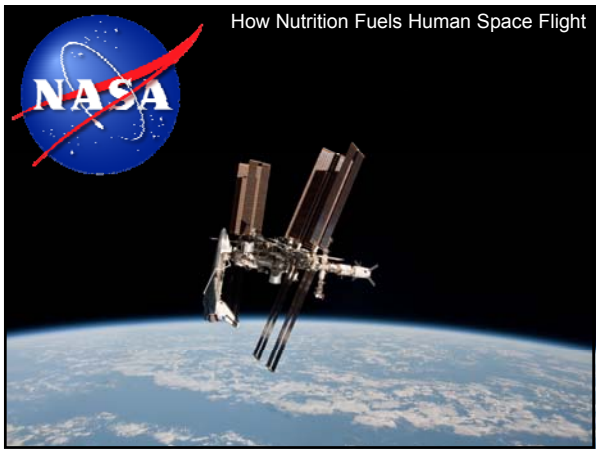
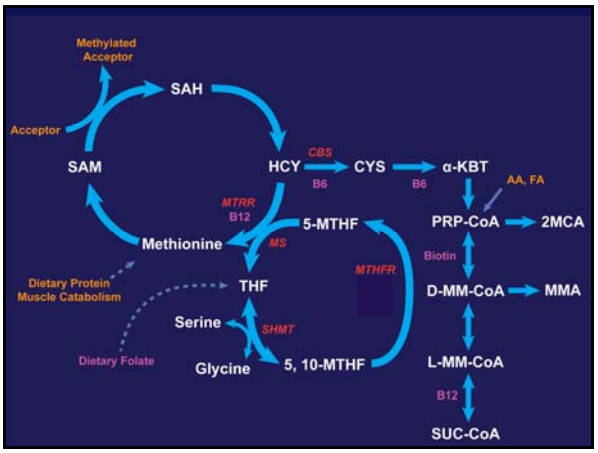
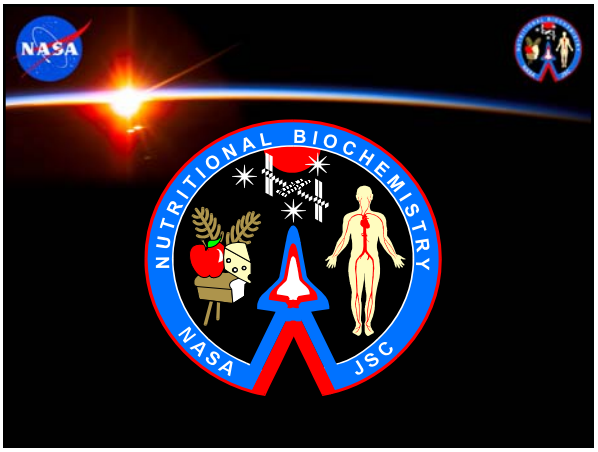
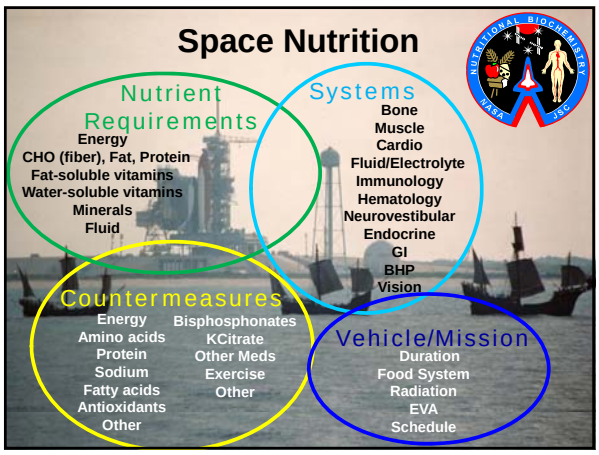
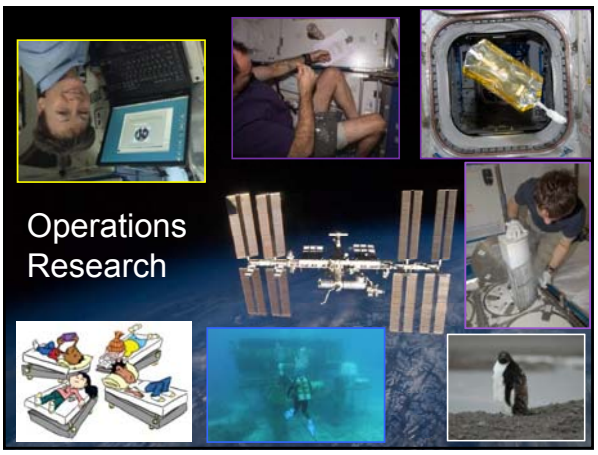
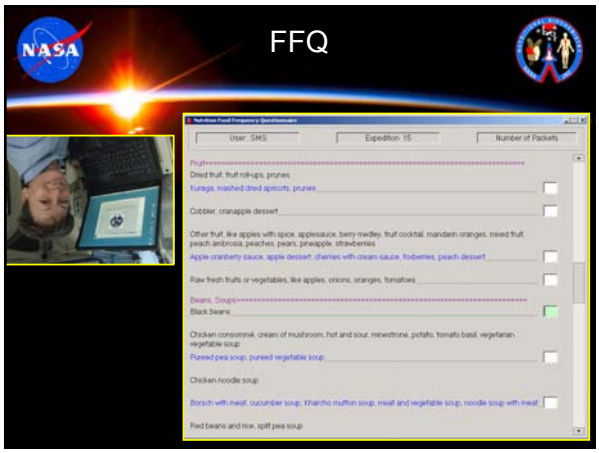

How Nutrition Fuels Human Space Flight
NASA


Methylated Acceptor
Acceptor
SAH
SAM
HCY
CBS
B6
CYS
B6
α-KBT
AA, FA
PRP-CoA
2MCA
MTRR
B12
5-MTHF
Methionine
MS
MTHFR
Biotin
Dietary Protein
Muscle Catabolism
THF
D-MM-CoA
MMA
Serine
SHMT
Dietary Folate
Glycine
5, 10-MTHF
L-MM-CoA
B12
SUC-CoA


NASA
NUTRITIONAL BIOCHEMISTRY
NASA
JSC

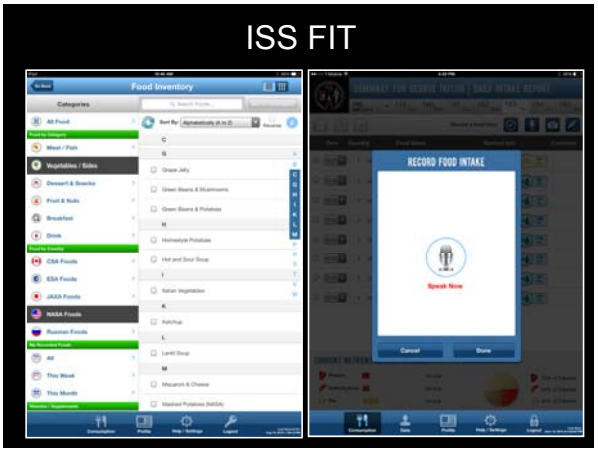

Space Nutrition
Nutrient Requirements
Energy
CHO (fiber), Fat, Protein
Fat-soluble vitamins
Water-soluble vitamins
Minerals
Fluid
Systems
Bone
Muscle
Cardio
Fluid/Electrolyte
Immunology
Hematology
Neurovestibular
Endocrine
GI
BHP
Vision
Countermeasures
Energy
Amino acids
Protein
Sodium
Fatty acids
Antioxidants
Other
Bisphosphonates
KCitrate
Other Meds
Exercise
Other
Vehicle/Mission
Duration
Food System
Radiation
EVA
Schedule


Operations Research

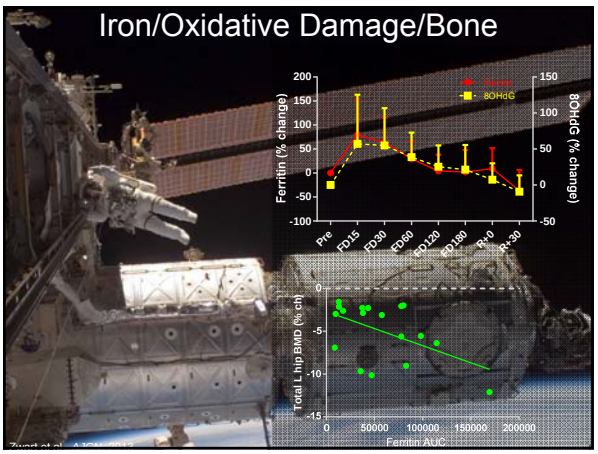

FFQ

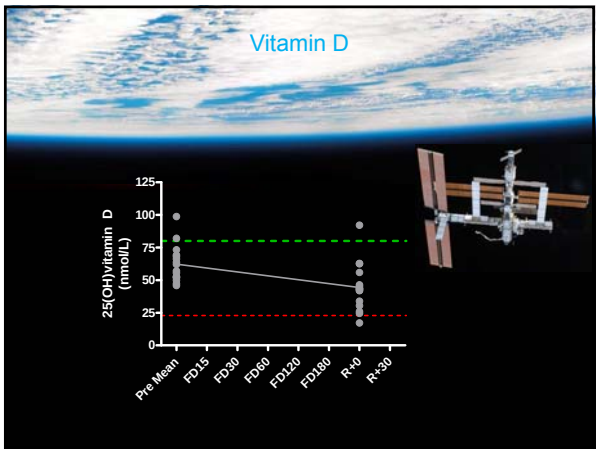

ISS FIT
NASA - ISS FOOD INTAKE TRACKER
PHOTO LOGIN
Daily Intake Report

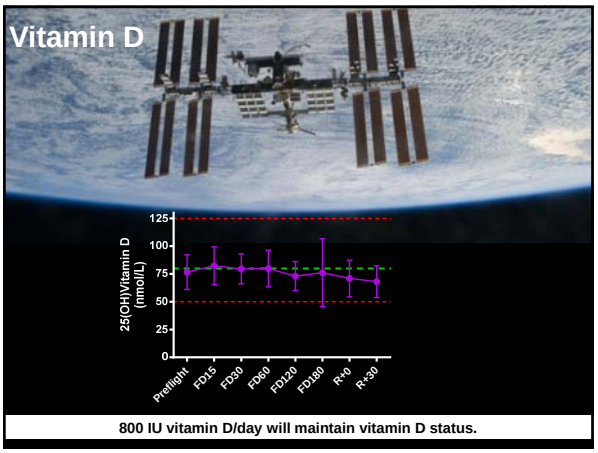

ISS FIT
DAILY INTAKE REPORT
Daily Intake Report

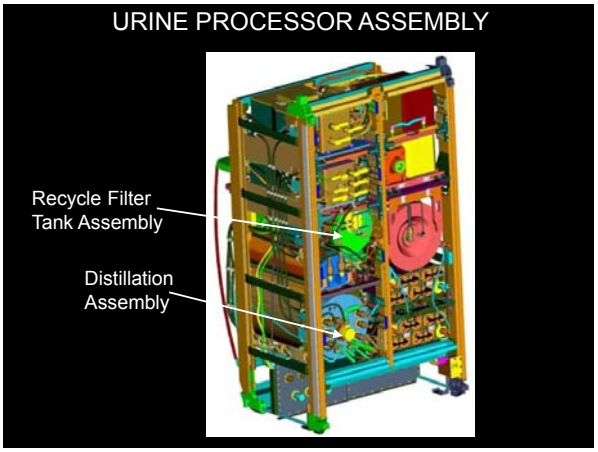

ISS FIT
Food Inventory
RECORD FOOD INTAKE

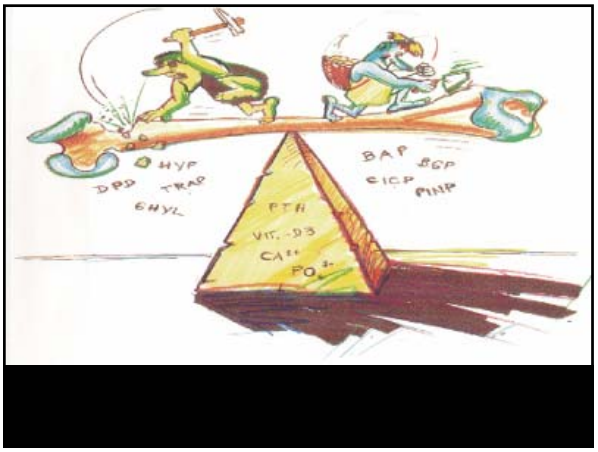

ISS FIT
NASA - ISS FOOD INTAKE TRACKER
PHOTO LOGIN
Daily Intake Report

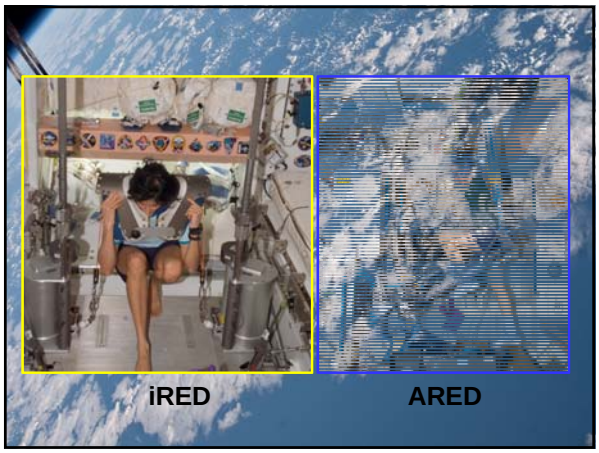

Iron/Oxidative Damage/Bone
Ferritin (% change)
8OHdG (% change)
Pre
FD15
FD30
FD60
FD120
FD180
R+0
R+30
Total L. hip BMD (% ch)
Ferritin AUC

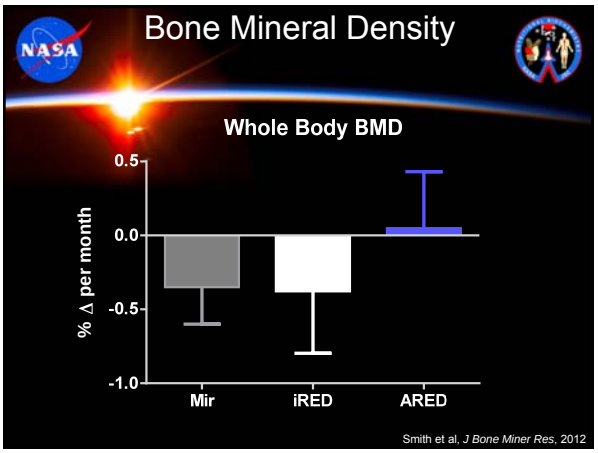

Vitamin D
25(OH)vitamin D (nmol/L)
125
100
75
50
25
0
Pre Mean
FD15
FD30
FD60
FD120
FD180
R+0
R+30

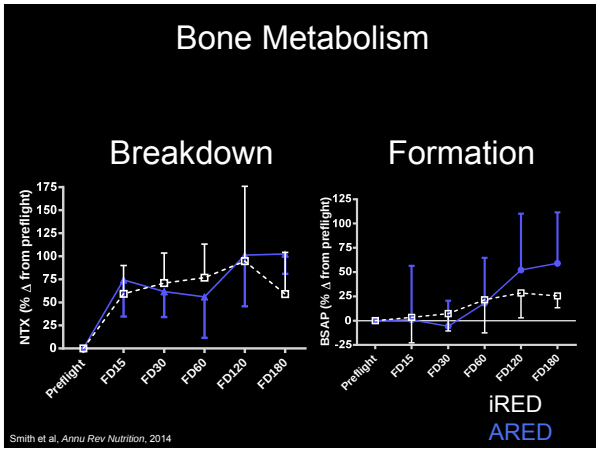

Vitamin D
25(OH)Vitamin D (nmol/L)
125
100
75
50
25
0
Preflight
FD15
FD30
FD60
FD120
FD180
R+0
R+30
800 IU vitamin D/day will maintain vitamin D status.


URINE PROCESSOR ASSEMBLY
Recycle Filter Tank Assembly
Distillation Assembly

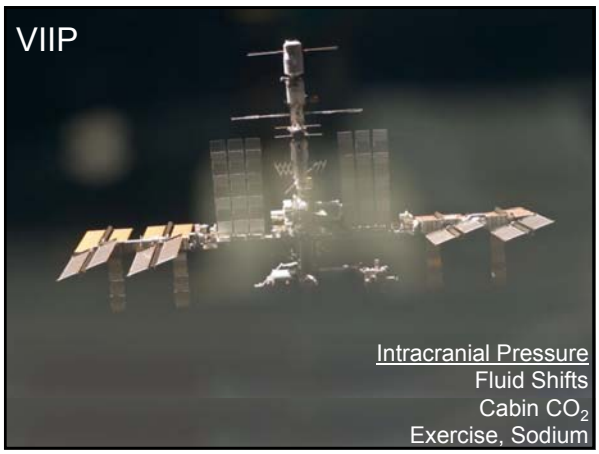

HYP
DPD
TRAP
BAP
BGP
PTH
VIT. D3
CA++
PO4-

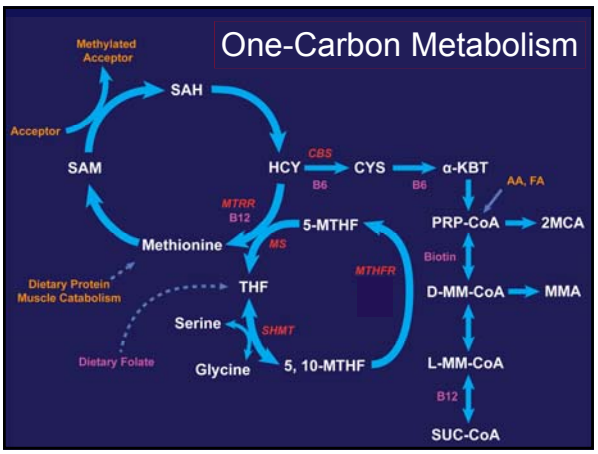

iRED
ARED

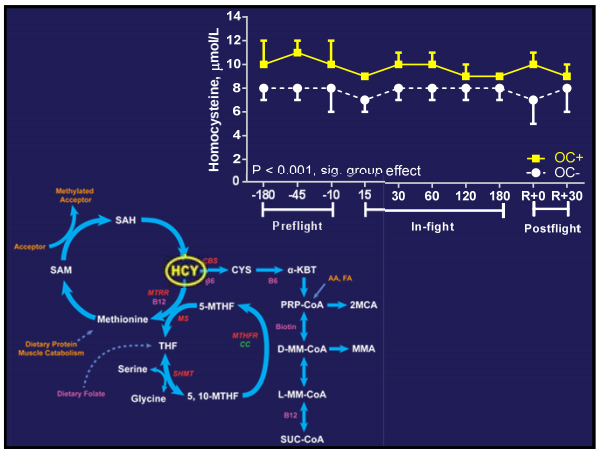

Bone Mineral Density
Whole Body BMD
% Δ per month
0.5
0.0
-0.5
-1.0
Mir
iRED
ARED
Smith et al, J Bone Miner Res, 2012

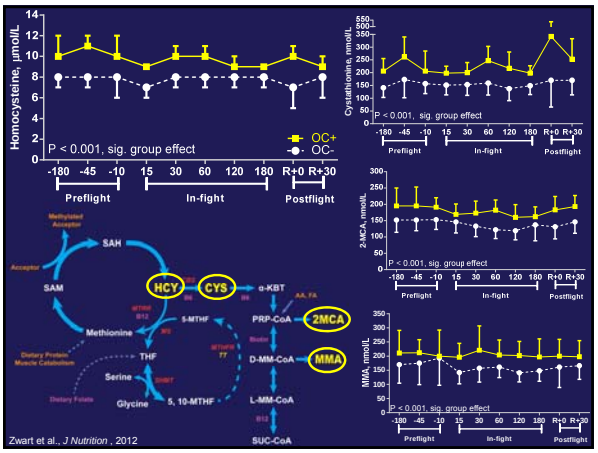

Bone Metabolism
Breakdown
Formation
NTX (% Δ from preflight)
BSAP (% Δ from preflight)
Preflight
FD15
FD30
FD60
FD120
FD180
iRED
ARED
Smith et al, Annu Rev Nutrition, 2014


Forward Work
Bone Strength?
Fracture risk?
Optimization
Exercise
Diet


VIIP
Intracranial Pressure
Fluid Shifts
Cabin CO_2
Exercise, Sodium


One-Carbon Metabolism
Methylated Acceptor
Acceptor
SAH
SAM
HCY
CBS
B6
CYS
α-KBT
AA, FA
PRP-CoA
2MCA
MTRR
B12
5-MTHF
MS
Methionine
Biotin
MTHFR
Dietary Protein Muscle Catabolism
THF
D-MM-CoA
MMA
Serine
SHMT
Dietary Folate
Glycine
5, 10-MTHF
L-MM-CoA
B12
SUC-CoA





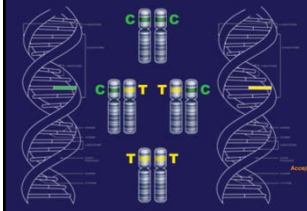
Enzymes

- Proteins, amino acid strings
- assembled from amino acids based on "blueprints"

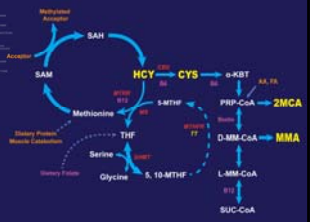
Enzyme Polymorphisms

- poly = multiple, "morph" = forms
- For many (all?) enzymes, there are small differences in blueprints across the population (e.g., blood types)

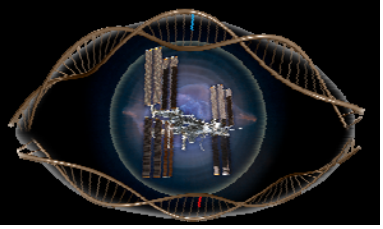
MTHFR C677T Polymorphism



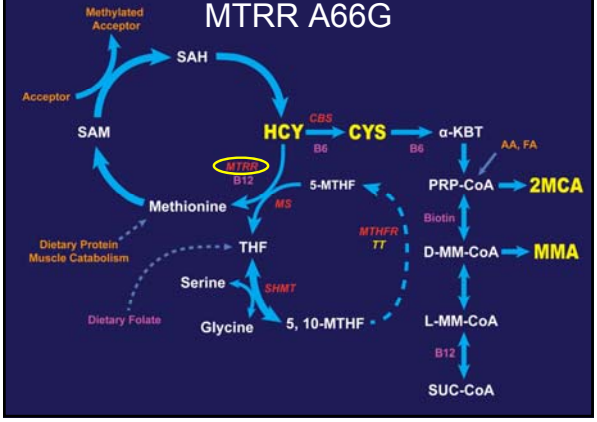
	% Pop	Enz Act.
C/C	~35%	100%
C/T(T/C)	~50%	~66%
T/T	~15%	~50%

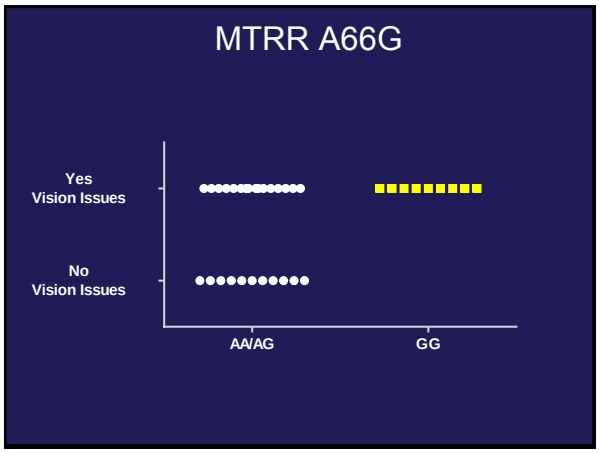


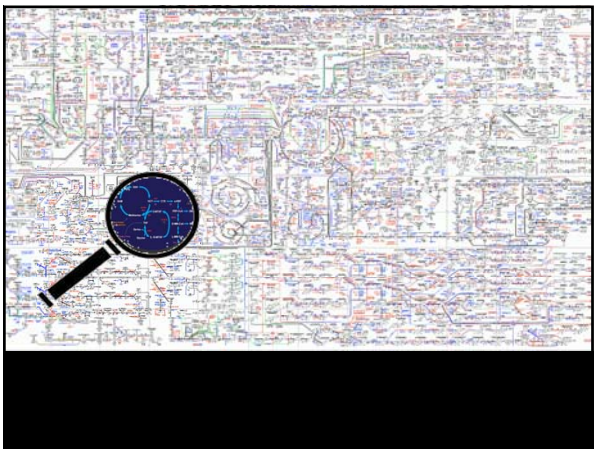
- Follow-on study:
  - Five 1C polymorphisms
  - Expanded biochemistry/metabolomics
  - Vision and related medical data
  - n = 70/72 ISS astronauts

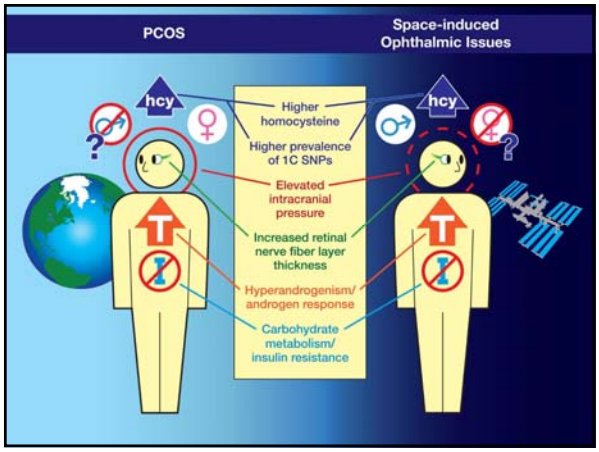


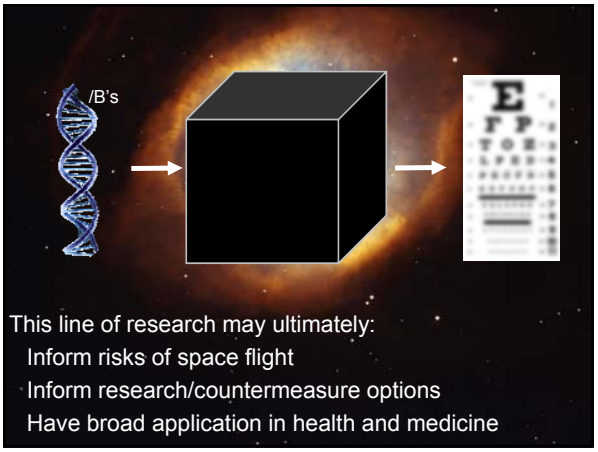
MTRR A66G

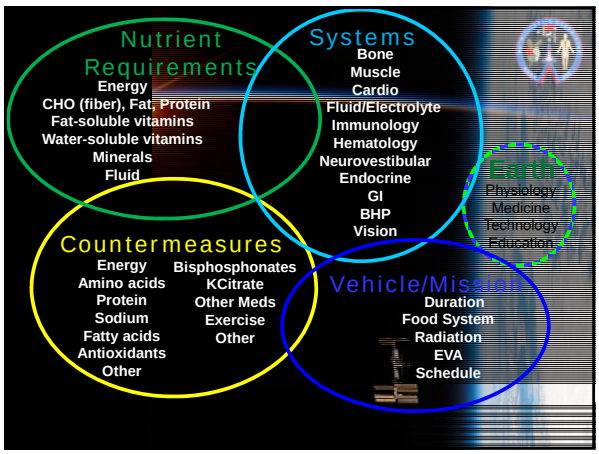


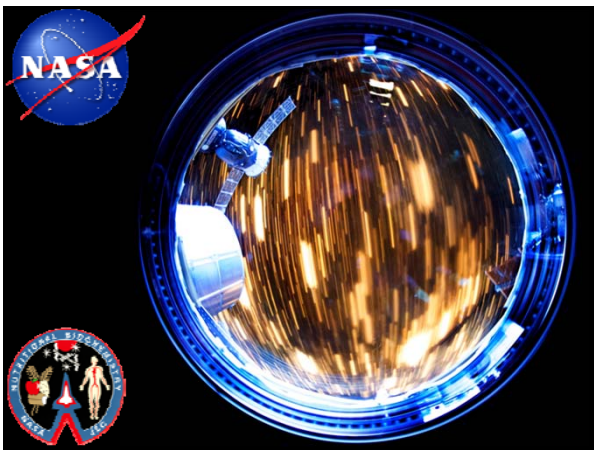

MTRR A66G
Yes
Vision Issues
No
Vision Issues
AA/AG
GG



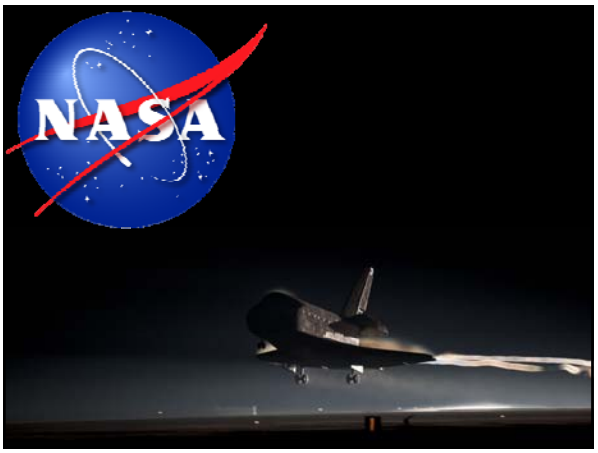

PCOS
Space-induced
Ophthalmic Issues
hcy
hcy
Higher
homocysteine
Higher prevalence
of 1C SNPs
Elevated
intracranial
pressure
Increased retinal
nerve fiber layer
thickness
Hyperandrogenism/
androgen response
Carbohydrate
metabolism/
insulin resistance


/B's
This line of research may ultimately:
Inform risks of space flight
Inform research/countermeasure options
Have broad application in health and medicine

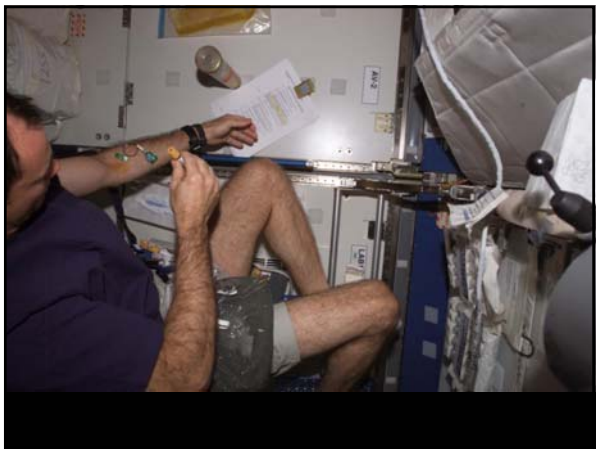

Nutrient
Requirements
Energy
CHO (fiber), Fat, Protein
Fat-soluble vitamins
Water-soluble vitamins
Minerals
Fluid
Systems
Bone
Muscle
Cardio
Fluid/Electrolyte
Immunology
Hematology
Neurovestibular
Endocrine
GI
BHP
Vision
Earth
Physiology
Medicine
Technology
Education
Countermeasures
Energy
Amino acids
Protein
Sodium
Fatty acids
Antioxidants
Other
Bisphosphonates
KCitrate
Other Meds
Exercise
Other
Vehicle/Mission
Duration
Food System
Radiation
EVA
Schedule

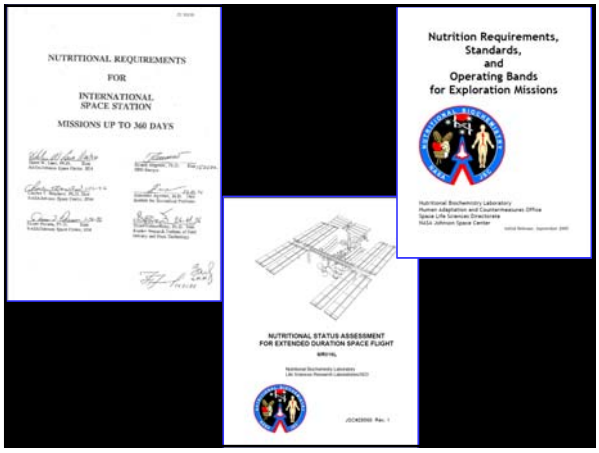

NASA

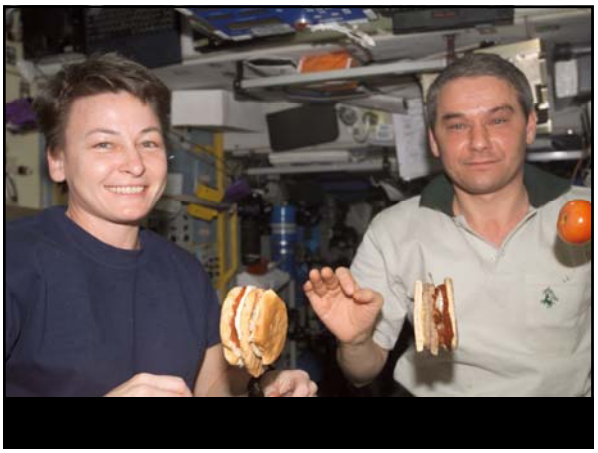

ORION EFT-1
ORION
EXPLORATION FLIGHT TEST


NASA

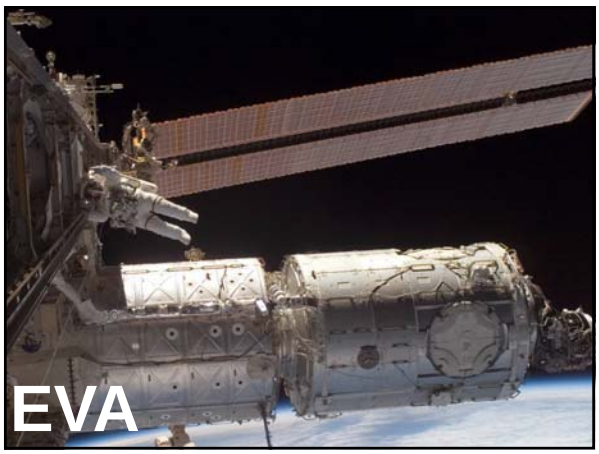

SLAMMD

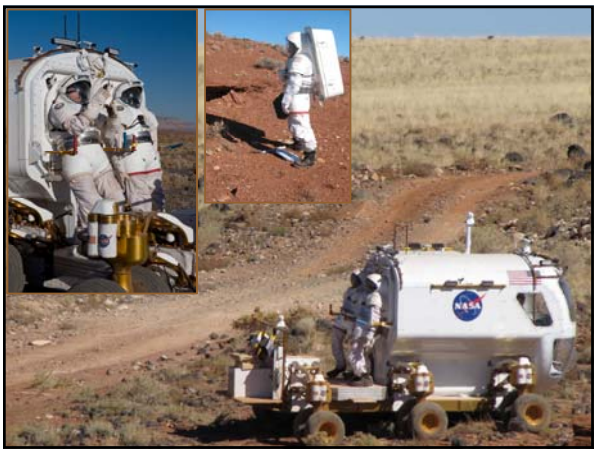



NUTRITIONAL REQUIREMENTS
FOR
INTERNATIONAL
SPACE STATION
MISSIONS UP TO 360 DAYS
Nutrition Requirements,
Standards,
and
Operating Bands
for Exploration Missions
NUTRITIONAL STATUS ASSESSMENT
FOR EXTENDED DURATION SPACE FLIGHT

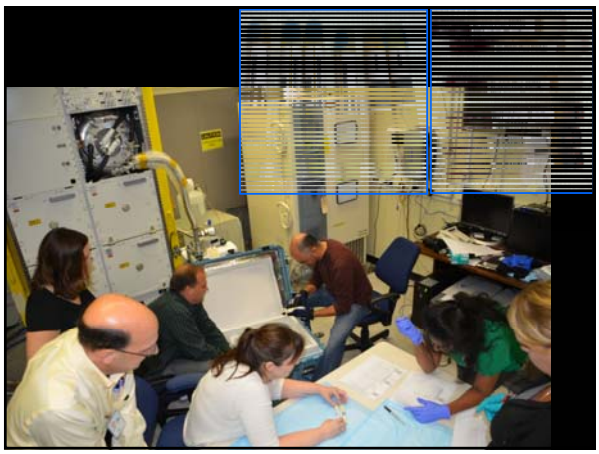


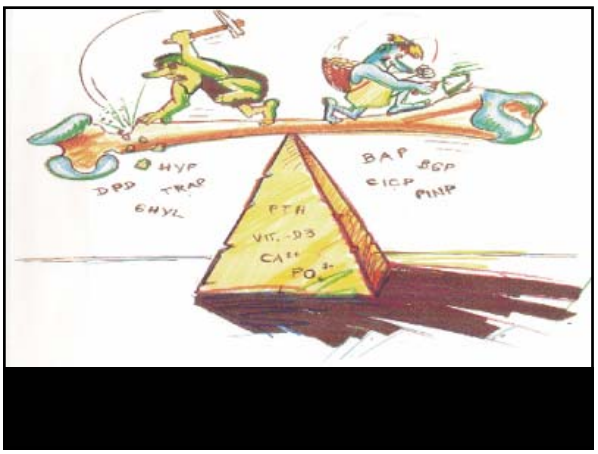

SPEED
LIMIT
28000
km/h


EVA




WHC
CAUTION
DO NOT OBSTRUCT OPENING
INTERNATIONAL SPACE STATION
ORBITAL OUTHOUSE TEAM




DPD
HYP
TRAP
EHYL
BAP
BGP
CICP
PINP
PTH
VIT.-D3
CA++
PO4--

Calcium Isotopes

^{48}Ca ^{46}Ca ^{44}Ca ^{43}Ca ^{42}Ca ^{40}Ca

Calcium Isotopes

^{48}Ca	^{46}Ca	^{44}Ca	^{43}Ca	^{42}Ca	^{40}Ca
0.187%	<0.1%	0.2086%	0.135%	0.647%	96.941%

Calcium Isotopes

^{48}Ca ^{46}Ca ^{44}Ca ^{43}Ca ^{42}Ca ^{40}Ca

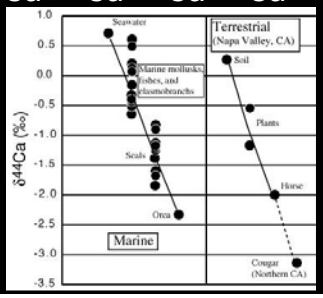
Bone formation favors light Ca isotopes

Calcium Isotopes

^{48}Ca ^{46}Ca ^{44}Ca ^{43}Ca ^{42}Ca ^{40}Ca

Higher δ44Ca = "heavier"

Lower δ44Ca = "lighter"

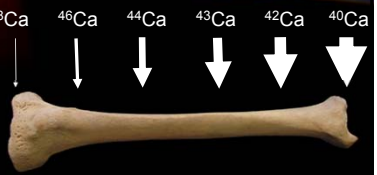


Skulan and DePaolo (1999); PNAS

Calcium Isotopes

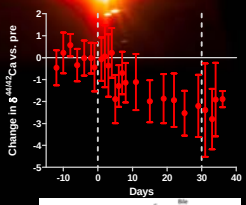
^{48}Ca ^{46}Ca ^{44}Ca ^{43}Ca ^{42}Ca ^{40}Ca

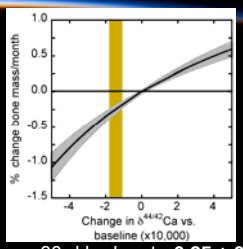
Bone formation favors light Ca isotopes



No isotope discrimination during bone resorption

Calcium Isotopes





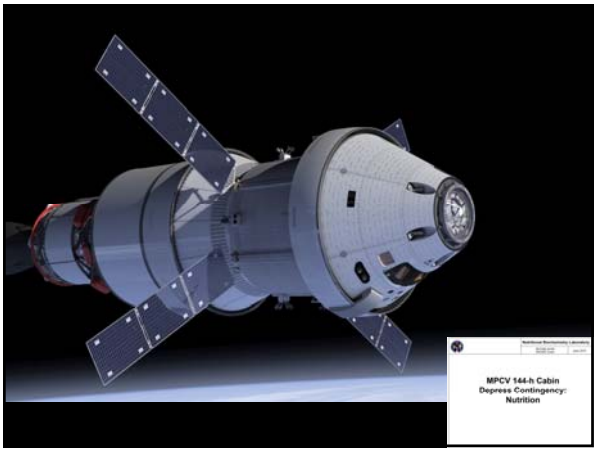
30-d bed rest: **-0.25 ± 0.07%**

119-d bed rest: **-1.36 ± 0.38%**

DXA 119-d bed rest: **-1.5 ± 1.0%**

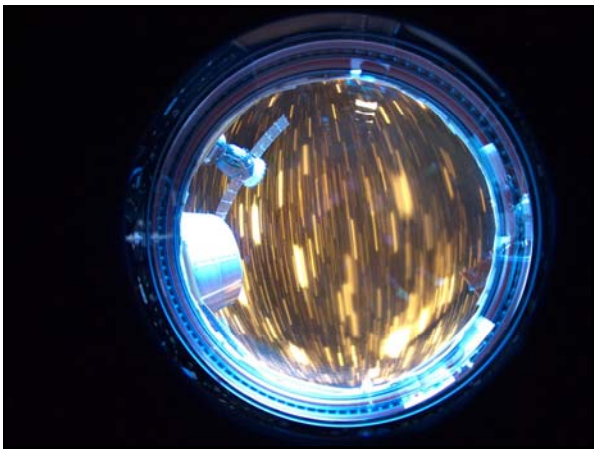
Morgan et al., PNAS, 2012

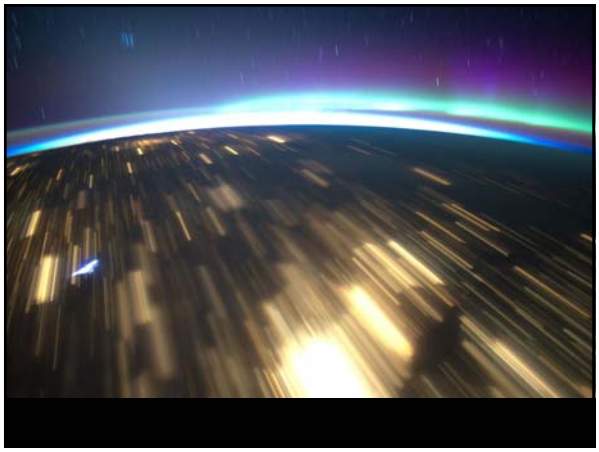

ORION EFT-1
ORION
EXPLORATION FLIGHT TEST

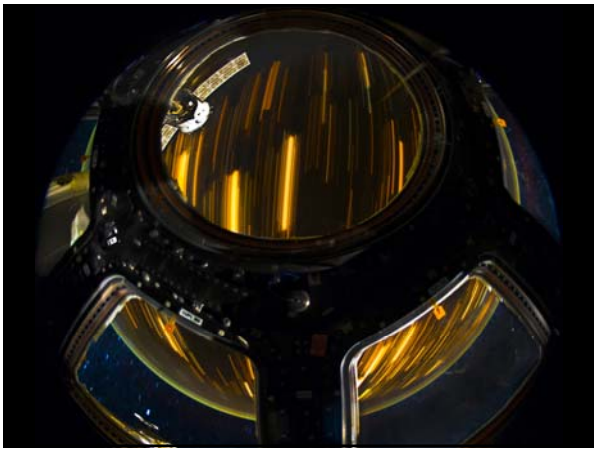

MPCV 144-h Cabin
Depress Contingency:
Nutrition


NASA
APOLLO 12


Nutritional Biochemistry of Space Flight
Space Nutrition
Human Adaptation to Spaceflight: The Role of Nutrition
http://www.nasa.gov/hhp/education





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