Biol. Training for Astronauts

PROPOSED BIOLOGY TRAINING PROGRAM FOR

APOLLO ASTRONAUTS

Prepared by

Harold J. Morowitz
Carl Sagan
Richard S. Young
Wolf Vishniac

Lecture 1

A. What is life?

1. Evolutionary definition
2. Metabolic definition
3. Thermodynamic aspects, and reconciliation of foregoing views; functional vs. chemical definitions; analogies with automata

B. Unity of life on Earth

1. Genetic: nucleic acids, proteins and the code
2. Chemical: ubiquity of a very few molecules out of many possible
3. Morphological: cells, subcellular organelles, 9 and 2 flagellar structure
4. Conclusion: All life on Earth is descended from a single instance of the origin of life

Lecture 2

Origin of life

1. Direct evidence on the earliest history of the Earth and life; time-scales
2. Thermodynamics and the origin of life: probable and improbable events
3. Cosmic abundance and models of the early history of the solar system
4. Production of organic molecules in simulated primitive terrestrial environments
5. Problems: Earliest nucleic-acid protein coupling; aqueous vs. non-aqueous environments, origin of the code, origin of subcellular organelles, origin of the cell, details of subsequent pre-Cambrian evolution
6. Possible alternative biochemistries

Lecture 3

A. General problems of exobiology

1. Exobiology as a critical approach to fundamental unsolved biological problems; obtaining biological perpective; geological vs. laboratory time-scales
2. Problems in analysis of organic molecules: examples from organic geochemistry and the study of carbonaceous chondrites; optical activity
3. Problems in searches for extraterrestrial life: examples from terrestrial sediments and from carbonaceous chondrites ("organized elements")
4. The contamination problem
5. The panspermia hypothesis
6. A few hypothetical extraterrestrial ecosystems

B. Biological interest in the moon

1. Models of lunar prebiological organic synthesis: indigenous vs. exogenous
2. Lunar surface and subsurface environments: temperatures, radiation fields, atmosphere, chemistry
3. Surface and subsurface survival of prebiological organic matter on the moon: Arrhenius plots, radiation damage
4. Lunar transient events
5. Possibilities of an extant or extinct lunar biology
6. Contamination of the moon: panspermia, impact spray from the Earth, spacecraft
7. Sites of potential organic chemical interest in typical Apollo landing areas: permanently shadowed crevasses, dark halo craters, rilles, crater walls
8. Problems in acquisition and storage of lunar subsurface samples
9. Spoor

Lecture 4

Ecology - The relation of living things to their environment and to each other.

A. Biogeochemistry

1. The lithosphere
2. The hydrosphere
3. The atmosphere
4. The bioshpere

(a) Mass
(b) Chemical composition

B. The relationship of organisms to environment

1. Physical constraints
2. Adaptation
3. The role of evolution

C. Energy Flow as the dominant theme in ecology

1. The primary trophic level

(a) Energy flow
(b) Photosynthesis

2. The concept of food chains and the trophic pyramid

D. The major biogeochemical cycles

1. Carbon

(a) The importance of CO_2 in regulating the biosphere and the properties of the earth's surface

2. Oxygen

(a) The significance of an oxidizing atmosphere
(b) Ozone and ultraviolet

3. Nitrogen

4. Sulfur, Phosphorous, and Minerals

Lecture 5

Ecosystems - Interactions among organisms

A. Classes of interactions

1. Predator-prey
2. Parasitisms
3. Symbiosis
4. Commensalism

B. The Concept of an Ecosystem

1. System properties
2. Ecological niches

C. Growth Curves

1. Exponential growth
2. Limitations to exponential growth
   (a) Exhaustion of Food
   (b) Toxins
   (c) Overcrowding
3. Other types of curves
   (a) Mortality data
   (b) The Foxes, Rabbits, Cabbages Problem

D. Unusual organisms and Unusual ecological niches

1. Environmental extremes
   (a) Temperature
   (b) pH
   (c) Salinity
   (d) Humidity and water content

Lecture 6

The Microbe as Organism

A. The World of Large and Small Organisms

1. Consequences of Size
2. Gravity versus Surface Tension
3. Motility
4. Films of Moisture and Movement of Dust Particles

B. Chemical and Physical Environments

1. Chemical Gradients
2. Concentration Gradients
3. Temperature Gradients
4. Light, Pressure, and Radiation Gradients

C. Structure of Microbial Cells

1. Mammalian and Bacterial Cells
2. Fungal and Protozoan Cells
3. What are viruses?
4. Characteristic Roles
5. Characteristic Structures
6. Characteristic Functions

D. Diversity of Microorganisms

1. Major Types of Microorganisms
2. Morphology
3. Physiology
4. Evolutional Relationships and Lack of Evidence

E. Control of Microorganisms

1. Growth on Solid and Liquid Media
2. Aseptic and Antiseptic Techniques
3. Control of Dust and Air Movements
4. Heat Sterilization, Chemical Sterilization, Filtration

Lecture 7

Chemical Activities of Microorganisms

A. Nutrition and Metabolism

1. The Selective Environment
2. Dual Role of Substrates
3. Assimilation and Respiration
4. Respiration as Electron Flow
5. Electron Donors & Acceptors
6. Oxygen as a Specialized Electron Acceptor

B. Primary Productivity and Food Chains

1. Carbon Dioxide as Product and Substrate
2. Photosynthesis and Chemosynthesis
3. Chemical Symbiosis
4. Energy Conversion in Food Chains
5. The Pyramid of Numbers
6. Predators and Prey

C. Recycling of Matter

1. Microorganisms as Regulators of the Environment
2. Cycles of the Elements
3. Isotope Fractionation

D. The Occupation of Ecological Niches

1. Minimum Demands on the Environment
2. Adaptive Radiation
3. Exploitation of New and Unknown Environments

Lecture 8

Kinetics of Microbial Activities

A. Rate of Growth

1. Rate of Metabolism as Compared to that of Higher Organisms
2. Metabolism and Growth
3. Concept of Molar Growth Yield
4. Concept of Generation Time

B. The Growth Curve

1. Growth in Stagnant Cultures
2. Initiation of Growth
3. Limiting Factors

C. Continuous Growth

1. The Unlimited Reservoir
2. Steady State Growth
3. The Kinetics of Continuous Growth
4. Selection and Evolution in Continuous Growth

Lecture 9

Ecological unbalance

A. Upsets caused by man

1. Destruction of species
2. Release of Toxins
   (a) accumulations in the food chain
   (b) Radioactive waste
   (c) Air pollution
3. Change of habitat

B. Succession as a general phenomenon

C. Epidemiology

1. Nature of Infectious disease
2. Spread of infectious disease
3. Populations succession in disease
4. Introducing new pathogens
   (a) Tuberculosis in North America
   (b) Measles in Hawaii
5. The great epidemics of history

D. Methods of preventing and combating epidemics

1. Isolation
2. Quarentine
3. Distructions of ecological agent
4. Medical care

Lecture 10

Radiation Biology

A. Brief review of types of radiation of biological importance

1. Charged particles

(a) α particles
(b) protons
(c) deuterons
(d) electrons
(e) nucleis

2. Electromagnetic Radiation

(a) ultraviolet
(b) X-rays
(c) γ-rays

3. Neutrons

B. Physical effects of radiation on matter

1. Ionizations and excitations
2. Radiochemistry
3. Direct and Indirect Effect

C. Genetic effects of radiation

D. Somatic Effects of radiation

1. Studies on microorganisms and macromolecules
2. Physiological effects on mammals

E. Radiation sterilization

Lecture 11

Biological Experiments in Space - A

A. A discussion of attempts to fly living organisms in spacecraft giving primarily a historical background of such attempts.

B. A discussion of the rationale for doing biological experiments in space.

1. Experiments required primarily in support of the Manned Space Flight Program done from the point of view of assessing the hazards of the space environment for manned space flight.

2. A discussion of the use of the unique of the aspects of the space environment for basic biological experiments, (e.g. Zero-gravity, radiation, etc.)

C. A discussion of the biological experiments flown most recently aboard manned orbital spacecraft and aboard the biosatellite spacecraft coming up in the near future.

The points to be stressed in all of these cases are the scientific reasons for doing these experiments in the first place and a discussion of what the biological scientists hope to learn from such experiments.

Lecture 12

Biological Experiments in Space - B

A. This lecture should stress the Moon. The reason for biological interest in the lunar surface and the rationale behind the so called "biological" exploration of the Moon. This will include a discussion of the likelihood of finding.

1. Viable microorganisms
2. Organic compounds on the surface of the Moon

B. A discussion of the potential sources of both living organisms and organic matter should be included as well as a discussion of the survivability of both under lunar conditions.

C. A discussion of the potential of in situ analyses vs. the analysis of returned samples is required. Some analyses may only be feasible by in situ examination whereas the bulk of examinations, at least in early missions, can probably best be done on returned samples.

D. A discussion of the actual techniques most likely to be employed in both in situ examinations and on returned samples is required. The problems to be encountered in performing in situ analyses and in obtaining and returning uncontaminated samples should be discussed. The methods of sample acquisition, the problems of the proximity of the astronaut and the potential contamination by the astronaut should be discussed in some detail. The maintenance of the integrity of the sample on returned flights to earth and handling in the quarantine laboratory should be stressed. A discussion of a rationale behind quarantine of these samples should be included if it has not already been discussed in earlier lectures.

Lecture 13

Biological Experiments in Space - C

A. In this lecture the other planets should be discussed essentially in the same way as the lunar lecture. The planets to be stressed are certainly Mars and Venus although a brief discussion of Jupiter might be included.

B. The in situ examination should be stressed although returned sample analyses must also be included. The role of contamination in the investigation of the planets becomes even more important because of the increased likelihood of contamination. The susceptibility of in situ life detection type experiments to bacterial contamination should be included. A discussion of the types of analytical techniques to be applied in planetary exploration which are relevant to biology should be perhaps the central theme of this lecture. The potential of remote investigations on orbiting fly-by spacecraft should be compared to that of investigations of unmanned landers and also investigations on manned landing spacecraft.

Laboratory 1 Sterile Technique, Spores, and assay of Bacteria

A. Methods of avoiding contamination

1. Pippetting
2. Petri Dishes
3. Tube caps

B. Methods of Bacterial assay

1. Plate count
2. End point Dilution

C. Sampling of air, water, milk, skin

D. Microscopy

1. The germination of bacterial spores

Laboratory 2

A. The mass of a bacterial spore

1. weighing
2. Titre

B. Exponential growth curve

C. Thermal inactivation curve on dried spores

Laboratory 3

A. Score Results of laboratory 2
B. Perform calculations
C. Microscopy
    2. Types of organisms

Laboratory 4

Bacteriological analysis of material obtained on geological field trip.