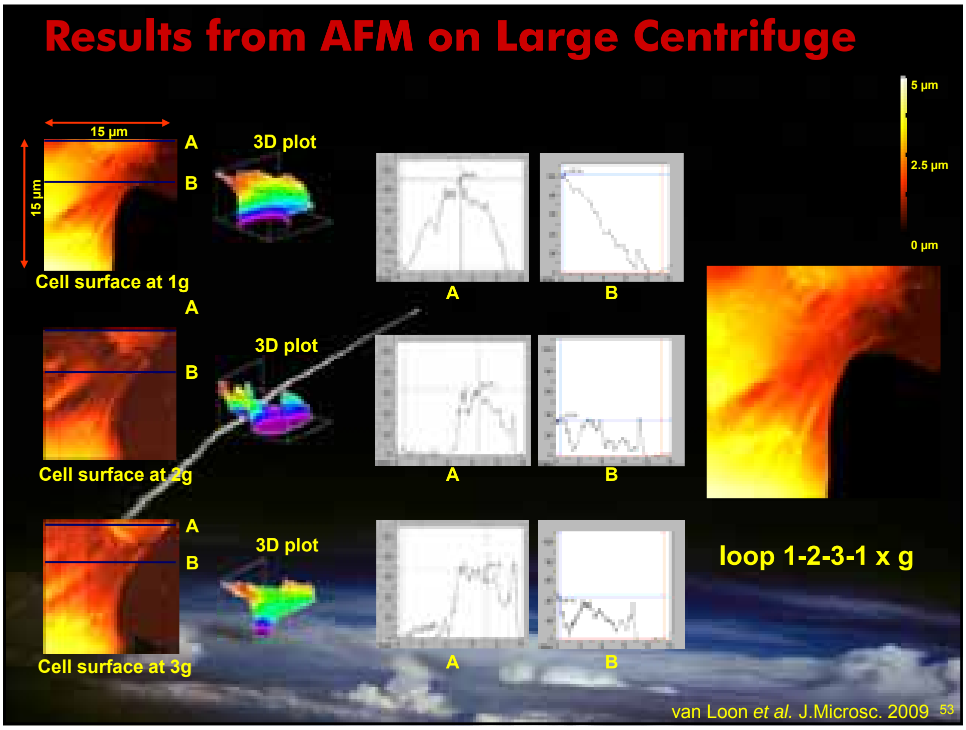
Mechano - Biology
mechanical force
(e.g. gravity)
cell
mechano-perception
mechano-transduction
mechano-adaptation
mechanosensor
cell response
(bio)physical changes*
(bio)chemical changes
(bio)chemical or morphological changes
genomics, proteomics
mechanobiology ('mechanomics')
'physicomics'
* Direct effects of gravity : No biochemical effect without a preceding physical (mechanical) change !
organel reposition (e.g. nucle(o)lus, ribosomes)
cytoskeleton conformation
ion channel
whole cell shape (membrane (wall)+cytoplasm)
potentials (electrical currents)
convection (fluid mechanics)
van Loon, ASGSB Bull. 2007
49



Single Cell Forces Involved
log F
(force)
electrical forces
weight
surface force
polymerization force
log a
(size)
MICRO
MACRO
after: Albrecht-Buehler, ASGSB Bull. 1990
cell
F.W. Went, 1968
'Standard' single cell :
d = 10μm
ρ = 1050 kg/m³
weight ~ 5 pN (apparent force 0.24 pN)
osteocyte: 0.09 pN,
(Cowin, 1998)
See also Todd et al., Lebert et al. . .
50


First Ideas of Gravity and Cytoskeleton
>40 Years ago !
Essential features that are proposed for the “zero-G-sensitive” model are:
(1) it possesses one or more rigid elements (Y) to which other important structural elements of the cell are attached,
(2) rigid elements are held in position by insertion into “cups” in elastic elements (e) whose ends are firmly attached to the cell wall, and
(3) the latter are connected by a flexible relatively inelastic fiber (f’) carrying a gravity-receptor 0~) at its midpoint and passing through a fixed frictionless ring or pulley system (p).
Albert Tyler, J. Theoret. Biol. (1966) 11, 59-62.
51


Extra– and Intracellular Components
- Focal Adhesions
- Mechano-sensitivion channels
- Conformational changes
- ......
Hayden Huang et al. Am J Physiol Cell Physiol, 2004
52



Results from AFM on Large Centrifuge
15 µm
15 µm
A
B
3D plot
Cell surface at 1g
A
B
3D plot
Cell surface at 2g
A
B
3D plot
Cell surface at 3g
A
B
A
B
A
B
5 µm
2.5 µm
0 µm
loop 1-2-3-1 x g
van Loon et al. J.Microsc. 2009
53

Centrifuges
54

'Centrifugal Force'

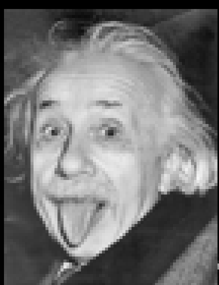
1659 Centrifugal force:
Christiaan Huygens coined the term "centrifugal force" in his 1659 De Vi Centrifiga and wrote of it in his 1673 *Horologium Oscillatorium* on pendulums.

Born : 14 April 1629 The Hague, Dutch Republic
Died : 8 July 1695 (aged 66) The Hague, Dutch Republic
Residence: Netherlands, France

Fields: Physics
Mathematics
Astronomy
Horology

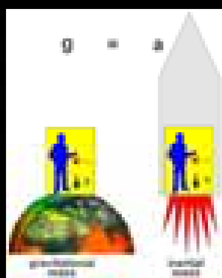
55

The principle of equivalence



Albert Einstein (1879-1955)

1907 paper 'principle of equivalence':
("Über das Relativitätsprinzip und die aus demselben gezogene Folgerungen," *Jahrbuch der Radioaktivitaet und Elektronik* **4** (1907))



"In a closed laboratory, no experiment can be performed that will distinguish between the effects of a gravitational field and the effects due to an acceleration with respect to some inertial reference frame."

56

'Artificial' gravity *i.e.* centrifuges

$$a_c = \omega^2 r$$

Where:
a_c = centripetal acceleration (m/s^2)
ω = angular velocity (rad/s)
r = radius (m)

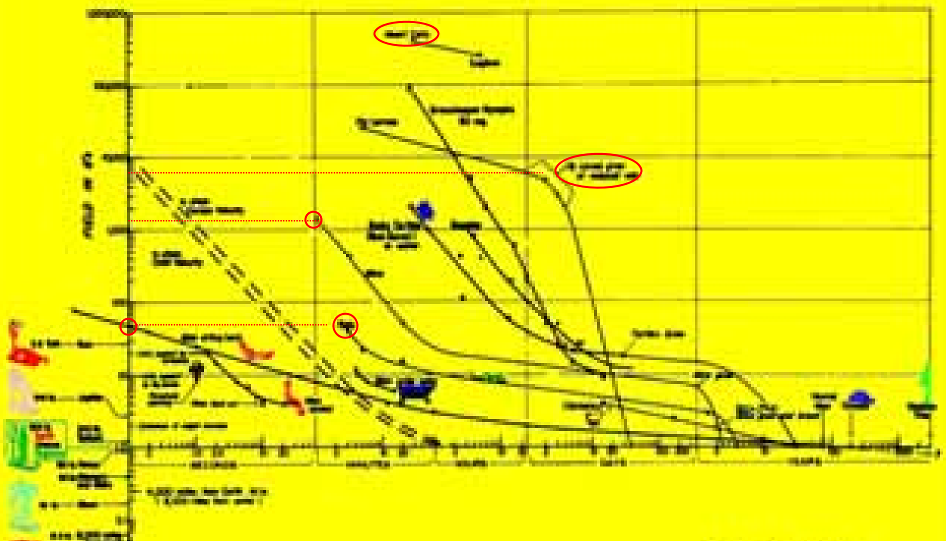
The force on this object would be a centripetal force:

$$F_c = ma_c = m\omega^2 r$$

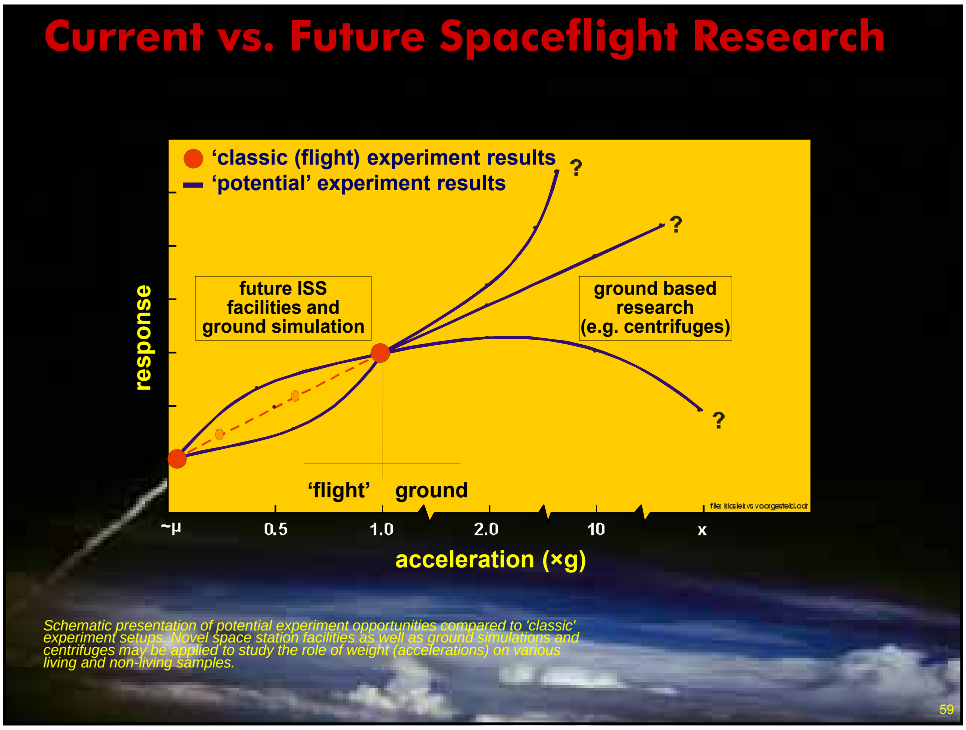
57

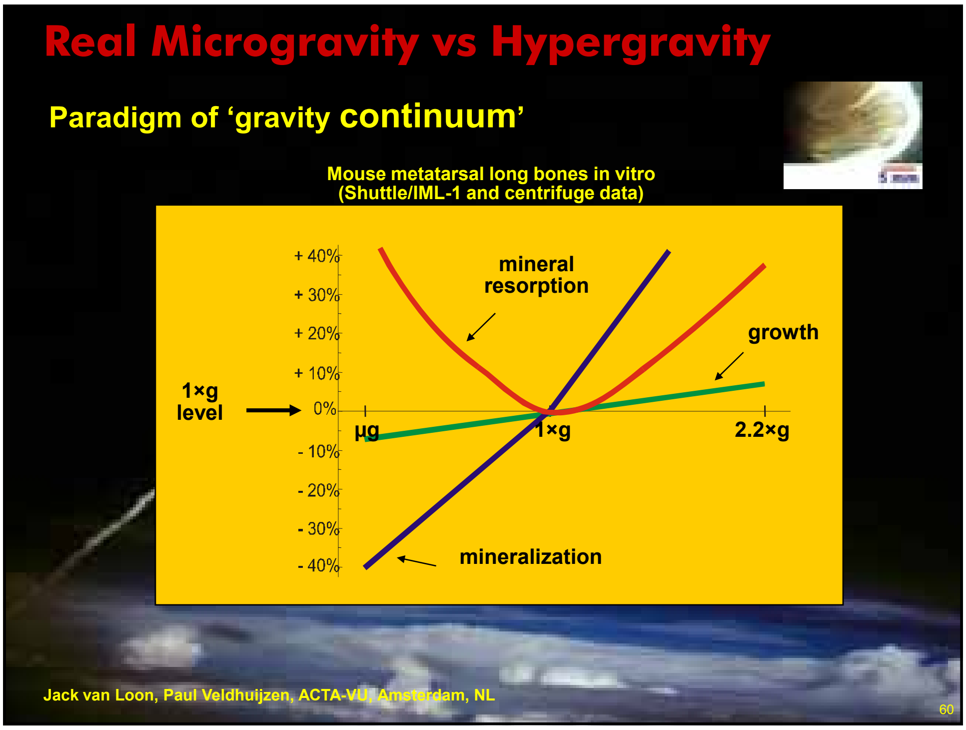
Historical Animal Centrifuge Studies

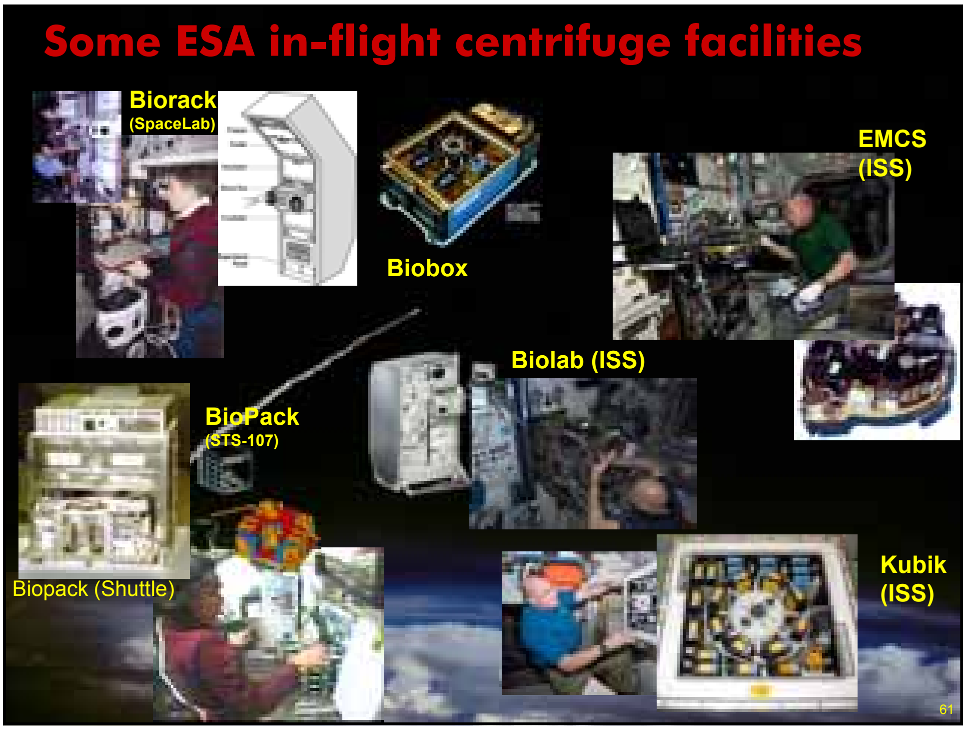
Survival time @ various g intensities

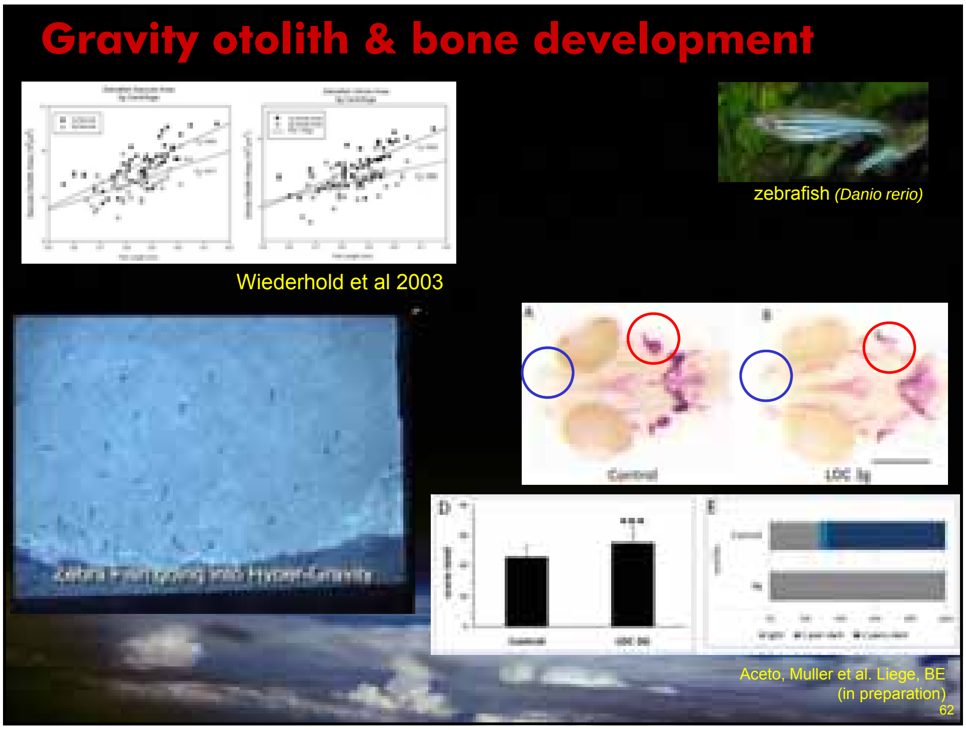


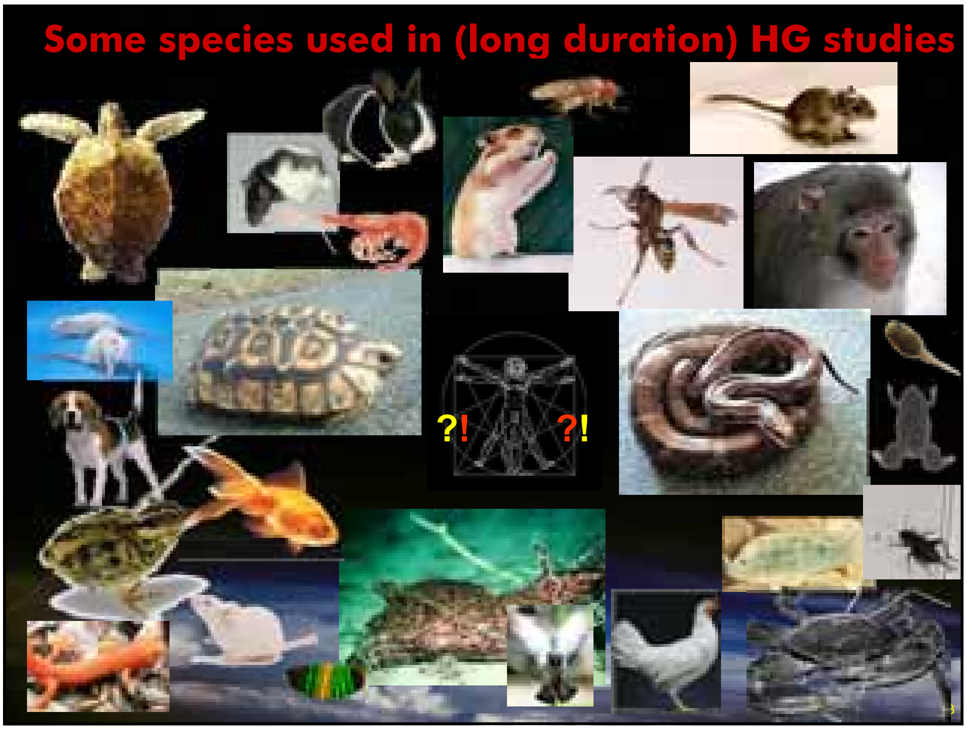
From: C.C. Wunder
General & Exp. Zoology, 1964


Current vs. Future Spaceflight Research
'classic (flight) experiment results
'potential' experiment results
?
?
?
future ISS facilities and ground simulation
ground based research (e.g. centrifuges)
response
'flight'
ground
~μ
0.5
1.0
2.0
10
x
acceleration (×g)
Schematic presentation of potential experiment opportunities compared to 'classic' experiment setups. Novel space station facilities as well as ground simulations and centrifuges may be applied to study the role of weight (accelerations) on various living and non-living samples.
59


Real Microgravity vs Hypergravity
Paradigm of 'gravity continuum'
Mouse metatarsal long bones in vitro
(Shuttle/IML-1 and centrifuge data)
+ 40%
+ 30%
+ 20%
+ 10%
0%
- 10%
- 20%
- 30%
- 40%
1×g level
mineral resorption
growth
μg
1×g
2.2×g
mineralization
Jack van Loon, Paul Veldhuijzen, ACTA-VU, Amsterdam, NL
60


Some ESA in-flight centrifuge facilities
Biorack
(SpaceLab)
Biobox
EMCS
(ISS)
Biolab (ISS)
BioPack
(STS-107)
Biopack (Shuttle)
Kubik
(ISS)
61


Gravity otolith & bone development
zebrafish (Danio rerio)
Wiederhold et al 2003
Zebra Fish going into Hyper-Gravity
Aceto, Muller et al. Liege, BE
(in preparation)
62

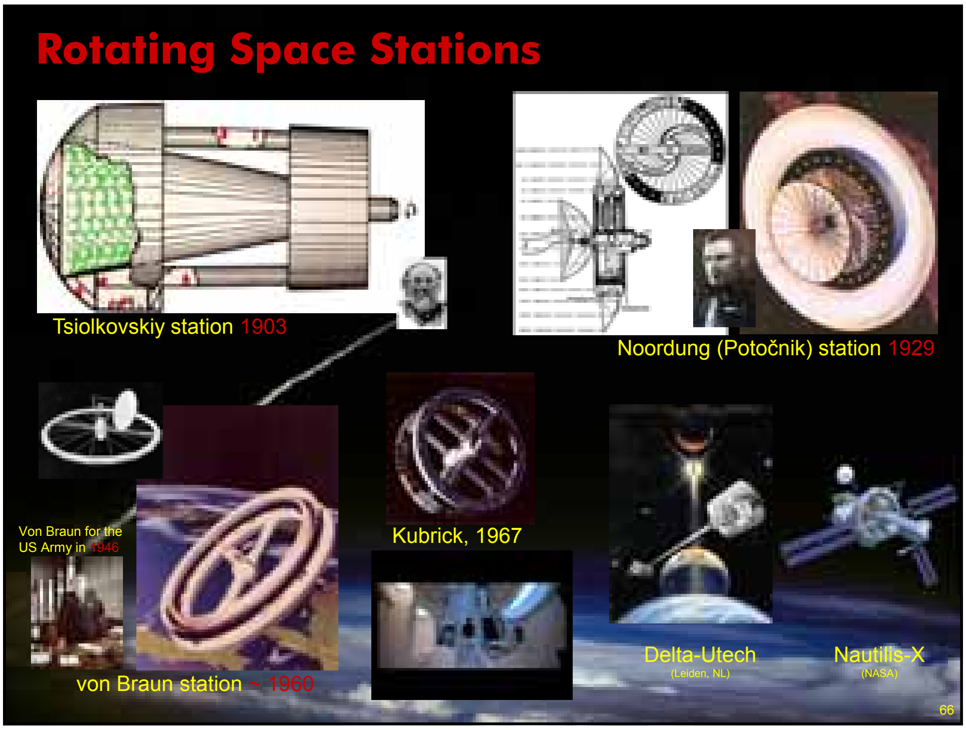


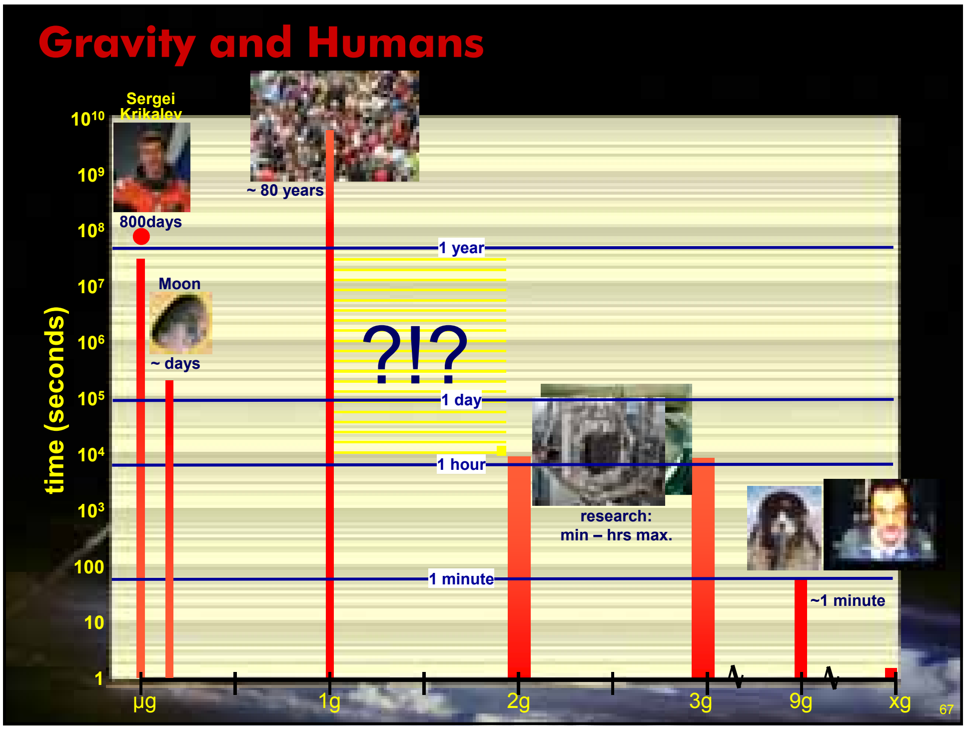
Systems involved in animal hypergravity respons

- immune system
- bone
- maternal behaviour
- cognitive functions
- vestibular system (otoliths, neuronal, composition ets.)
- muscle (skeletal, heart)
- lung morphology
- circadian rhythms
- nutrition
- endocrinology (hormonal, metabolites)
- water / energy balance
- activity (behaviour / locomotion)
- body mass /composition
- embryonic development
- mammary metabolism
- haematological adaptation
- etc.

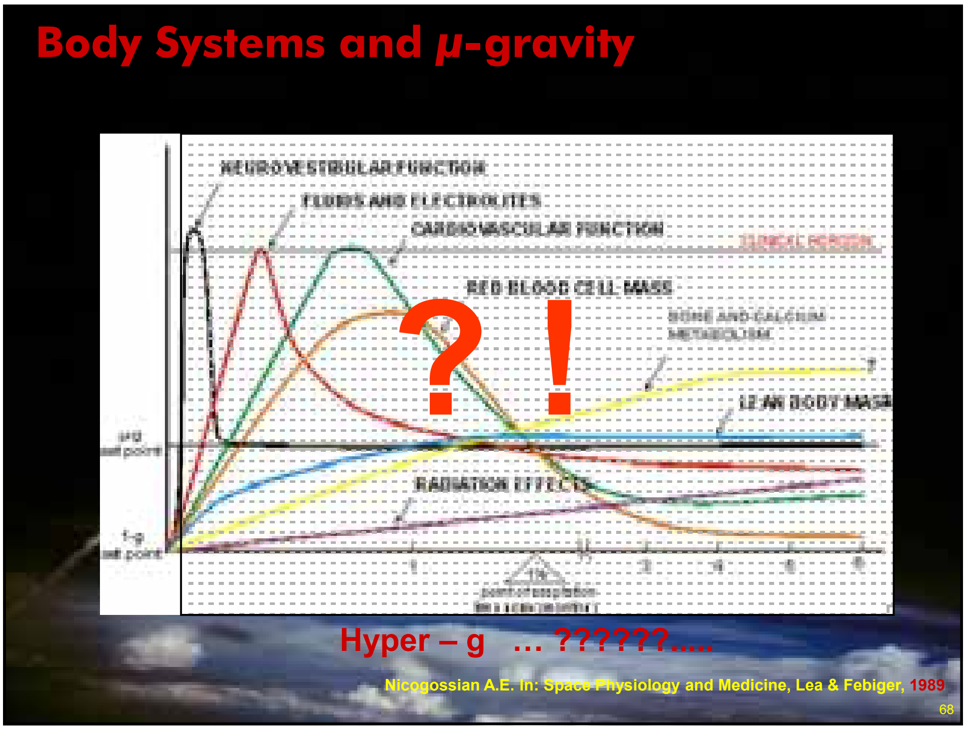
64


Some Human Rated (Training) Centrifuges
JAXA-Japan
Star City, RU
Stockholm, SE
New Delhi, India
DESDEMONA Soesterberg, NL
Brooks AFB, US
ETC/Shimadzu, Japan
Linköping, SE
Königsbrück, DE
NASTAR, US
Soesterberg, NL
NASA-Ames, US
Toronto, CA
Beijing, CN
65

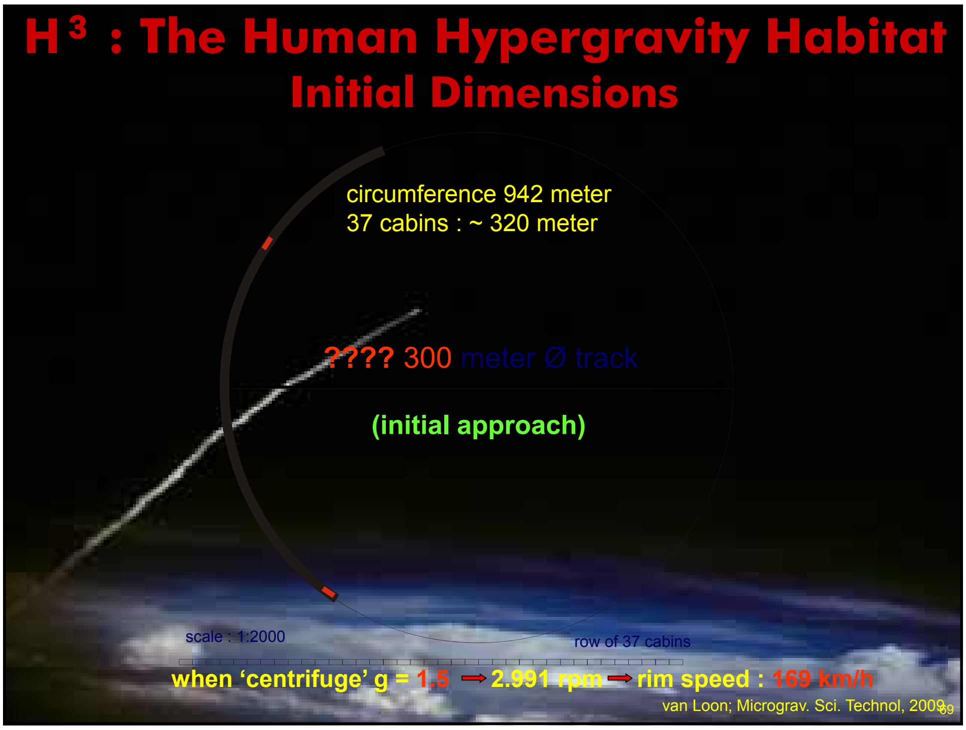

Rotating Space Stations
Tsiolkovskiy station 1903
Noordung (Potočnik) station 1929
Kubrick, 1967
Von Braun for the
US Army in 1946
von Braun station ~ 1960
Delta-Utech
(Leiden, NL)
Nautilis-X
(NASA)
66

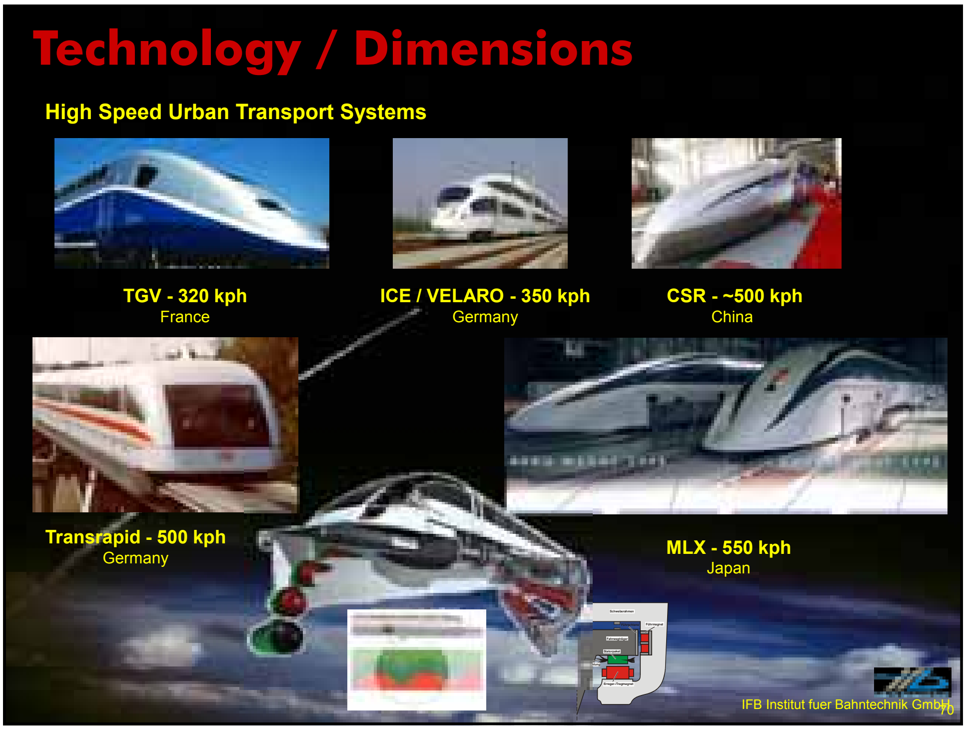


Gravity and Humans
Sergei Krikalev
800days
~ 80 years
1 year
Moon
~ days
?!?
1 day
1 hour
research:
min – hrs max.
1 minute
~1 minute
time (seconds)
1
10
100
10^3
10^4
10^5
10^6
10^7
10^8
10^9
10^{10}
µg
1g
2g
3g
9g
xg
67



Body Systems and µ-gravity
? !
Hyper – g … ??????.....
Nicogossian A.E. In: Space Physiology and Medicine, Lea & Febiger, 1989
68


H 3 : The Human Hypergravity Habitat
Initial Dimensions
circumference 942 meter
37 cabins : ~ 320 meter
???? 300 meter Ø track
(initial approach)
scale : 1:2000
row of 37 cabins
when 'centrifuge' g = 1.5 → 2.991 rpm → rim speed : 169 km/h
van Loon; Micrograv. Sci. Technol, 2009
69


Technology / Dimensions
High Speed Urban Transport Systems
TGV - 320 kph
France
ICE / VELARO - 350 kph
Germany
CSR - ~500 kph
China
Transrapid - 500 kph
Germany
MLX - 550 kph
Japan
IFB Institut fuer Bahntechnik GmbH
70

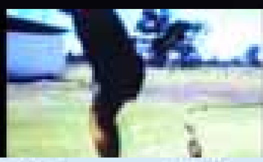
Technology / Levitation

evico

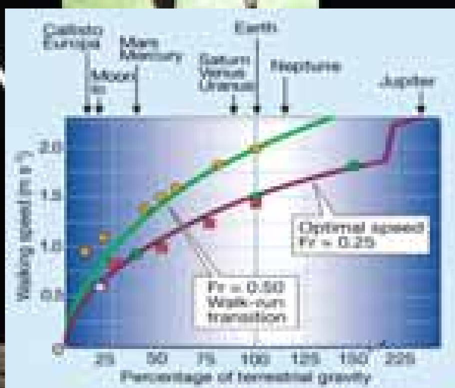
IFW

Gait & Gravity

long-eared jerboa in Gobi Desert (J. Baillie, 10 Dec. 2007)

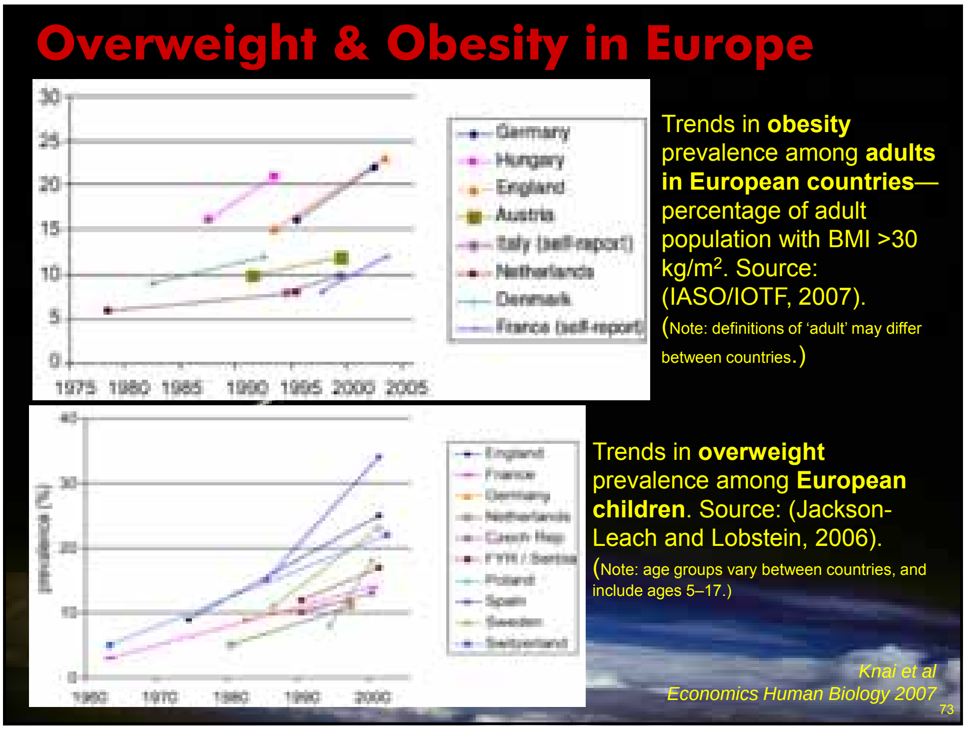


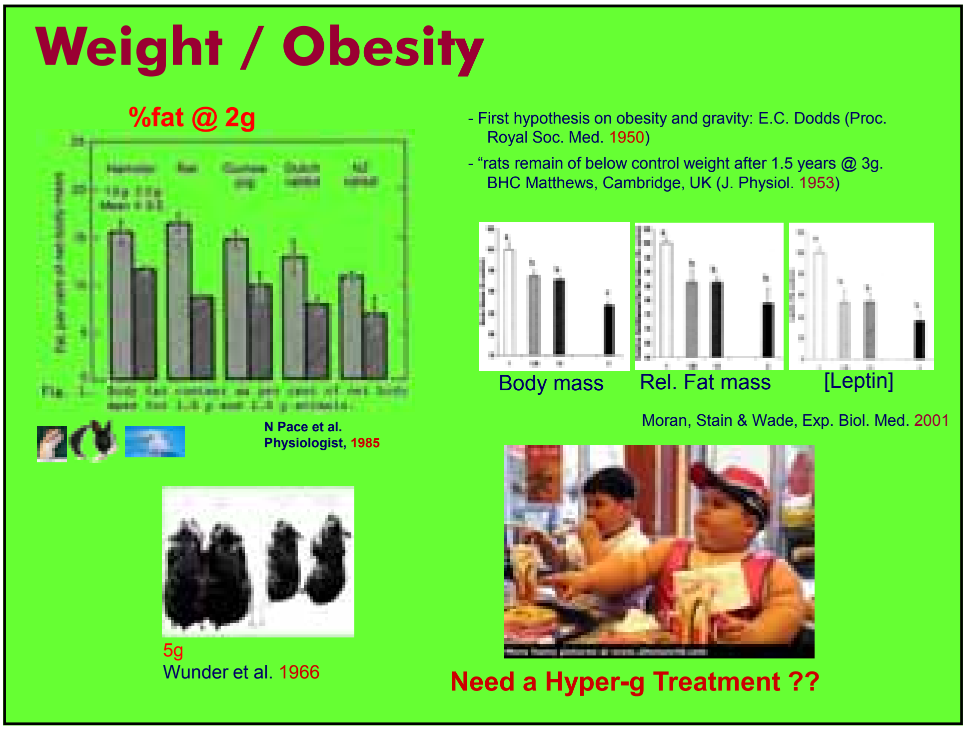
Astronaut during Apollo 17 mission



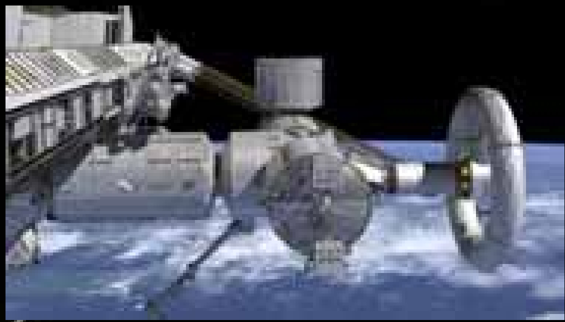
Minetti AE: "Walking on other planets." Nature, 2001

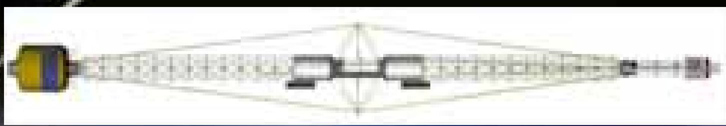
Background: Apollo 15


Overweight & Obesity in Europe
Germany
Hungary
England
Austria
Italy (self-report)
Netherlands
Denmark
France (self-report)
1975 1980 1985 1990 1995 2000 2005
Trends in **obesity** prevalence among **adults in European countries**—percentage of adult population with BMI >30 kg/m². Source: (IASO/IOTF, 2007).
(Note: definitions of 'adult' may differ between countries.)
Trends in **overweight** prevalence among **European children**. Source: (Jackson-Leach and Lobstein, 2006).
(Note: age groups vary between countries, and include ages 5–17.)
Knai et al
Economics Human Biology 2007
73


Weight / Obesity
%fat @ 2g
N Pace et al.
Physiologist, 1985
5g
Wunder et al. 1966
- First hypothesis on obesity and gravity: E.C. Dodds (Proc. Royal Soc. Med. 1950)
- "rats remain of below control weight after 1.5 years @ 3g. BHC Matthews, Cambridge, UK (J. Physiol. 1953)
Body mass
Rel. Fat mass
[Leptin]
Moran, Stain & Wade, Exp. Biol. Med. 2001
Need a Hyper-g Treatment ??

Gravity and Angular Velocity





H^3 in preparation for large in-flight rotating systems

75

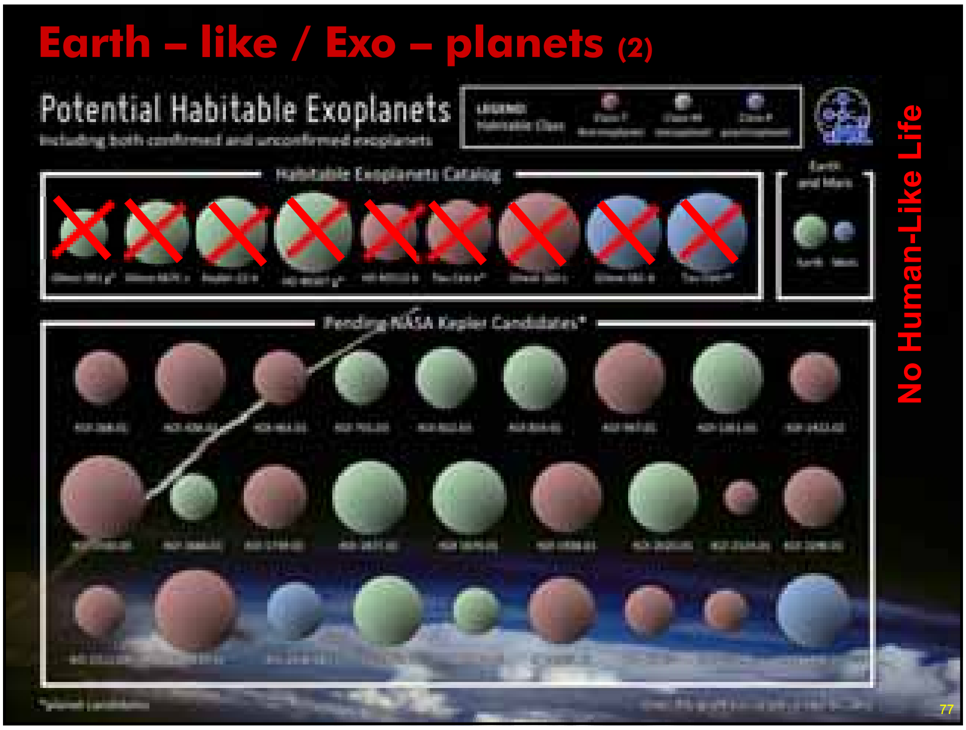
Earth – like / Exoplanets

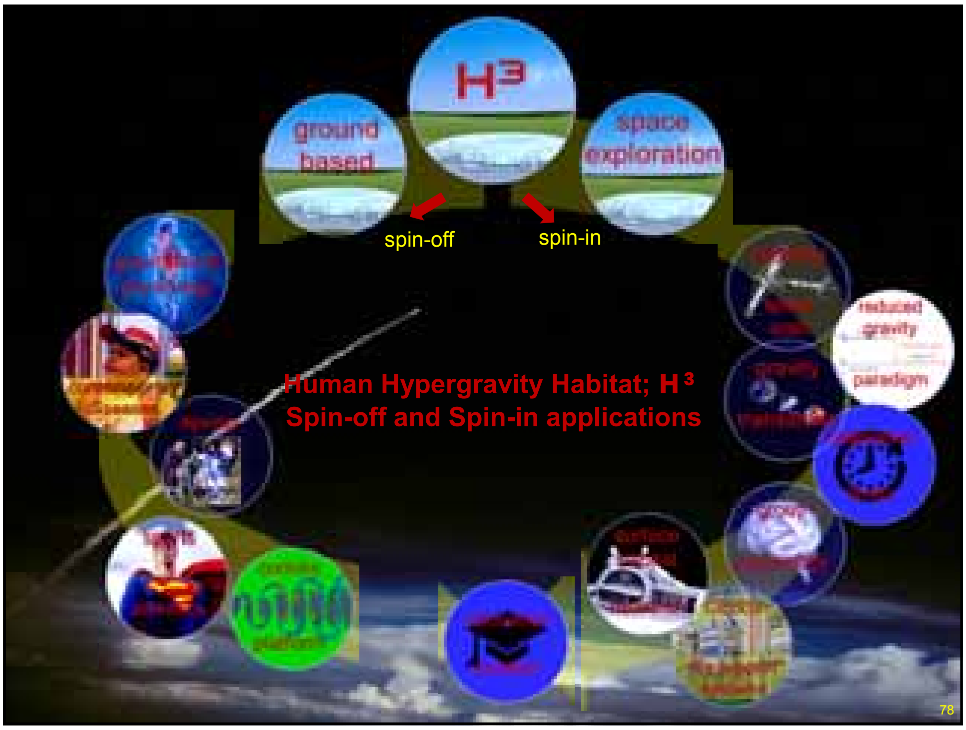
ESA Press Photo 22a/07 (25 April 2007

Gliese 581 Planetary System Data

Planet Designation	Orbital Elements		Orbital Period (years)	Minimum Mass (M_E)	Discovery	
	Semimajor Axis (AU)	Eccentricity			Discoverer Name	Announcement Date
Gl 581 b	0.041	0.02	0.014698	15.7	X. Bonfils, et al	2005 August 22
Gl 581 c	0.073	0.16	0.035406	5.03	S. Udry, et al	2007 April 24
Gl 581 d	0.25	0.20	0.229	7.7	S. Udry, et al	2007 April 24

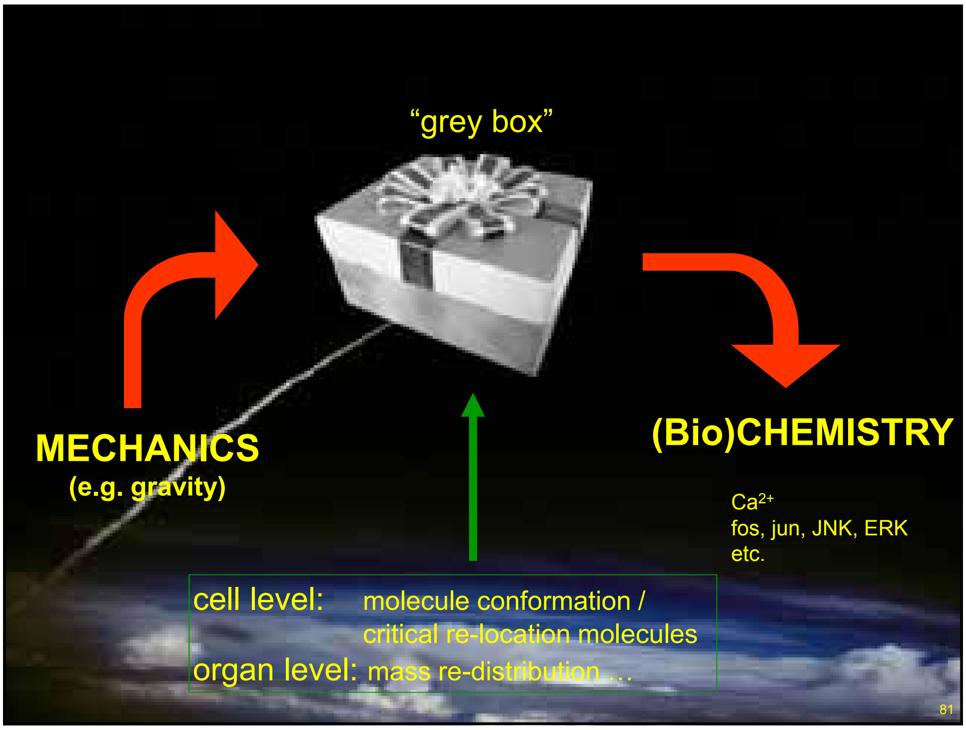
76


Earth – like / Exo – planets (2)
Potential Habitable Exoplanets
Including both confirmed and unconfirmed exoplanets
Habitable Exoplanets Catalog
Earth and Mars
Pending NASA Kepler Candidates*
No Human-Like Life
77


H3
ground based
space exploration
spin-off
spin-in
reduced gravity
paradigm
Human Hypergravity Habitat; H 3
Spin-off and Spin-in applications
78


The Human Hypergravity Habitat, H 3
An Altered Gravity Platform
~ 175 m
✓BERTE bvba
✓BETAQUA
✓QinetiQ
✓IFB GmbH
79


Finally : ..
80



Some books gravitational biology (o.a.)

"Laboratory Science with Space Data. Accessing and Using Space-Experiment Data." Beysens, D.; Carotenuto, L.; van Loon, J.J.W.A.; Zell, M. (Eds.) Springer, Heidelberg, Dortrecht, London, New York, 2011.

"Biology in Space and Life on Earth: Effects of Spaceflight on Biological Systems".
Edt. Enno Brinckmann. Wiley 2007.

(Some Physics: J. van Loon: "The Gravity Environment in Space Experiments")

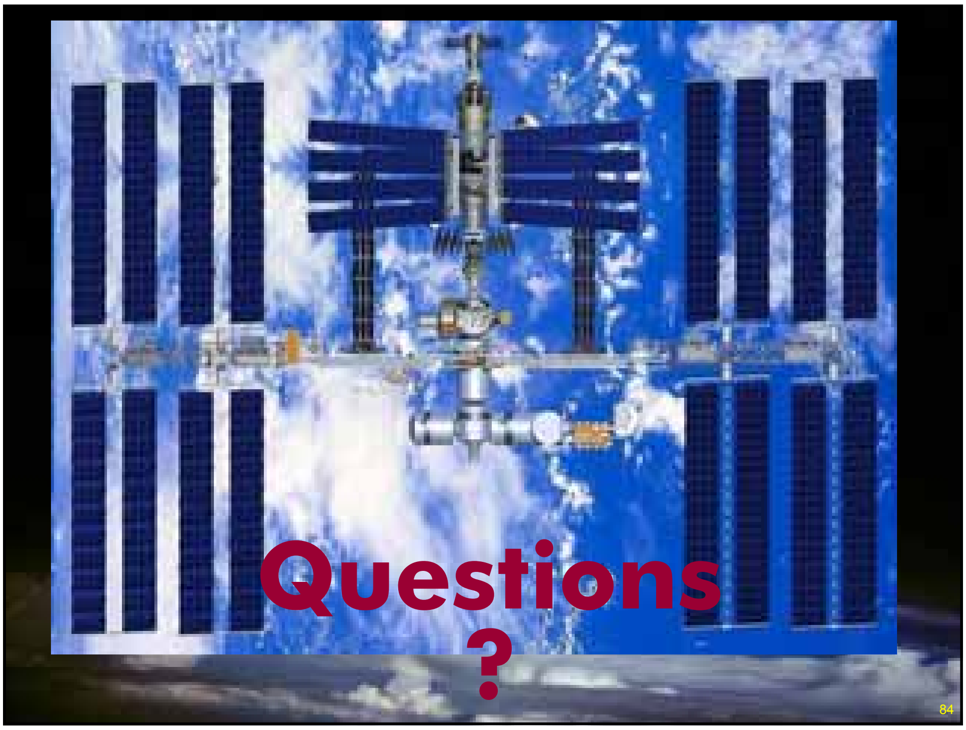
"Fundamentals of Space Biology: Research on Cells, Animals, And Plants in Space." Edt. Gilles Clement & Klaus Slenzka. Springer-Verlag 2006.

"Gravity and the Behavior of Unicellular Organisms" By Donat-Peter Häder, Ruth Hemmersbach, Michael Lebert. Cambridge University Press, 2005..

Cell Mechanochemistry. Biological Systems and Factors Including Mechanical Stress. such a Light, Pressure and Gravity. Edt. Monica Monici, Jack J.W.A. v. Loon, Transworld research network, 2010.

82


Acknowledgements
Thanks to all who have provided information and data for this presentation
Supported by the
- European Low Gravity Research Association
83


Questions
?
84