

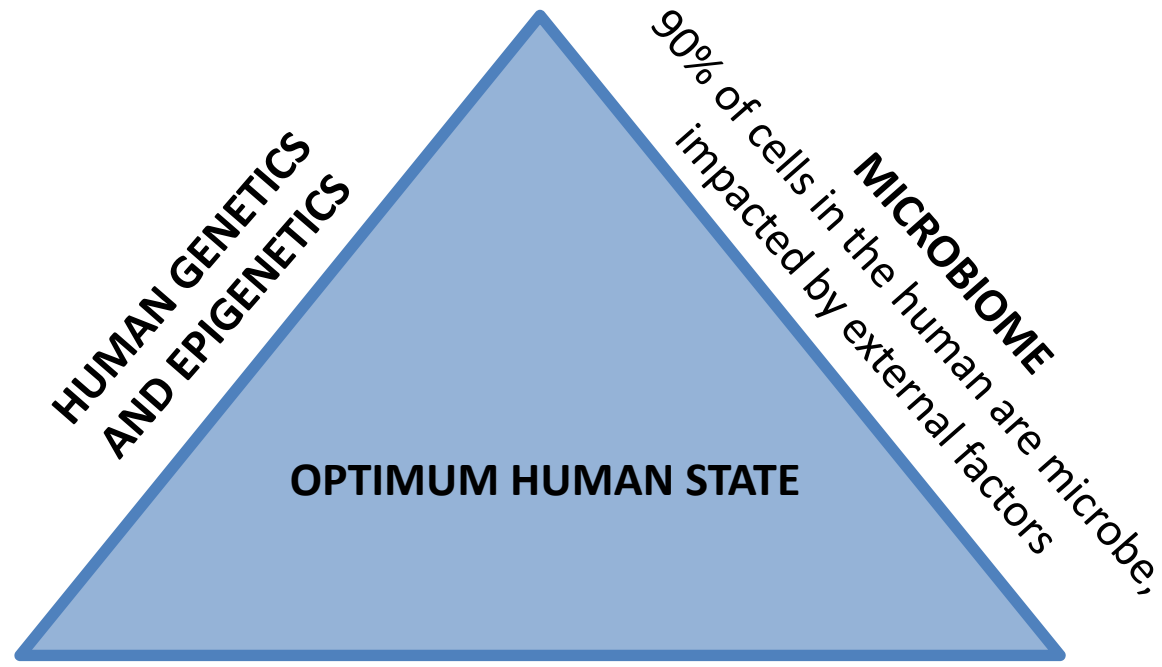
Probiotics in the Space Food
System:
Delivery, Microgravity Effects,
and the Potential Benefit to
Crew Health

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Influences are Environment, stress, mood, and health:

- Microgravity
- Sleep shift
- Temperature
- Air Quality
- Light
- Exercise
- Antibiotics/Meds
- Pathogens

FOOD



Daily environmental influence that is greatly modifiable

EFFECTS: Cardiovascular, bone, muscle, behavioral health and performance, immune response, etc.



Probiotics



- Why?
 - Why probiotics?
- How?
 - How do we deliver probiotics in spaceflight?
 - How do probiotics respond to microgravity?
- What?
 - What is the human response to probiotics in microgravity?





WHY: Probiotics?

HUMAN STATE IN SPACEFLIGHT

Stress, Anxiety, Depression
(Slack et al. 2009)

Elevated inflammatory cytokines
(Crucian et al. 2014)

Reduced immune cell function
(Crucian et al. 2008)

POSSIBLE OUTCOMES

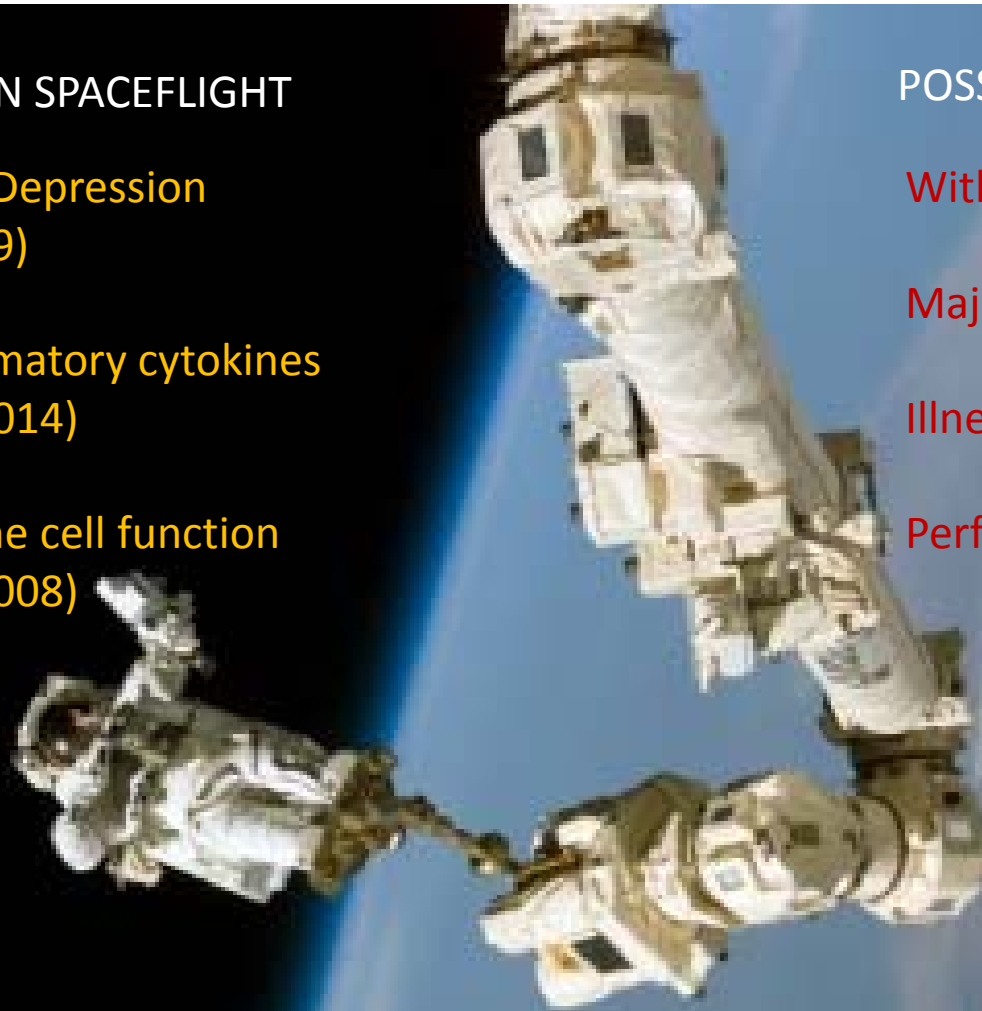
Withdrawal, Conflict

Major Psychological Event

Illness

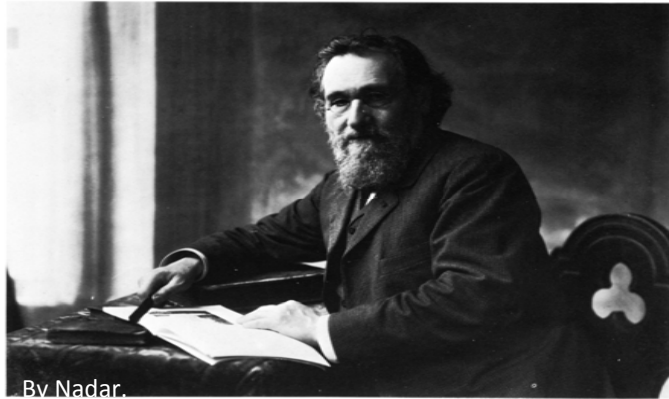
Performance Decrement

NEED FOR NONINVASIVE
COUNTERMEASURES

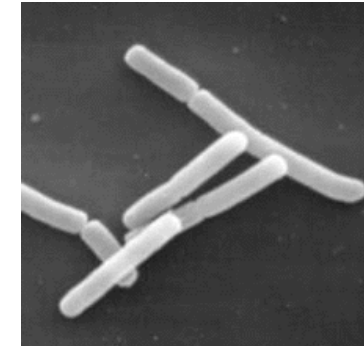




Lactobacilli and health



By Nadar.



www.uga.edu/biz/en/q818771/

1907
Elie Metchnikoff
publishes *The
Prolongation of
Life: Optimistic
Studies*.

1915
Leo Rettger
proposes *L.
acidophilus* as a
suitable
probiotic.

1930
Minoru Shirota
isolates *L. casei*,
develops and
commercializes
Yakult.

1950+
Techniques
developed
enabling
genomic
elucidation of
probiotic
mechanisms.

2010
Human gut
microbiome
catalogued.



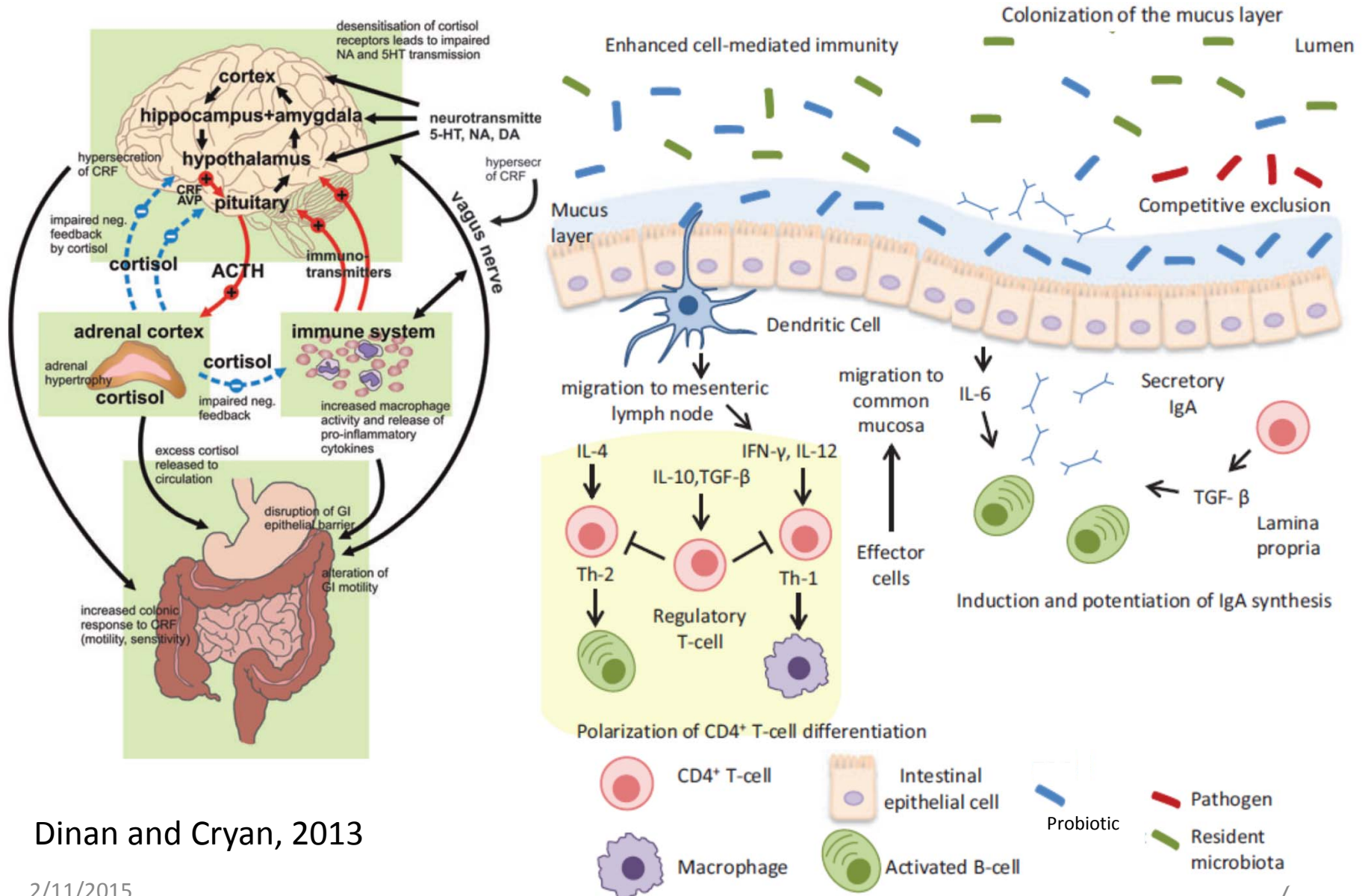
Probiotics are “live microorganisms which when administered in adequate amounts confer a health benefit on the host” (WHO/FAO)

Probiotic-Associated Benefit	Reference
Protection against infection	Corr et al. (2007)
Lowered incidence of diarrhea	Leyer et al. (2009)
Lowered risk of antibiotic-associated diarrhea	Gao et al. (2010)
Lowered levels of cold and influenza-like symptoms	Leyer et al. (2009)
Inhibition of <i>H. pylori</i>	Fujimura et al. (2012)
Prevention of upper respiratory infection	Hao et al. (2011)
Return to pre-antibiotic baseline flora	Engelbrektson et al. (2009)
Epithelial barrier function	Mennigen and Bruewer (2009)
Increased humoral Immunity via secretion of IgA	Viljanen et al. (2005)
Competitive exclusion of pathogens	Lee et al. (2003)
Neuroactive compound production	Wall et al. (2014)
Reduced psychological distress	Messaoudi et al. (2011)
Reduced anxiety	Rao et al. (2009)

Modified from O’Flaherty and Klaenhammer, 2010



Probiotic Mechanisms



Dinan and Cryan, 2013

2/11/2015

Modified from Selle and Klaenhammer, 2013



HOW: deliver within Food System Constraints

Mars Expedition Scenario:

- 2.5 year mission
- Microgravity and reduced gravity
- No resupply
- Food may be prepositioned (5 year shelf life)
- Constrained mass and volume



Within this scenario, probiotics must:

- Survive
- Maintain probiotic attributes
- Provide similar benefits as those recorded on Earth





Probiotic Survival

CAPSULE



VS

FOOD



ROOM TEMPERATURE STORAGE

VS

COLD STORAGE

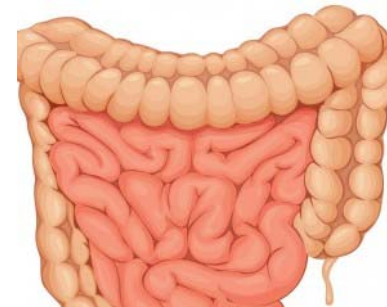
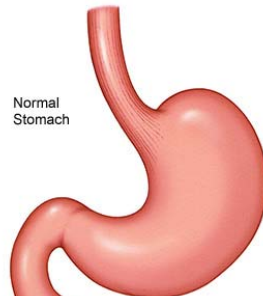


SURVIVAL THROUGH DIGESTIVE TRACT

pH 2, pepsin

VS

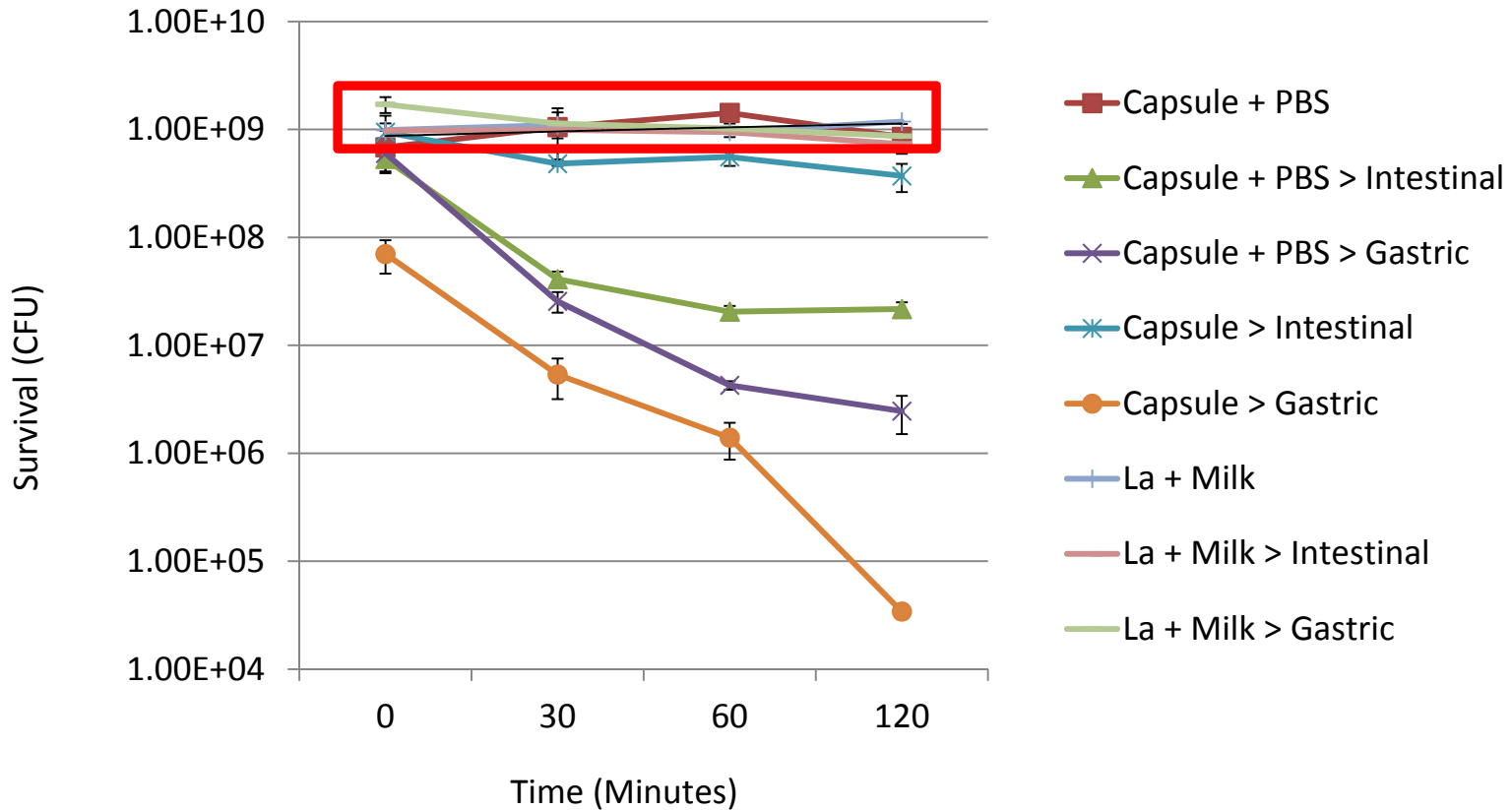
pH 8, pancreatic juice





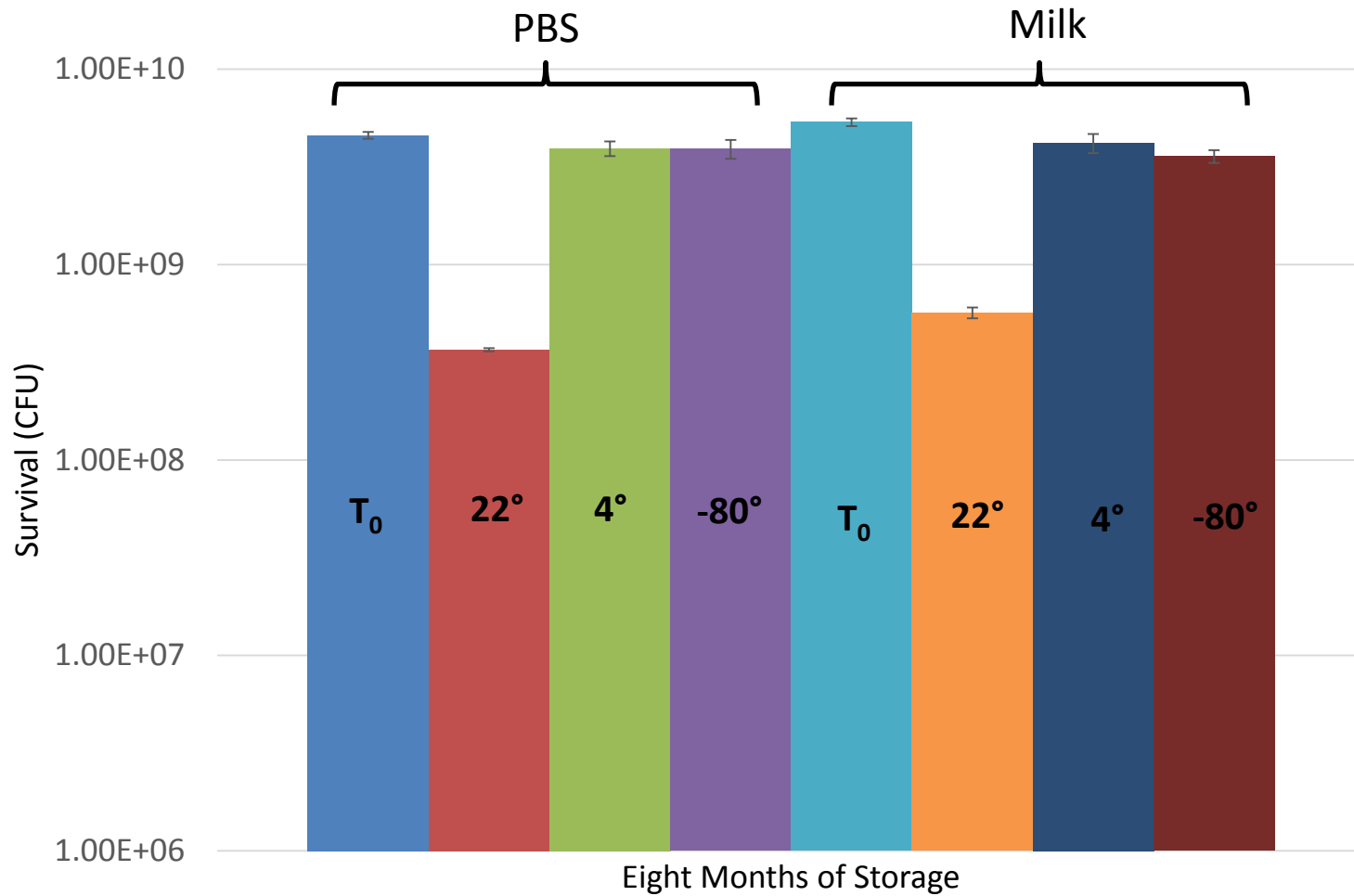
Stability of Commercially Available Probiotic

Nonfat Dry Milk as a Delivery Vehicle



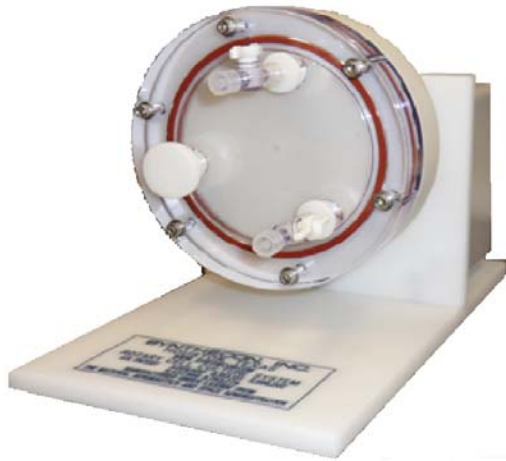


Storage Temperature





HOW: Respond to Microgravity

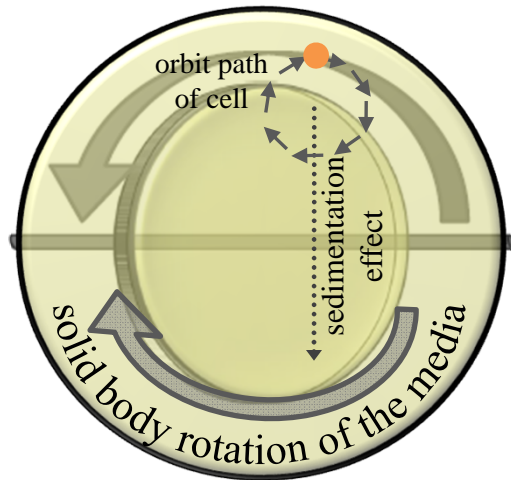


Rotating-wall vessel (RWV)
Synthecon (Houston, TX)

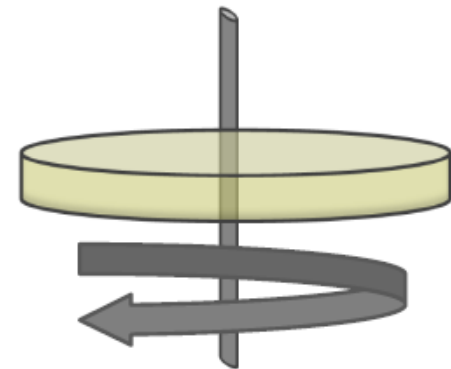


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LSMMG
Orientation



Control
Orientation





Microgravity Response

- Effect on survival in simulated GI conditions
- Effect on growth
- Effect on gene expression



Illumina MiSeq

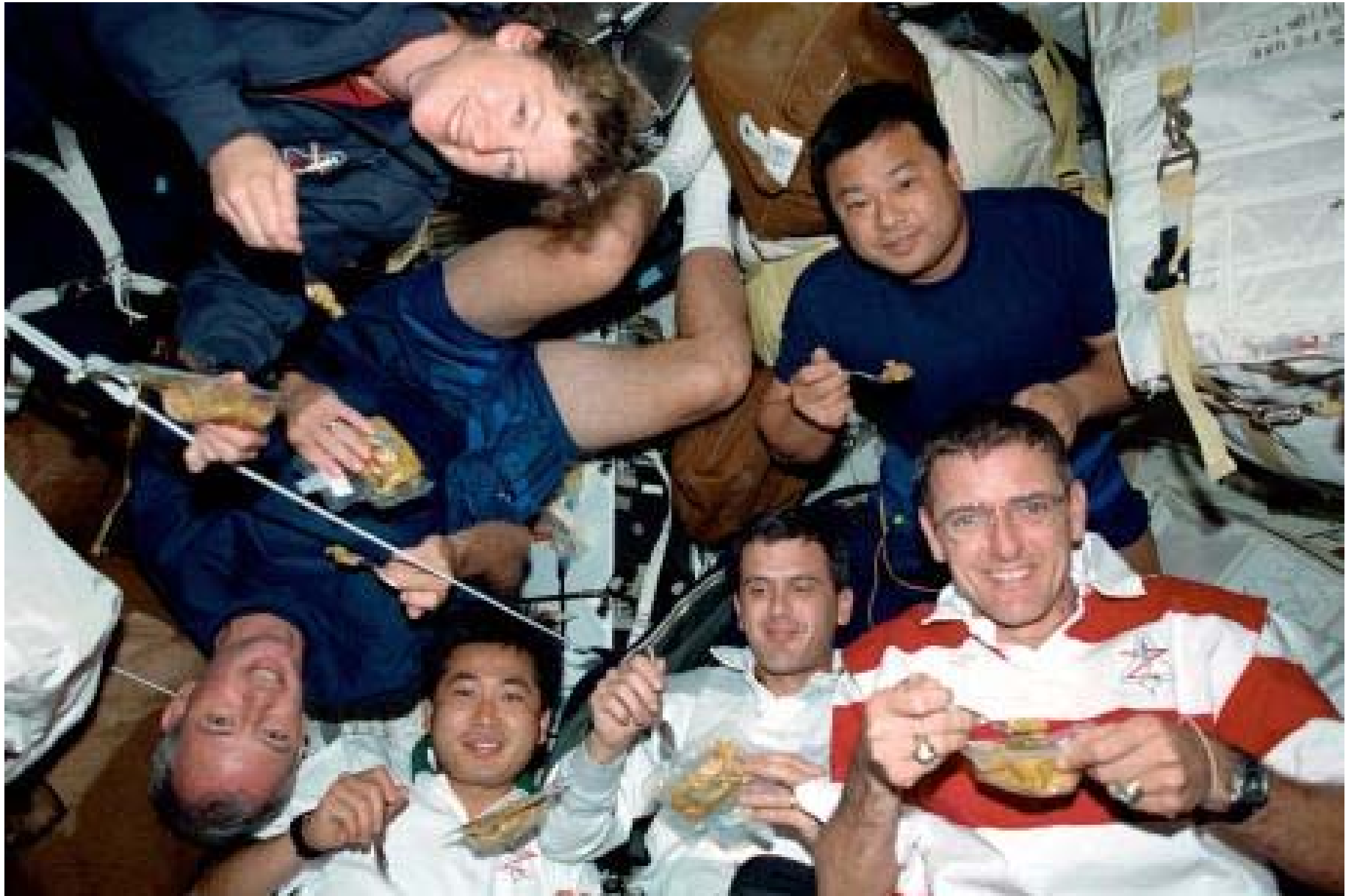


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- Microbiology Laboratory



Questions





Probiotic Mechanisms

