Biological Effects of Lunar Surface Mineral Particulates

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Particulate Toxicity

- "No pulmonary risks"

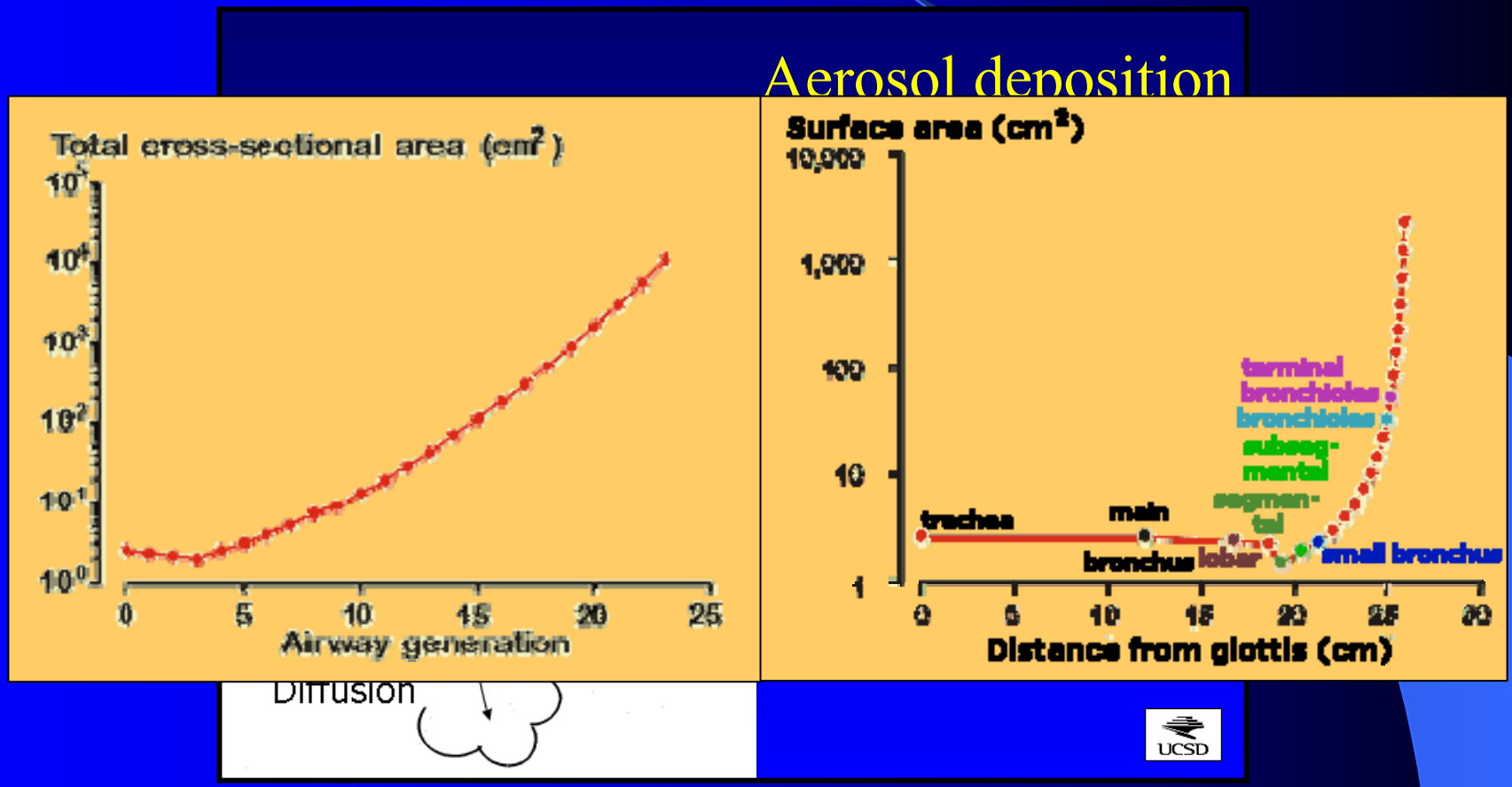
Topics

- Relevant mineralogy
- Pulmonary particle handling
- Analog natural diseases
- Experimental lunar toxicology
- Ames dust workshop

Boilogically Relevant Mineralogy

- Lunar regolith soils are unique
- Formed through billions of years of micrometeorite impacts
- “Heterogeneous Agglutinitic Glass”
- Absence of fluids weathering: very abrasive
- Silicate content, grain morphology foci of worry

Pulmonary Particle Handling



Courtesy: Kim Prisk, UCSD

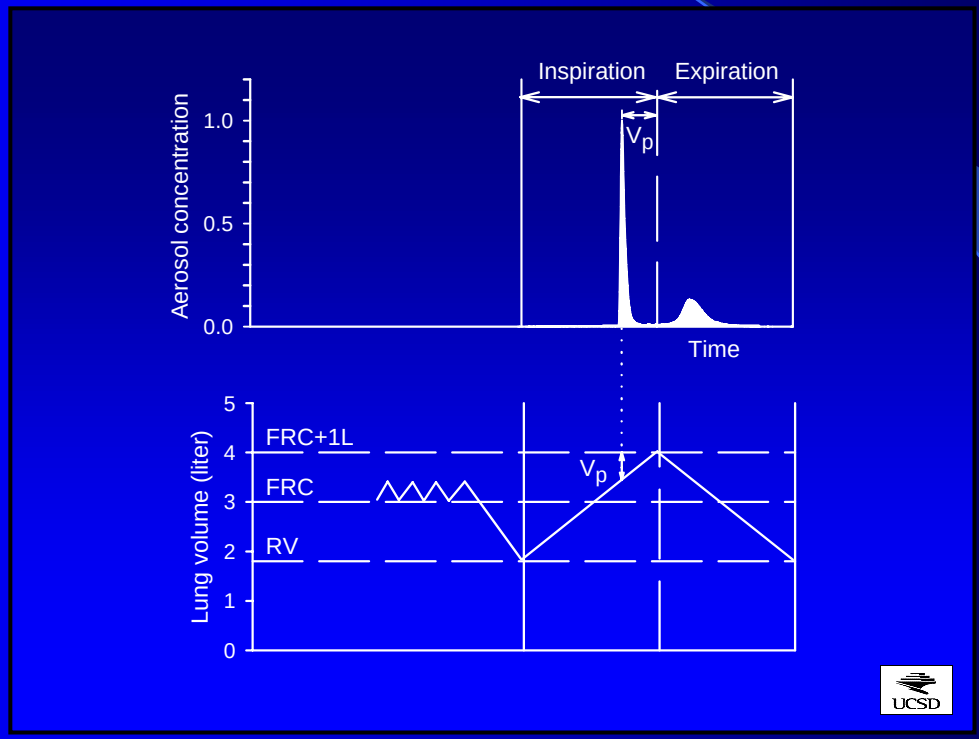
Pulmonary Particle Handling

KC-135 experiments

Courtesy: Kim Prisk, UCSD

Janelle Fine performing experiments in the KC-135. Photomoter and flowmeter are on the platform in front of her. Aerosol was contained in the black bag.

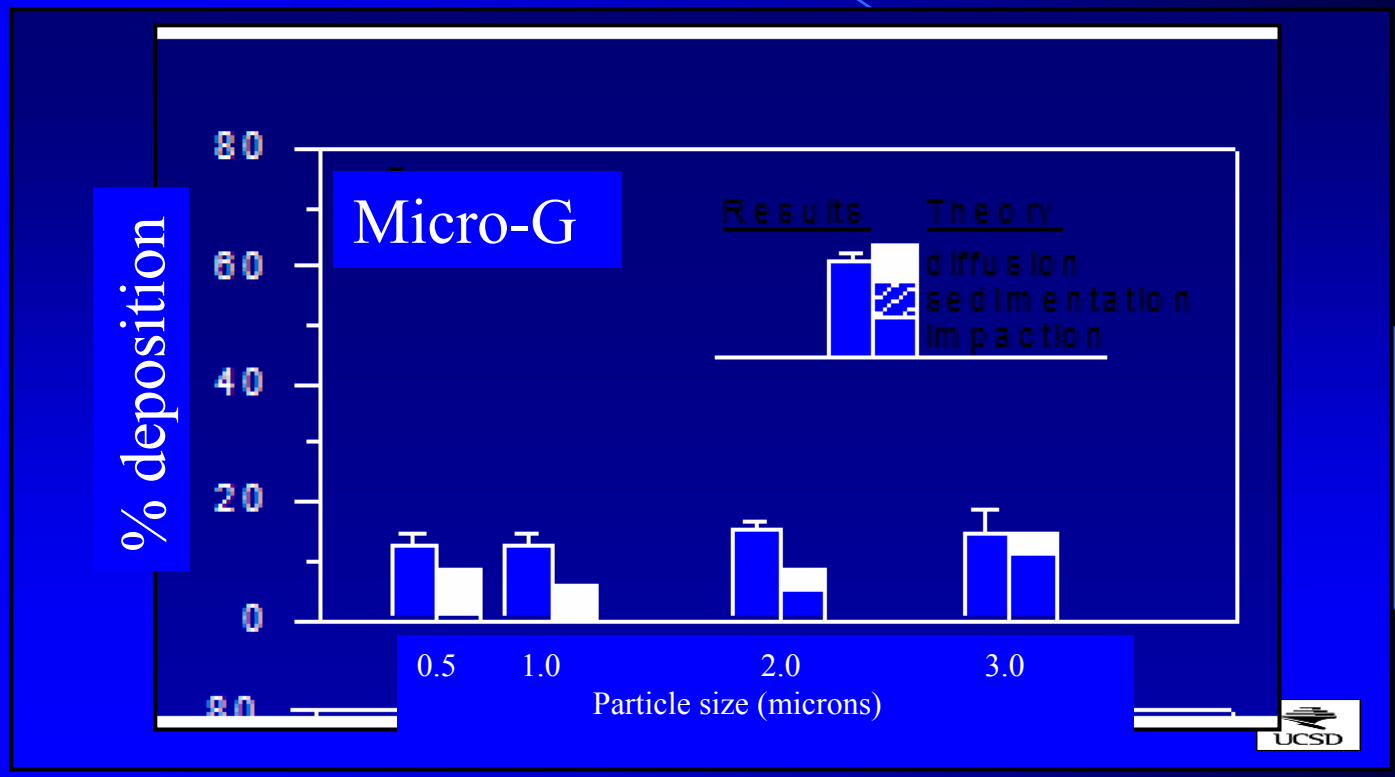
Pulmonary Particle Handling



Courtesy: Kim Prisk, UCSD

- The bolus experiment. A small bolus of aerosol can be introduced anywhere in a controlled breath allowing probing of central (a bolus introduced very late in the breath) or peripheral airways (a bolus introduced early in the breath).

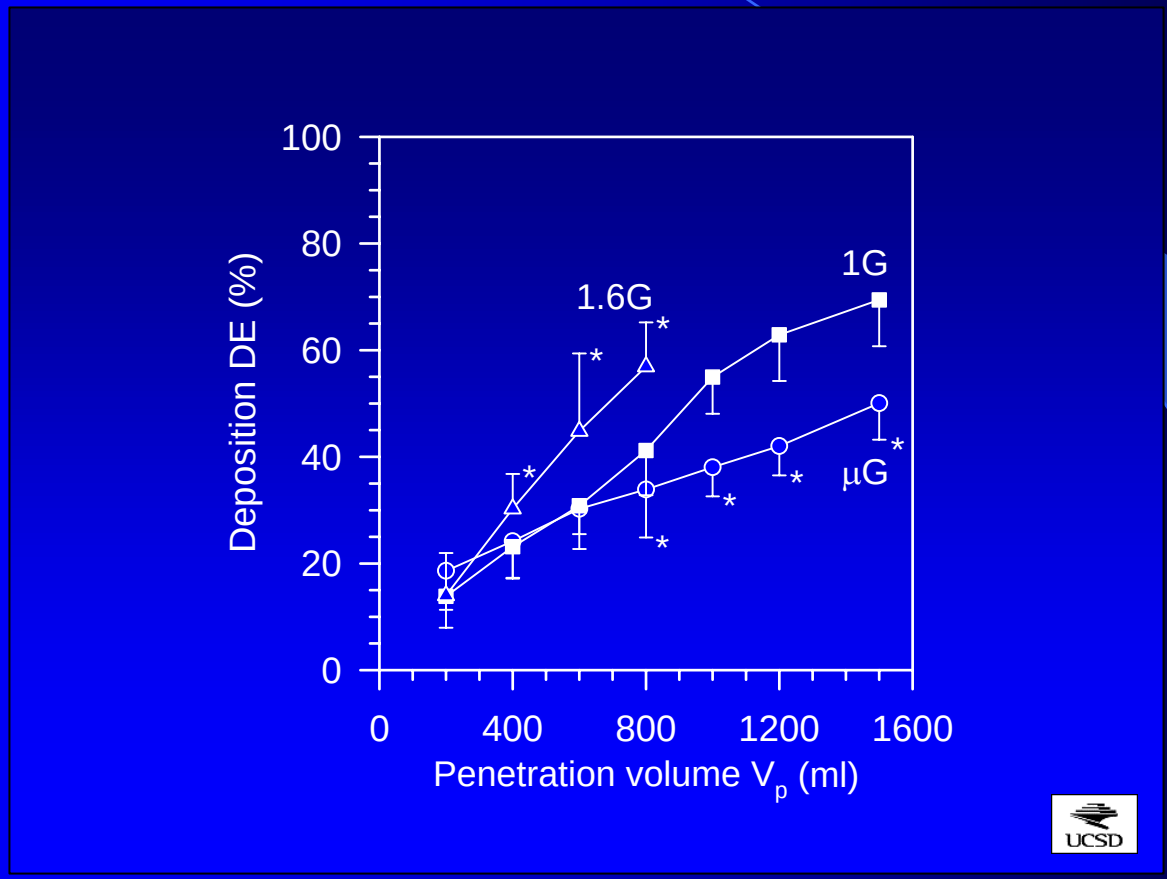
Pulmonary Particle Handling



Courtesy: Kim Prisk, UCSD

Total % deposition (DE) as a function of particle size and gravity level (separate panels). The left bar of each pair is the experimental data form KC-135. The right bar of each pair is the deposition predicted from existing models and shows the contributions from impaction, sedimentation and diffusion. For particles around 1 micron, measured deposition is about twice that predicted.

Pulmonary Particle Handling



Courtesy: Kim Prisk, UCSD

In microG, very high deposition levels are achieved even though sedimentation is absent. Indeed, for these particles in which sedimentation is thought to be a mechanism of considerable importance, it is clear that other factors dominate.

Pulmonary Particle Handling

Aerosols in μG

- Total deposition is unexpectedly high for small particles
  - Small aerosol particles are implicated in adverse health effects of pollutants
  - Suggests transport mechanism(s) that have been previously ignored
- Bolus deposition shows considerable deposition deep within the lung in μG
  - Consitent with the studies of total deposition
  - Suggests that in μG or low-G environments, peripheral deposition is likely very high

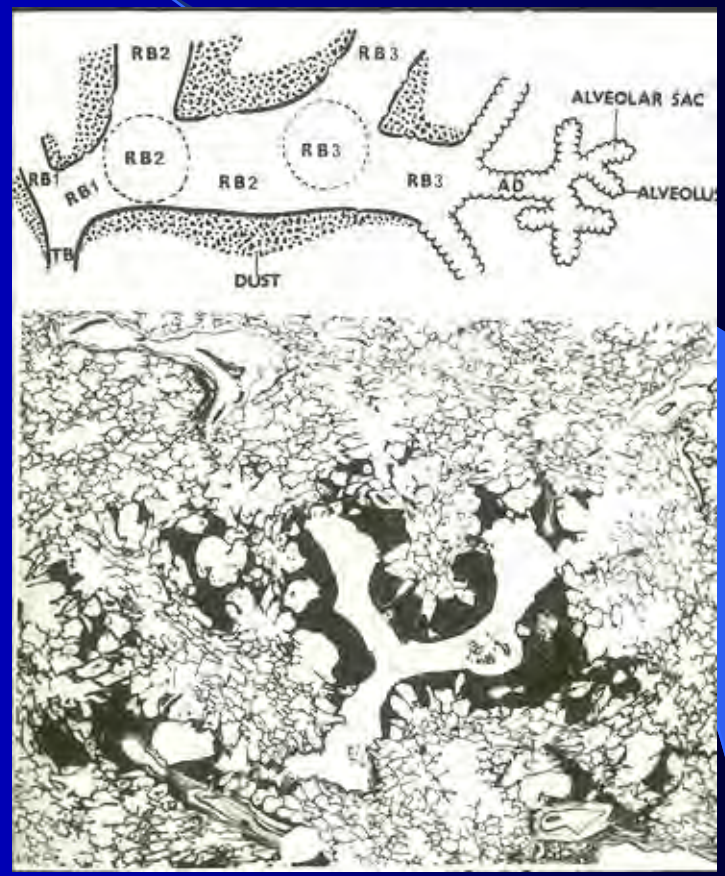
UCSD

Courtesy: Kim Prisk, UCSD

Pulmonary Particle Handling

Nanoparticles: Recent interest due to carbon nanotube work; clearance mechanisms unique.

Pulmonary toxicity of any sort of particles << 1 micron not well understood.

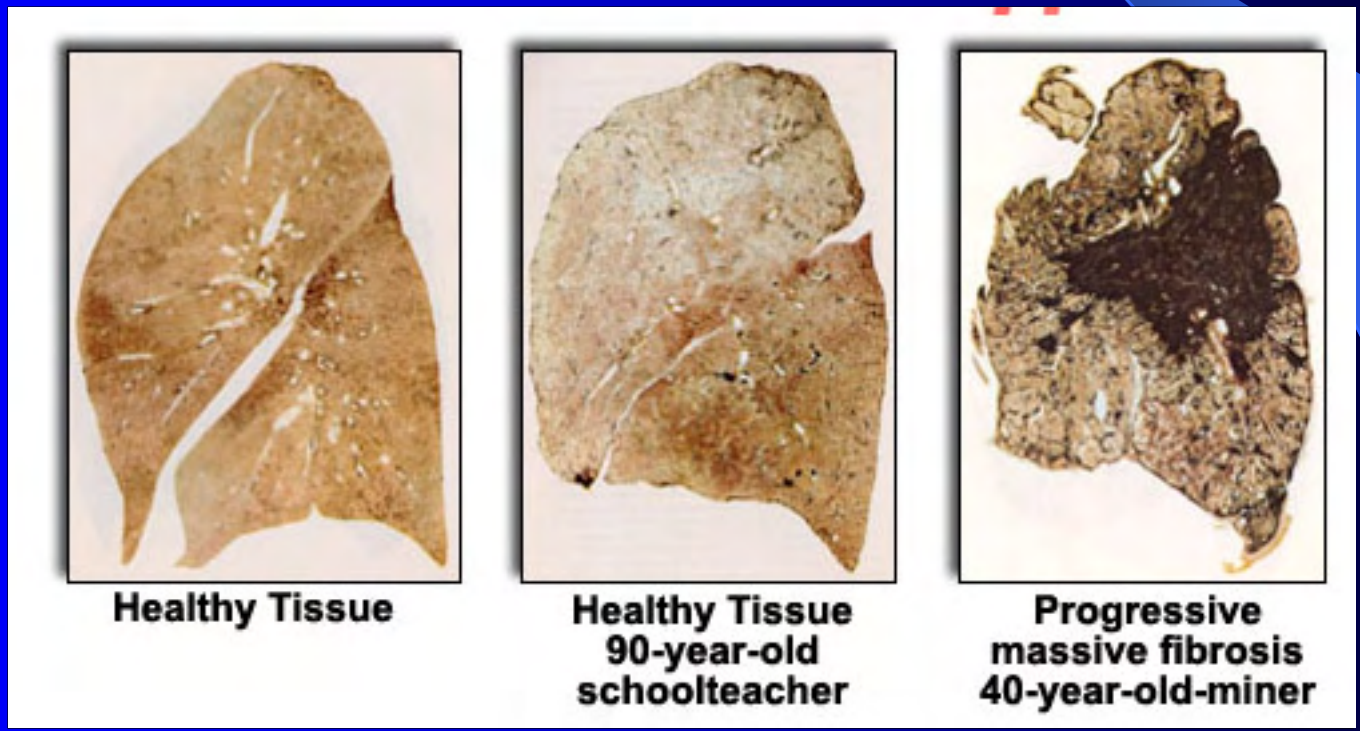


Analog Natural Diseases

- *Pneumoconiosis*
  - General term for lung disease caused by inhalation and deposition of mineral dust.
  - Can result in crippling or fatal pulmonary fibrosis (one of the worst ways to die)
  - Primarily industrial diseases, where offending agents are concentrated from nature
  - Big Three: Anthrocosis (black lung; coal miner's disease), Asbestosis, Silicosis
  - All on the decline in the U.S.

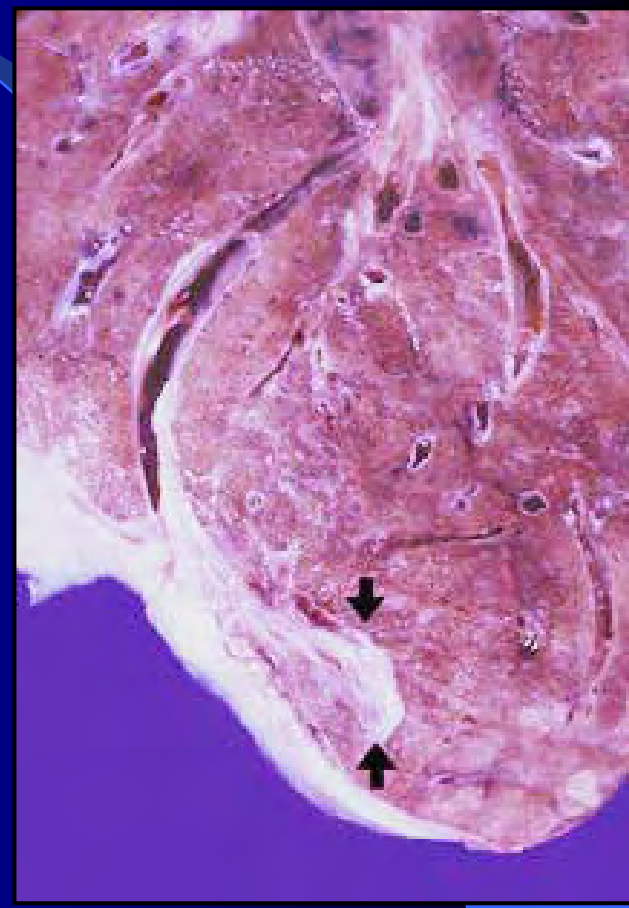
Analog Natural Diseases

- Anthracosis (coal miner's lung; black lung)



Analog Natural Diseases

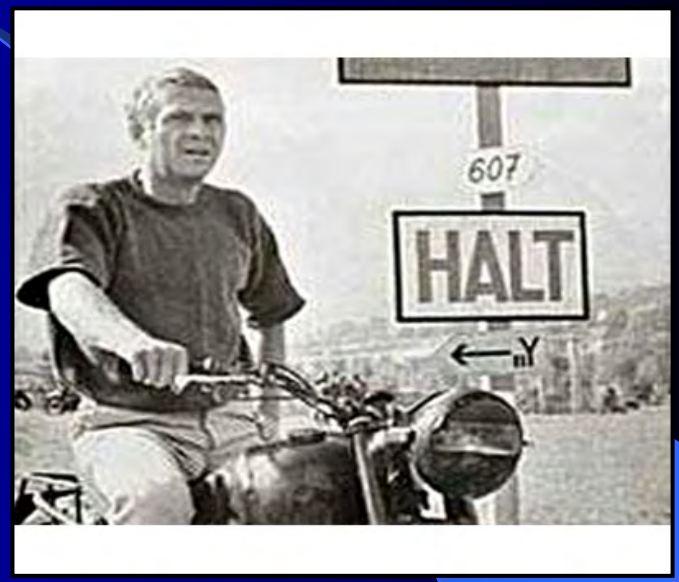
- Asbestosis
  - "inextinguishable" [Greek]
  - Asbestos is a group of naturally occurring, heat-resistant fibrous silicates
  - Associated with fibrosis and malignancy (bronchogenic carcinoma, mesothelioma)



Analog Natural Diseases

- Asbestosis pathophysiology:
  - The cumulative dose, type, durability, and dimensions of the fiber influence carcinogenicity and fibrogenicity.
  - All types of asbestos fibers are fibrogenic to the lungs.
  - Amphiboles, particularly crocidolite fibers, are markedly more carcinogenic to the pleura.
  - Fibers with diameters smaller than 3 micrometers are fibrogenic because they penetrate cell membranes.
  - Long fibers (ie, >5 micrometers) are incompletely phagocytosed and stay in the lungs, setting up cycles of cellular events and the release of cytokines.
  - Oxygen free radicals (eg, superoxide anion, hydrogen peroxide, hydroxy radicals) that are released by the macrophages damage proteins and lipid membranes and sustain the inflammatory process.
  - Individuals probably differ in their susceptibility to asbestosis based on respiratory clearance and other unidentified host factors.
  - Because the development of asbestosis is dose dependent, symptoms appear only after a latent period of 20 years or longer. This latent period may be shorter after intense exposure.

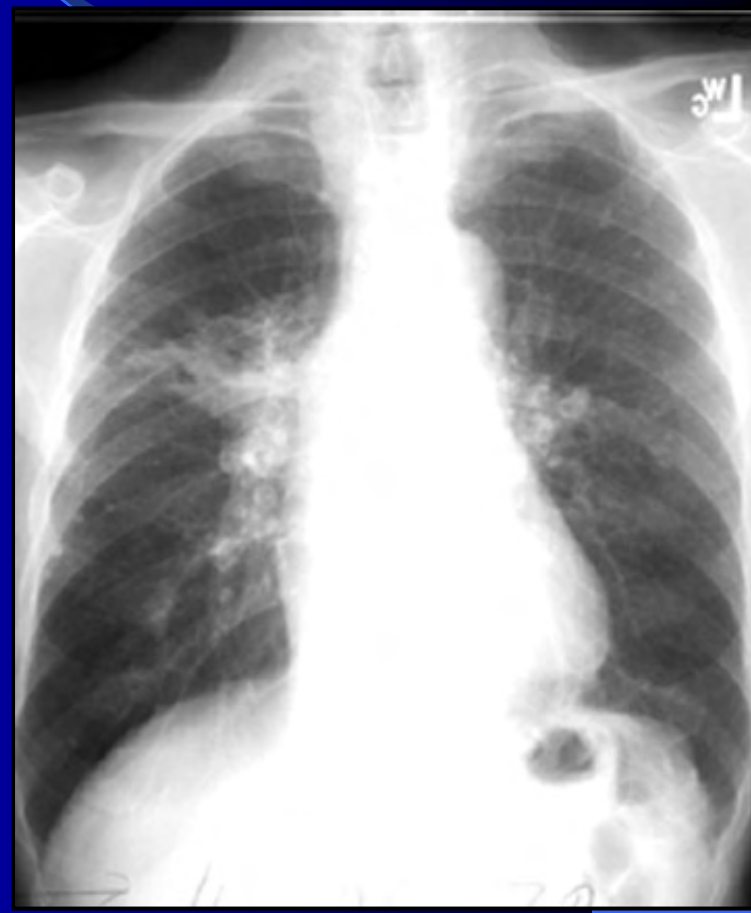
Analog Natural Diseases



- Asbestosis/carcinoma
- Most famous victim: Steve McQueen
  - surrounded by asbestos all his life
  - odd jobs-at construction sites
  - found on movie sound stages
  - brake linings of race cars
  - in the protective helmets and suits worn by race car drivers

Analog Natural Diseases

- Silicosis
  - Arguably, the most dangerous pneumoconiosis
  - “Stone grinder’s disease”: prevalence increased markedly with the introduction of mechanized mining
  - a fibronodular lung disease caused by inhalation of dust containing usually crystalline silica (alpha-quartz or silicon dioxide), or its polymorphs (tridymite or cristobalite)



Analog Natural Diseases

- Silicosis: Pathophysiology
  - ~1 micron particles generate silicon-based radicals that lead to the production of hydroxyl, hydrogen peroxide, and other oxygen radicals that damage cell membranes by lipid peroxidation and inactivate essential cell proteins.
  - Alveolar macrophages ingest the particles, become activated, and release cytokines that recruit other inflammatory cells damaging resident cells and the extracellular matrix, stimulating fibroblasts to proliferate and produce collagen; fibrosis results.
  - Silica particles outlive the alveolar macrophages that ingested them, thereby continuing the cycle of injury.

Analog Natural Diseases

- Silico… …nts
  - **Simp**… …ore than 20 years… …ssness and may resem… …sis can be either… …massive fibros…
  - **Simp**… …dyspnea and cough… …ronic bronchitis and e…
  - **Accel**… …ca over a shorte… …s progress faster…
  - **Acute**… …re to very large amou… …d, causing sever… …follows massi… …causes sympt…
  - What… pneu… …known?

Analog Natural Diseases

- Other Pneumoconioses:
- AMA Arch Ind Health. 1957 Jul;16(1):55-63.
  Experiments on diatomaceous earth pneumoconiosis. I. Natural diatomaceous earth in guinea pigs.
  TEBBENS BD, BEARD RR.

- **Gig Tr Prof Zabol. 1990;(5):14-7.**
  - **[Morphology of pneumoconiosis induced by natural zeolite]**
    [Article in Russian]
  - **Kruglikov GG, Velichkovskii BT, Garmash TI.**
    Pneumoconiosis was induced in white rats through intratracheal administration of natural zeolite. It was characterized by intensive phagocytosis of the specks of dust, moderate cytotoxic action on the macrophages, as well as inflammatory processes in the vascular system and alveolar epithelium. Zeolite induced fibrosis did not develop to the extent as in case with quartz induced massive collagen formation.

Experimental Lunar Toxicology

- No full-scale toxicologic studies performed on lunar dust simulants or the Apollo samples.
  - Basic toxicological responses, acute and chronic
  - Synergisms with < 1g, radiation, cabin atmospheres, altered pharmacokinetics/pharmacodynamics of Rx: flight studies
  - Size particles: how good does the life support filtration system have to be? EVA design impacts.
  - Effects on eyes, skin, gastrointestinal system, systemic leakage from lungs (seen with other minerals)
- Small scale animal studies using intratracheal instillation of saline suspensions have shown marked inflammatory response.
- KC-135 fractional G studies (moon, Mars) using rodents planned by UCSD group.
- Because of scarcity of actual lunar samples, focus will be on simulants; but Catch-22: How much fidelity will be required in the simulant for biological studies? Need tox studies to tell.

Biological Effects of Lunar Soils: A Workshop

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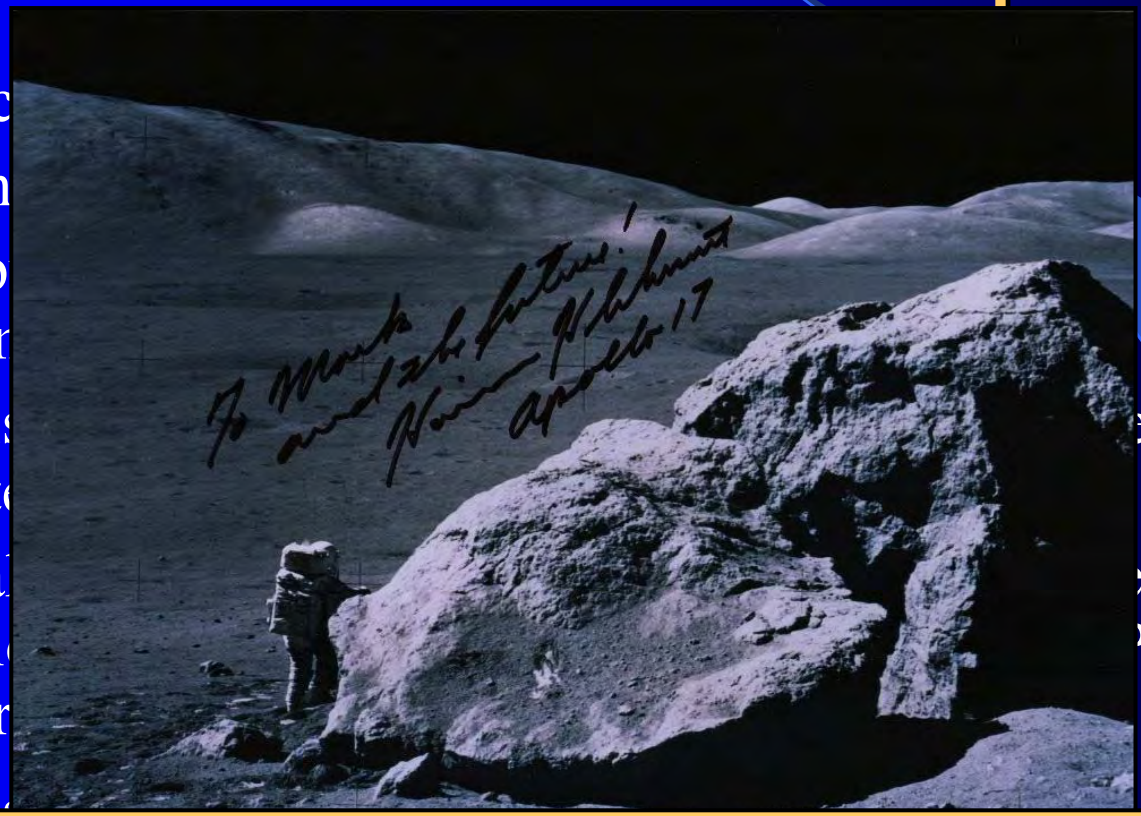

Planetary surfaces present all of the problems encountered in spaceflight, plus a complex set of new unknowns.

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