



CELL BIOLOGY IN SPACE

Neal R. Pellis, Ph.D.
Senior Scientist
Space Life Sciences
NASA Johnson Space Center
Houston, TX 77058
neal.r.pellis@nasa.gov

Terrestrial Life and Microgravity

- As life evolved on earth a multiplicity of changes in physical and chemical factors invoked adaptations and participated in the complicated selection process
- For many factors there are clear examples of the role of changing physical forces in evolution
- A notable exception is gravity. It has been constant for 4.8 billion years
- Therefore, there is little or no genetic memory of life responding to force changes in the low gravity range
- It is likely that terrestrial life adapting to microgravity will reveal many novel mechanisms that will be helpful in biomedical research, commercialization, fundamental science, and space exploration



Why Space Cell Biology?

- As is true for terrestrial based biomedicine, analysis of the cellular response to microgravity offers the prospect of elucidating underlying mechanisms that can be the basis for effective treatment.
- Observation of the cellular response to variation in 'G' reveals novel adaptive mechanisms.
- Understanding basic cellular mechanisms necessary for the adaptation of terrestrial life to low gravity environments will reveal novel adaptation mechanisms useful space exploration but moreover may reveal novel mechanisms important in human health



Unique aspects of μG

- No sedimentation
- Loss of gravity driven convection
- Decreased hydrodynamic shear
- No hydrostatic pressure
- Mass transfer is limited to the rate of diffusion



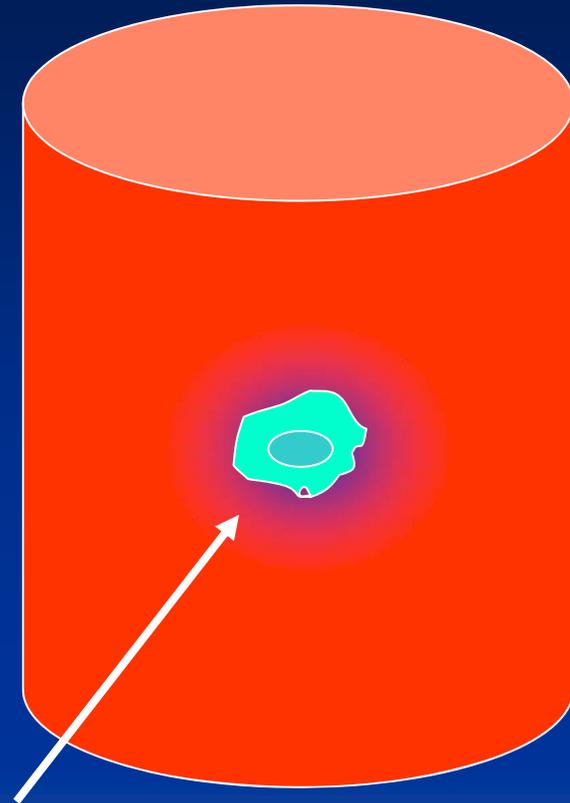
Cells in Microgravity

Theoretical Effects

- Absence of gravity driven convection
- Nutrient transfer limited to the rate of diffusion
- Cells become anoxic

Actual Effects

- They don't die
- There may be non gravity driven convections that facilitate mass transfer



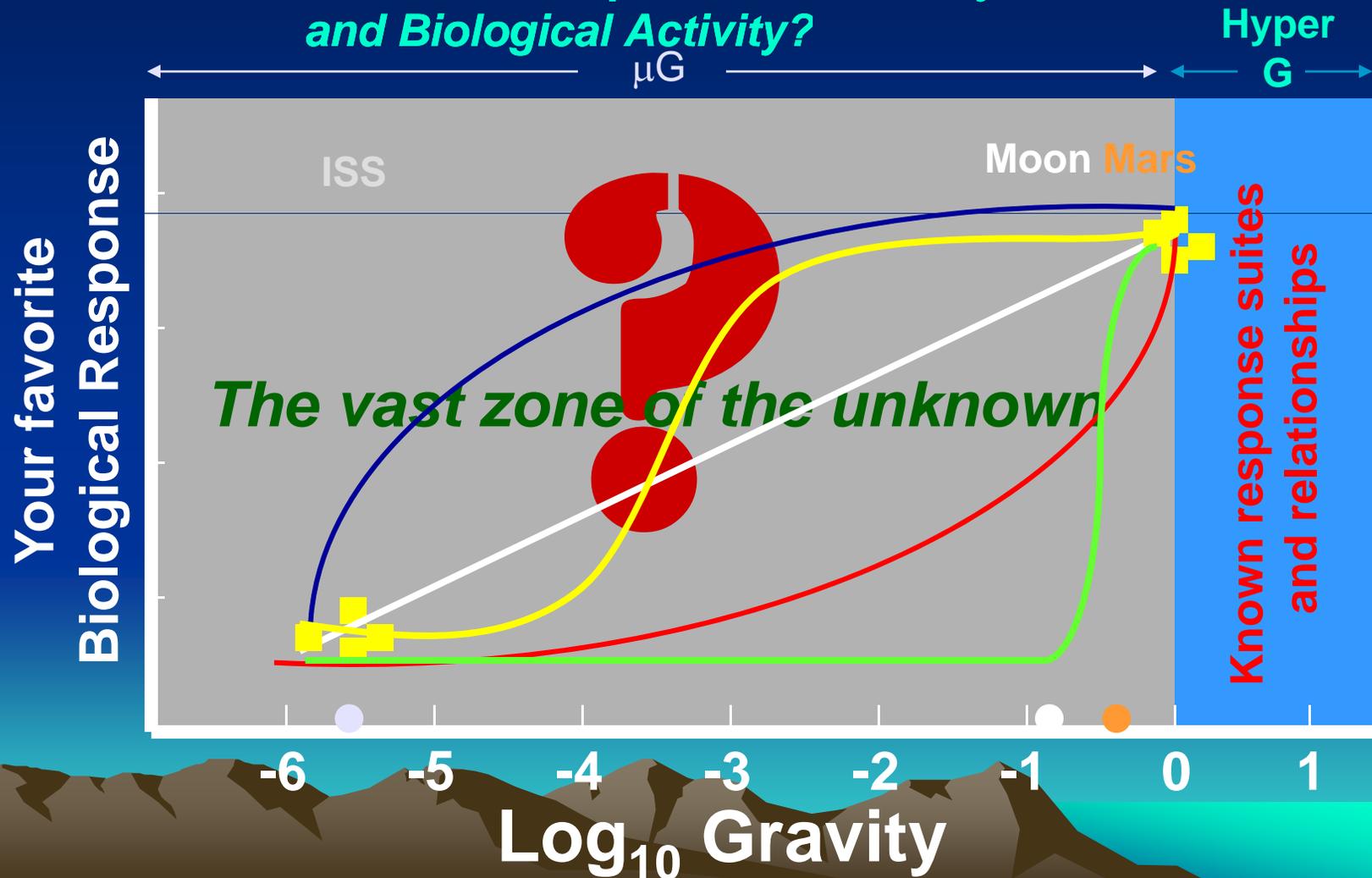
Zone of depletion
O₂ is depleted first
Glucose is second
Others follow

Fundamental Questions

- **What is the basis of the cellular response to microgravity?**
 - Intrinsic response in the cell (gravisensor?)
 - Cellular response to environmental changes induced by gravity
 - Shear
 - Mass transfer
 - Surface contact
 - No sedimentation
- **How is response different in microbial cells (that are bound by a cell wall) vs. eukaryotic/mammalian cells that do not have a cell wall?**
- **What is the threshold 'G' necessary for normal function?**
- **How does microgravity change cell response thresholds to other stimuli (radiation, magnetic fields, shear, toxins, other chemicals)?**
- **How do the changes in individual cells relate to tissues, organs, and organisms?**

An Important Question in Space Cell Biology

What is the Relationship Between Gravity and Biological Activity?

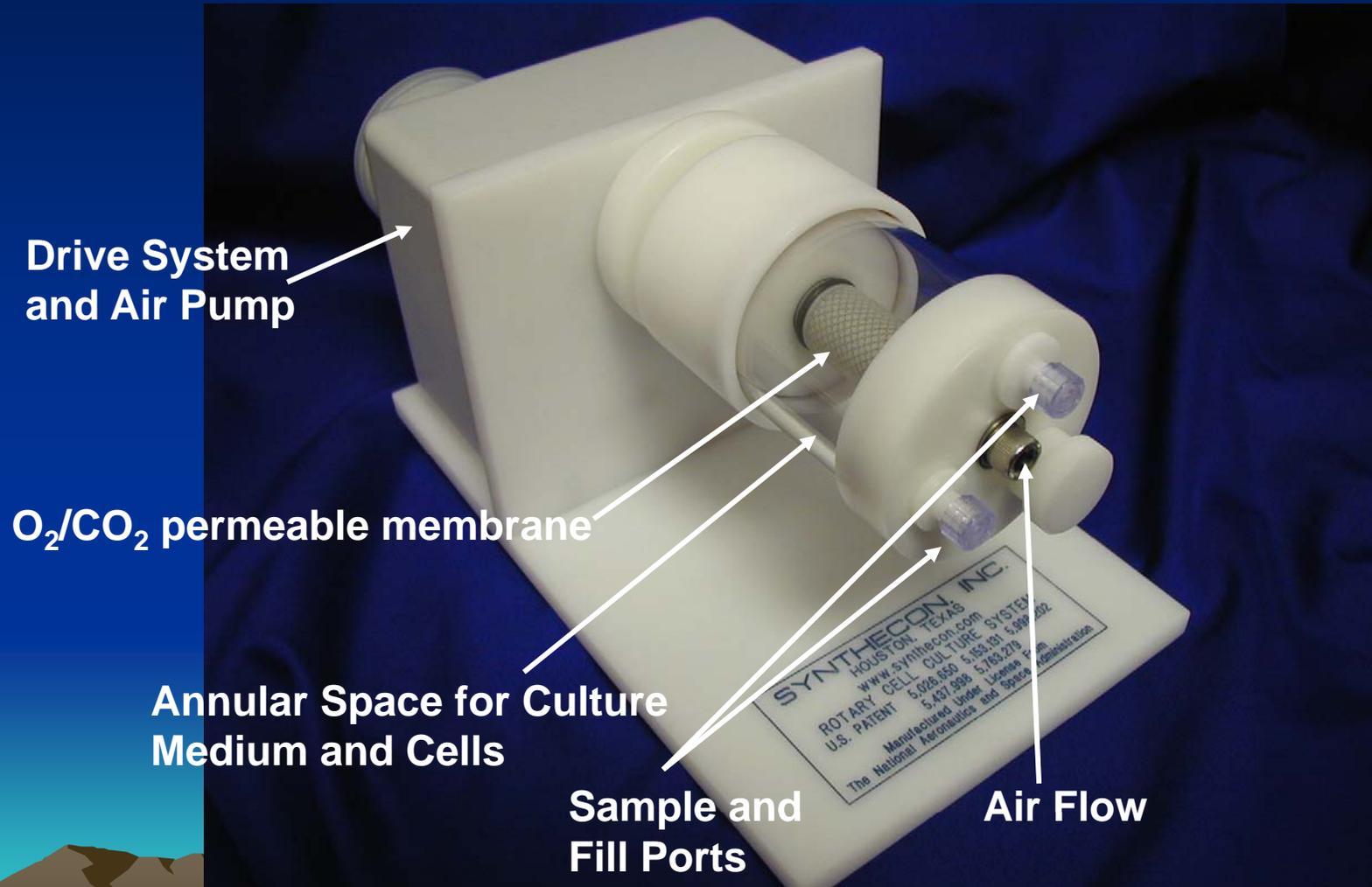


Implementation Questions to Address

- How to conduct focused programs of investigation in space?
- What are the appropriate analogs for μG to use in cell biology experiments?
- What are the controls that maximize the opportunity to ascribe a biological phenomenon to the influence of μG ?



NASA Microgravity Analog Cell Culture System



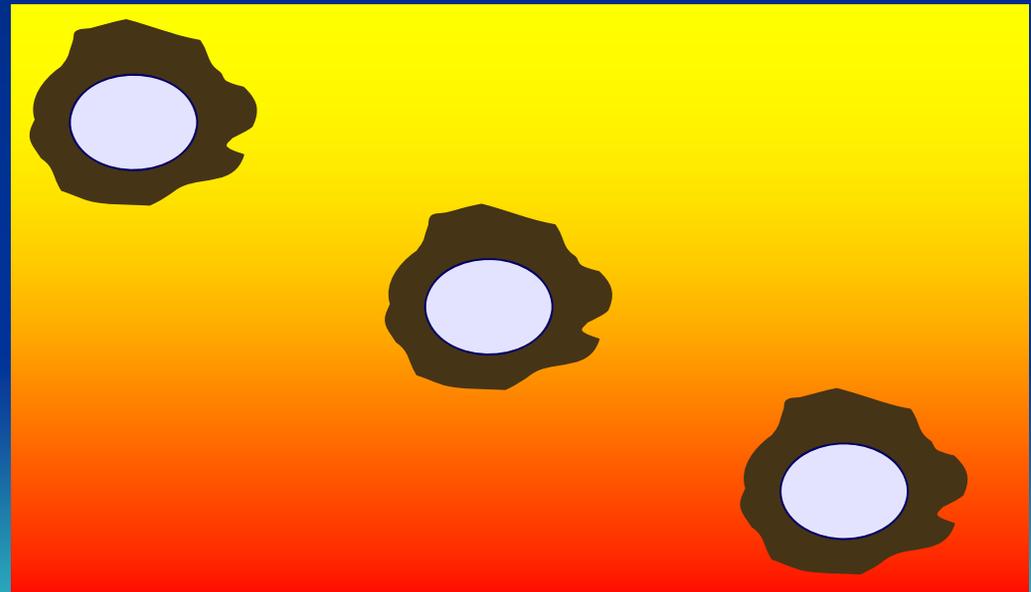
Manufactured by Synthecon, Inc.

Microgravity Cell Culture Analog Conditions

Randomized G



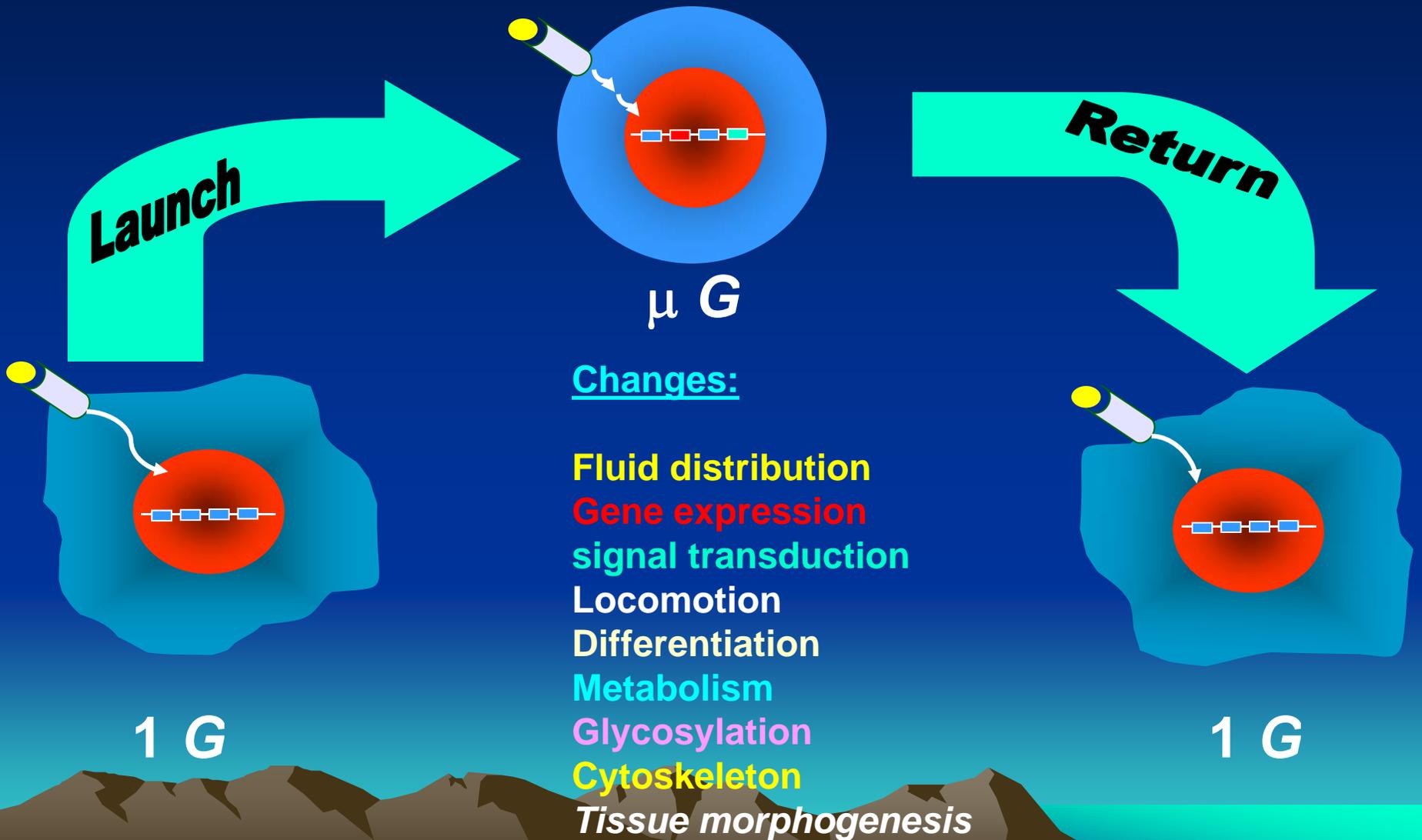
Terminal Velocity
Sedimentation



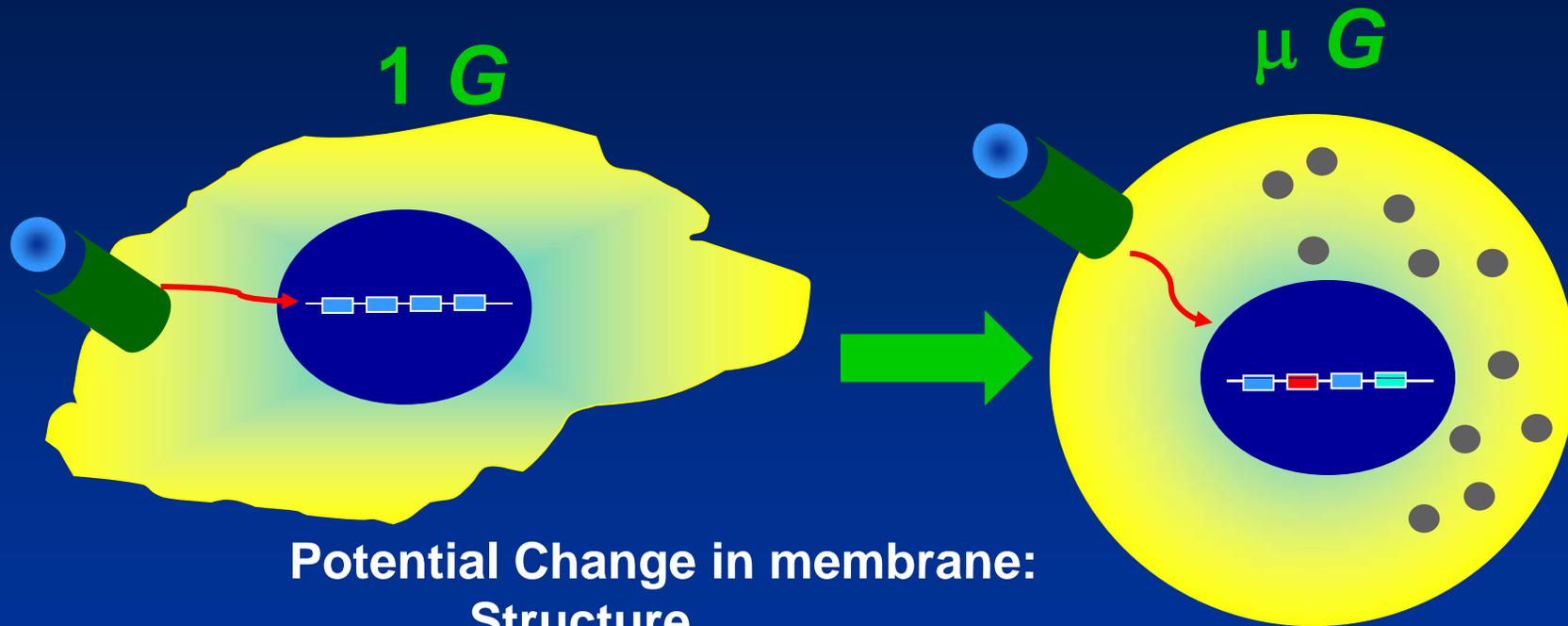
Time



Animal Cells in Space



Theory of the Effect of μG on Mammalian Cells



Potential Change in membrane:

Structure

Composition

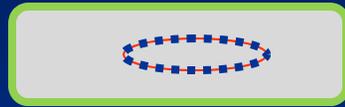
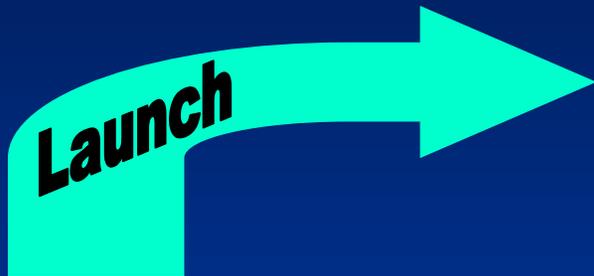
Bileaflet organization

Lipid rafts

Association with the cytoskeleton

Perhaps the 'forced' shape change induces a cascade of responses otherwise unrelated to μG

Bacteria in Space



μG



Changes:

Bacillus spacecowboyum



1 G

- Gene expression
- Shift to secondary metabolism
- Quorum sensing?
- Virulence
- Mechano-responsive mechanisms
- Replication rates
- Biofilm formation



1 G

Significance

- There is little doubt that cells respond decreased gravity environments.
- The mechanism of gravity induced responses in cells is unknown.
- Nevertheless, microgravity affords a unique tool to probe the underlying mechanisms in cell biology.
- We plan use of this tool in novel ways to increase our understanding of the role of gravity in life processes, to achieve goals in applied biological science and technology development, and to elucidate the long term effects of microgravity on terrestrial life.