Strategies to design healthy processed foods in space

Vincenzo Fogliano

Chair Food Quality & Design group

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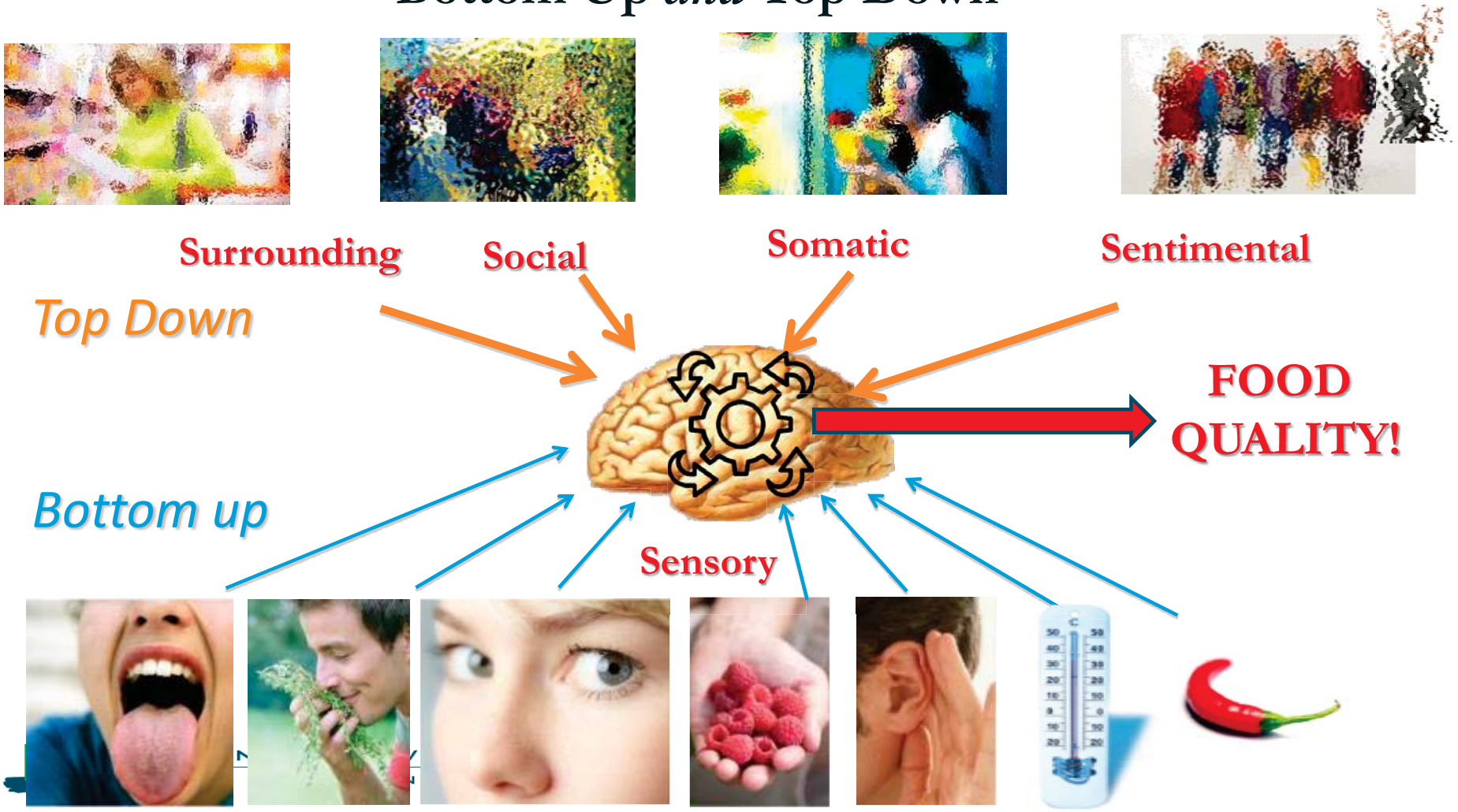
Outline

- Food quality in space
- The food chain approach for healthy food design
- Nutritional and health needs
  - Micronutrients & Phytochemicals
  - Proteins
- Which functional foods for astronauts
- Take home message

Intrinsic and Extrinsic food quality attributes: Bottom Up *and* Top Down



Pizza quality….. different for each of us

Perceived food quality during space missions

- **Only calorie to survive**: tube and cube foods (Mercury and Gemini)
- **"Like on the Earth" feeling**: processed food and use of cutlery and kitchen aids (Apollo)
- **Focus on the nutritional needs:** vitamins, mineral, and antioxidants supplementation (Skylab)
- **Sensory and pleasure:** refrigerators and heating systems (Skylab)

Perceived food quality during space missions

- **Focus on the consumer**:
  - Broad assortment of condiments in liquid form (ISS)
  - Ready to eat intermediate moisture foods under vacuum (granola, nuts, biscuits (Shuttle)
  - Dried food hydrated by users at the moment of consumption (Shuttle)
  - Variety of menu, attention to cultural aspects (ISS)
- **Focus on sustainability: (future long term missions)**
  - Freshness and harvesting (bioregenerative food systems)
  - Long term self-production: all attributes of food quality very similar to the plans for feeding the planet in 2050!

Toward consumer-oriented healthy food design

Future: Astronauts decide according their needs

- ~~Price~~
- Pleasure
- Convenience
- **Healthiness**

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Healthy Food Design: the chain approach

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Healthy Food Design: the chain approach

Identification physiological targets

Processing technology

Raw material selection and improvement

Formulation

Consumer & players behaviour

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Dekker, Verkerk et al., Trends Food Sci (2000)

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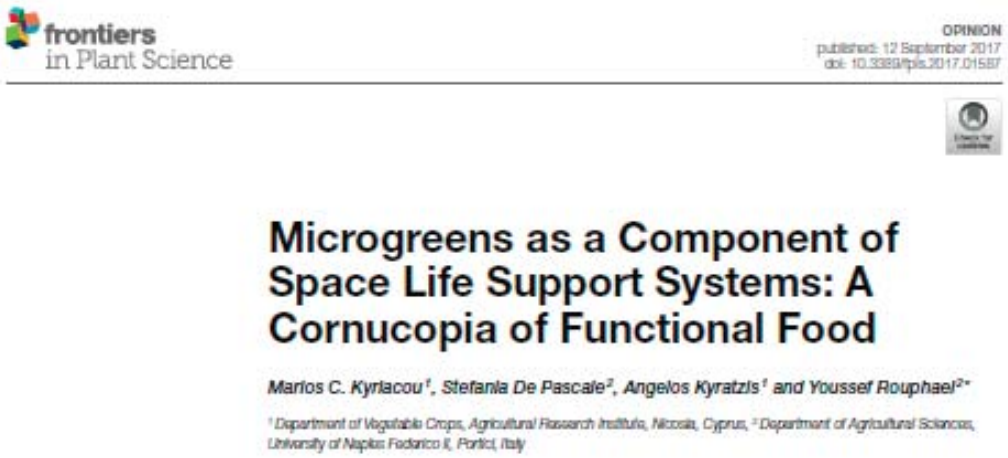
Vitamins and phytochemicals from veggies

- Freshly harvest veggies/small fruits: microgreens as resilient phytochemicals factory
  - None or minimally processed
  - "…These are not foods!" Formulation and combination with condiments is key for acceptability and bioavailability



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Vitamins and phytochemicals from plant-based food

- Processed plant-based foods are often nutritionally better than raw vegetables
  - Many vitamins and phytochemicals are more bioaccessible after processing (carotenoids, flavonoids, Vitamin E) only few are destroyed by processing (Vitamin C and anthocyanins)
  - Processed dietary fibre is better used by microbiota
  - Food processing and formulation can generate a variety of foods and ingredients

Which are feasible processes?

- Food processing in space
  - Many system constrains (energy, weight, dimension, water use)
  - Environmental advantages (baking, vacuum, absence of oxygen)
  - Compact, multipurpose food processors are promising
- Food storage in space
  - Sanitization treatments: cold and mild technologies
  - Shelf life: packaging is needed, however waste management remains a big issue

Proteins production is a matter of nitrogen utilization. We need to use efficient converters of nitrogen into proteins

Traditional Food	% protein (dry matter)
Meat & fish	67
Eggs	47
Skim Milk	43
Soybean	42
Peanuts	37
Wheat	12
Corn	11
Rice	8

Novel protein sources

Innovative Food	% protein (dry matter)
Microalgae	25-70
Yeast	55-70
Quorn (mycoproteins)	40-50
Duckweed	25-35
Insects	35-65

A lot has been done…

- Soybean:
  - Sprouts
  - Proteins (milk, SPI, Okara)
  - Oil
- Microalgae:
  - CO2 and nitrogen fixation
  - Proteins production
- Insects:
  - Entomophagy
  - By products reuse

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plant biology
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REVIEW ARTICLE

Soilless cultivation of soybean for Bioregenerative Life-Support Systems: a literature review and the experience of the MELiSSA Project – Food characterisation Phase I

R. Paradiso, V. De Micco, R. Buonomo, G. Aronne, G. Barbieri & S. De Pascale
Department of Agricultural Sciences, University of Naples Federico II, Portici, Naples, Italy

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Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research 41 (2008) 742–747
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Development of a ground-based space micro-algae photo-bioreactor

W. Ai [a,b,*], S. Guo [b], L. Qin [b], Y. Tang [b]
[a] College of Resources and Environmental Sciences, China Agricultural University, Beijing 100094, China
[b] Department of ECLSS, China Astronaut Research and Training Center, Beijing 100094, China

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ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Entomophagy: A key to space agriculture

N. Katayama [a], Y. Ishikawa [b], M. Takaoki [c], M. Yamashita [d,*], S. Nakayama [e], K. Kiguchi [f], R. Kok [g], H. Wada [h], J. Mitsuhashi [h], Space Agriculture Task Force

Soybean-based meat replacer: texture **was** the main problem

By a specific shearing extrusion technology a meat-like texture was obtained starting from soybean proteins

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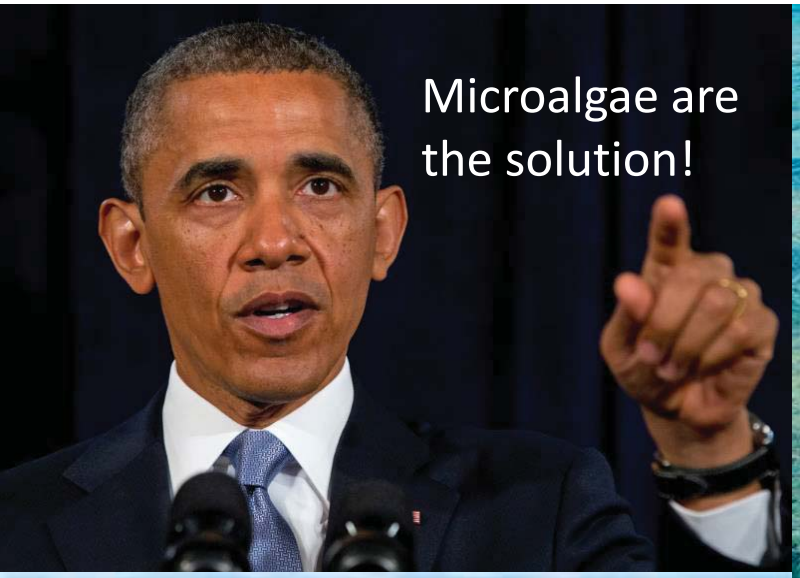
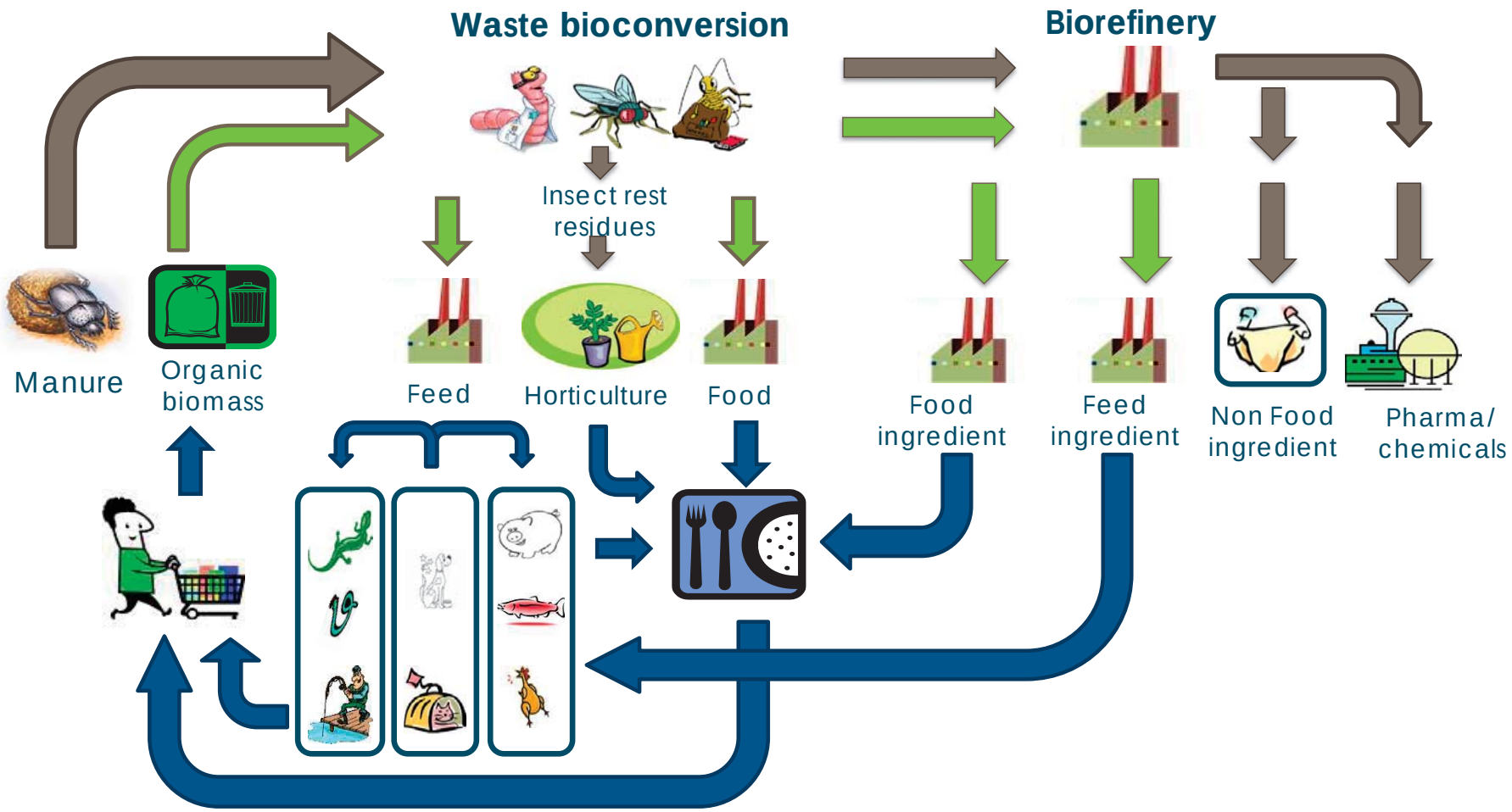

Microalgae are
the solution!

Insect as food: forget entomophagy!

Insects as food

Insect: the perfect tool to close the circle of food production



"Invisible insects" as food
Which are the challenges

- Scale up of rearing facilities
- **Techno-functional properties** (water holding, gelling, texture, color, foaming)
- Nutritional properties
- Safety (allergens)
- Regulatory framework

Insect fractionation

- **Mechanical separation/damage**

  Small scale extruder

- **Enzymatic treatment**

  Use of proteolytic enzymes

- **Mild Centrifugation**

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Contents lists available at ScienceDirect

Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

Harnessing functional food strategies for the health challenges of space travel—Fermented soy for astronaut nutrition ☆

Nicole D. Buckley [a,*], Claude P. Champagne [b], Adriana I. Masotti [c], Lisa E. Wagar [c], Thomas A. Tompkins [d], Julia M. Green-Johnson [c]

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Functional (healthy) foods for astronauts: which are the specific needs?

- ✓ Insufficient micronutrients and phytochemicals
- ✓ Alterations in body fluid distribution leading to circulation problems
- ✓ Increased cancer risk due to radiation exposure
- ✓ Bone-demineralization (50% less Calcium absorption and 50% more Calcium loss in urines)
- ✓ Space motion sickness
- ✓ Constipation
- ✓ Changes in the patterns of intestinal microflora
- ✓ Immune dysfunction: increase risk of infections and antibiotic less effective

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Feed the microbiota!!

- Microbiota of people in confined space lose diversity
- Microbiota diversity is key for health (not only gut health)
- **Probiotic** and **prebiotic** foods might be relevant functional foods for astronauts

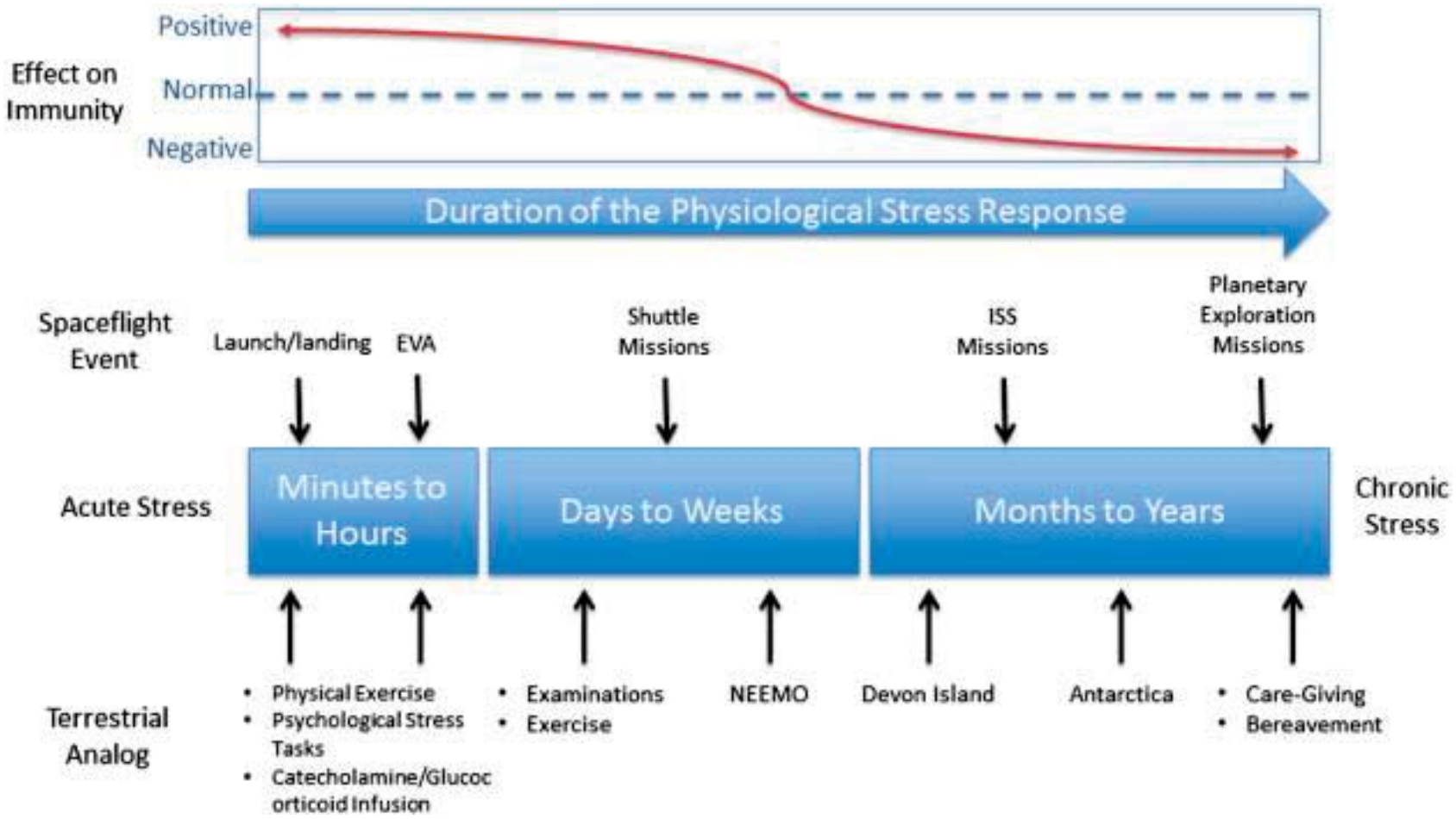
Turroni *et al. Microbiome* (2017) 5:39
DOI 10.1186/s40168-017-0256-8

Microbiome

RESEARCH Open Access

Temporal dynamics of the gut microbiota in people sharing a confined environment, a 520-day ground-based space simulation, MARS500

Help the immune system!!



Help the immune system!!

JLB

Could spaceflight-associated immune system weakening preclude the expansion of human presence beyond Earth's orbit?

Nathan Guéguinou,[*,†] Cécile Huin-Schohn,*[*,†] Matthieu Bascove,* Jean-Luc Bueb,[†] Eric Tschirhart,[†] Christine Legrand-Frossi,* and Jean-Pol Frippiat*[*,1]*

JOURNAL OF WOMEN'S HEALTH
Volume 23, Number 11, 2014

DOI: 10.1089/jwh.2014.4913

Effects of Sex and Gender on Adaptation to Space:
Immune System

COUNTERMEASURES

- Dietary nucleotide (especially pyrimidine) induces spleen production of beneficial cytokins
- Active exose correlated compounds (*basidiomicetus* oligosaccharides)

Healthy food design in space: take home

- A chain approach is required
- No compromise with food quality… this is true also for astronauts
- Invisible insects solution deserves more attention
- Astronauts are a fascinating target for healthy food design
- Immunostimulation and feed microbiota are the two emerging needs

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Thank you for your attention!

Any questions?

vincenzo.fogliano@wur.nl

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