DOES SIZE MATTER?

SOME FACTORS INFLUENCING THE RADIATION ROBUSTNESS OF MICROBES VOYAGING THROUGH SPACE

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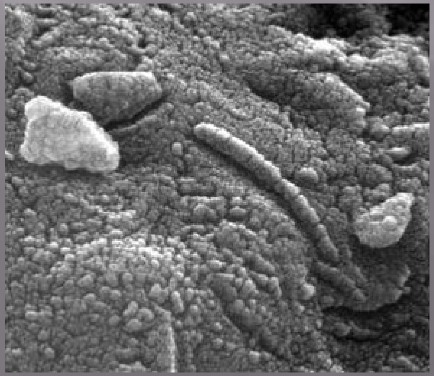
Panspermia?

- For decades, many have wondered about the possibility that living organisms can travel through space
- Some have speculated that Earth was "seeded" with microbes from Mars, or vice versa
  - For example, the Allen Hills (Antarctica) meteorite (ALH 84001)



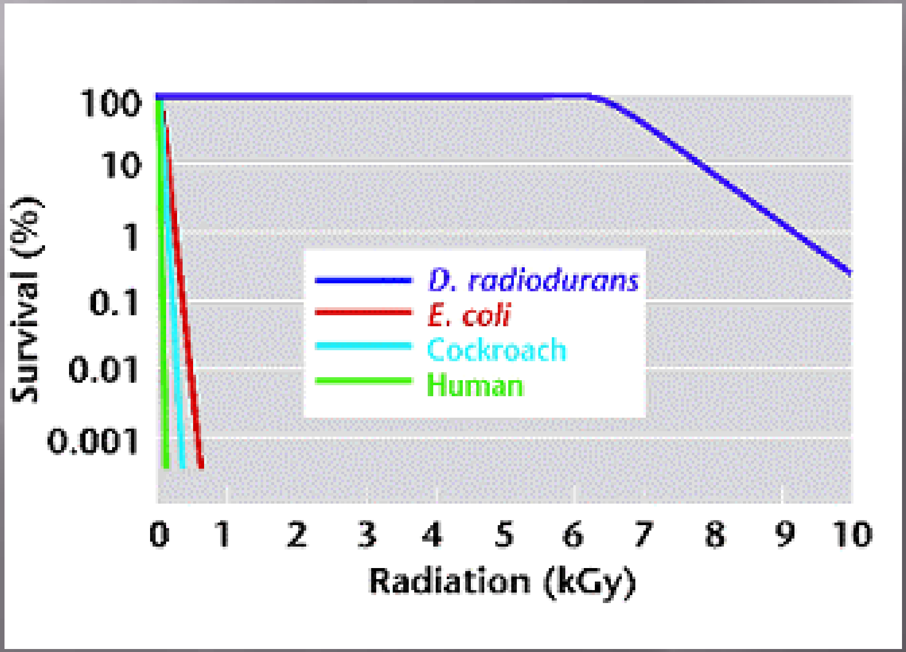
And don't forget Apollo 12

- Found live microbes (Streptococcus mitis) on pieces of the Surveyor probe returned from the Moon
- This was after three years of unprotected exposure to cosmic radiation, vacuum, and the lunar freeze-thaw cycles!

- So can living microbes travel through space?

A bit of a comparison

- Humans are more resistant to radiation damage than are many other complex organisms
- But many microbes are astonishingly resistant to radiation exposure – why?



BUGS IN SPACE!

So what is important?

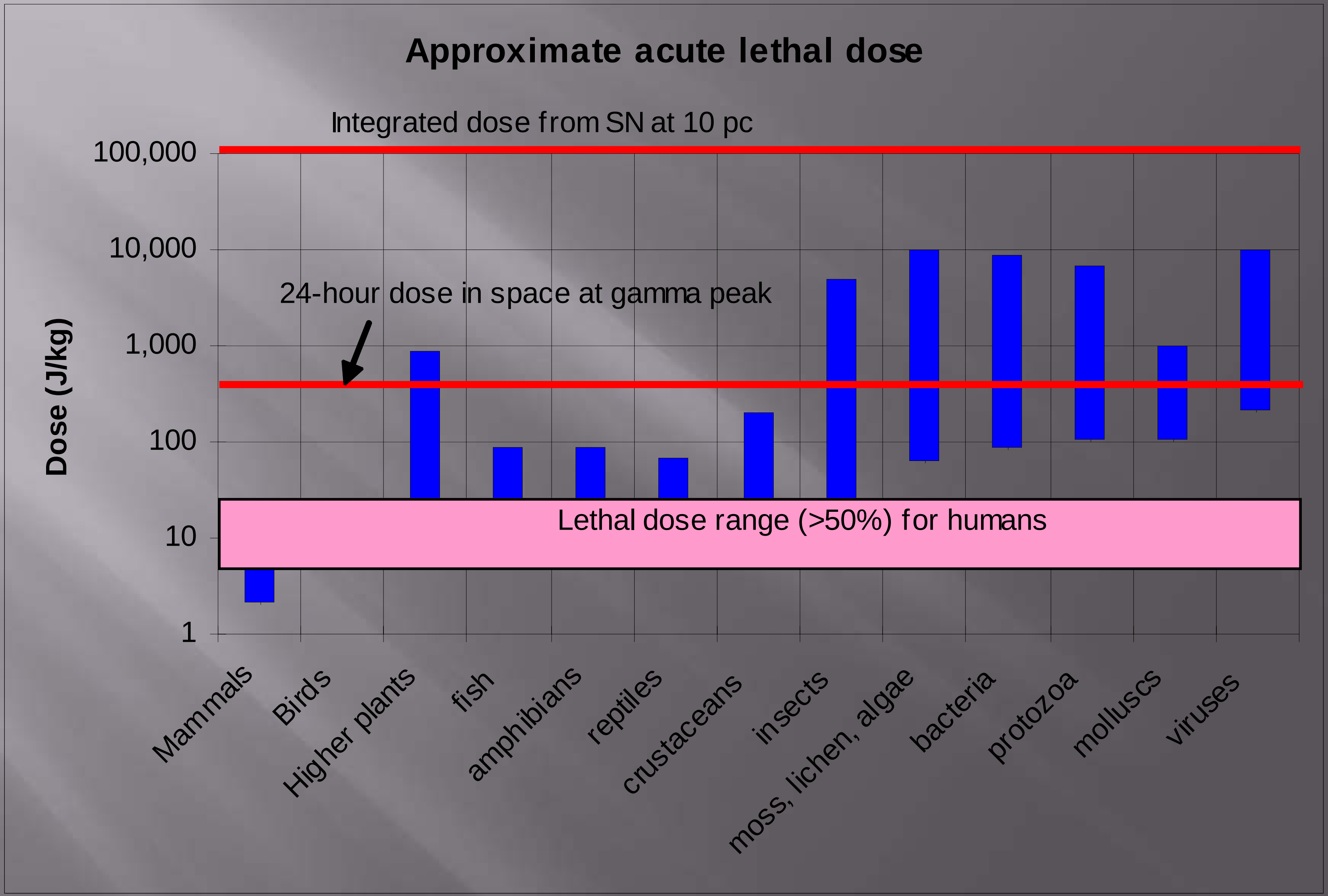
- Radiation type and intensity
  - Photons versus particles
  - Energy distribution
- Mode of transport (e.g. ice, dust)
  - Opacity/density
  - Size (shielding and secondary electron buildup)
- The organism
  - Organism size
  - Genome size and activity

IONIZING RADIATION PARAMETERS

Radiation in space

- Photons
  - UV (not very penetrating)
  - X-ray (moderately penetrating)
  - Gammas (most penetrating)
- Particles
  - Electrons (bremsstrahlung)
  - Protons (generate secondary electrons)
  - Higher-Z particles (generate secondary electrons)
- The radiation environment changes according to location in space (i.e. near a star, galactic “outskirts”, proximity to SNe or GRB, etc.)
- Most extreme challenge comes from SNe and GRB

From UNSCEAR 1996



Organisms in space

- The most significant effects may be on space-borne organisms
- Any organism in a piece of rock or ice less than about a few tens of cm across may well become sterilized as it transits space
- It seems reasonable to think that very small rocks or dust are not healthy abodes for any except the most radiation-resistant bacteria, or for any but the shortest transit times

MODE OF TRANSPORT

Transport parameters

- Composition (rock, ice, metal)
- Size and opacity
- Time of transit
  - Longer transit time means more chances for high-dose event

Photon shielding

- Photon attenuation increases with depth
  - So the interior of larger objects will be better-shielded than that of smaller ones
- However, much of the radiation dose comes from secondary electrons
  - If there is insufficient thickness for the photons to interact, they can't deposit energy
  - So if an object is very small, radiation dose may actually drop

Large objects

- Very large objects (say, a meter or more in radius) provide ample radiation shielding for interior organisms
- There is room for secondary electrons and bremsstrahlung x-rays to be absorbed

- However, large objects require more energy to reach escape velocity
- Also have to survive entry into an atmosphere

Intermediate sizes

- Smaller objects are much more numerous
- Easier to reach escape velocity
- However, they don't provide as much shielding from direct photon radiation
- Also leave room for secondary electron buildup
- And they have those pesky reentry problems

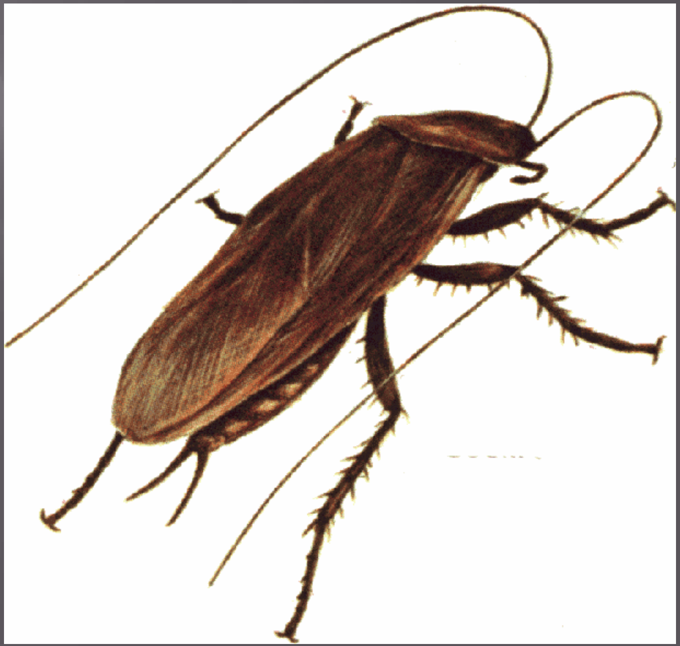
Very small objects

- Dust grains require the least energy to reach escape velocity
  - However, may also be more prone to heating when they are blasted into space
- May be too small for photons to interact, reducing absorbed dose and electron buildup
- Reentry likely to be gentler than with larger objects
- However, UV exposure may be a problem

So…..

- The largest objects may provide the most reliably hospitable environment for microbes traveling through space (assuming they can survive reentry)
- However, the smallest objects (dust) may be a very good second choice
  - Assuming that charged particles and UV are not too bad

ORGANISM VARIABLES



Genome size

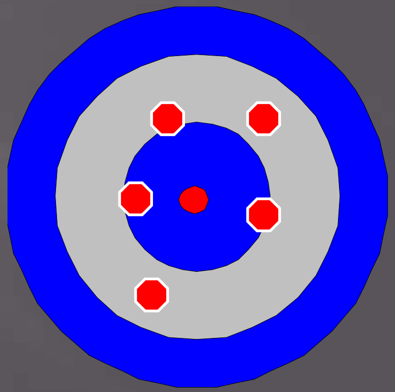
- More genes provide more targets, and more things that can be damaged
- More genes also imply a more complex organism
- However, more genes also imply more DNA repair mechanisms

Organism activity levels

- May be reproducing more rapidly
  - Less time to repair damage
- More genes are active
  - more targets that can be damaged

Organism size

- Individual microbes can be exceptionally radiation resistant
- In addition to some of the previously mentioned factors, it may also be related to the size of an organism
- Small targets are hard to hit



1000 rads is fatal to people, and won't even bother a D. radiodurans

- Consider a 2 μm diameter organism with a cross-sectional area of about 3.1×10^{-8} cm^2
- An organism receiving integrated dose of 1000 rads (in the form of 1 MeV photons) will experience about 15-20 photons passing through
- With a linear attenuation of about 0.08 cm^{-1} and a depth of 2 μm , these photons will probably not interact at all
- Even if one does, the odds are very high that there will be little damage – and that the damage will not be fatal to the cell
- This may help explain the radiation resistance of many microbes –especially in the form of spores

Remember – microbes are not us

- A person is optically thick, even to gamma radiation
- In both humans and microbial colonies, the odds are against any individual cell being killed or mutated
- However, it takes the death of only a small fraction of human cells to cause death
- On the other hand, survival of a microbial colony requires the survival of only a handful of microbes

SO PUTTING IT ALL TOGETHER

Highest survivability in space

- The very largest or the very smallest particles will experience the lowest dose to organisms hitching a ride on the particles
  - And dust may be more likely to survive atmospheric entry
- The very small size of most microbes helps them avoid photon hits
- Thus – microbes on dust grains may be very robust