Environmental Lung Disease

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Rochester, Minnesota USA

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- Employed by: Mayo Clinic

Objectives

- Understand atmospheric divisions and the effects of reduced pressure at altitude
  - ❑ Partial pressure of gases vs. FiO2
  - ❑ Hypoxia
  - ❑ Dysbarisms
- Appreciate issues associated with ambient air pollution and smoking
- Review basics of toxic inhalations, including RADS

You decide to buy a ticket on *Virgin Galactic and* take a suborbital ride to the edge of space. During your flight you decide to pop the latch and determine the FiO_2 outside the capsule. What is the FiO_2 at 60,000 ft (18,882 m)?

A. 21%

B. 18%

C. 8%

D. 2%

E. Cannot calculate at that altitude

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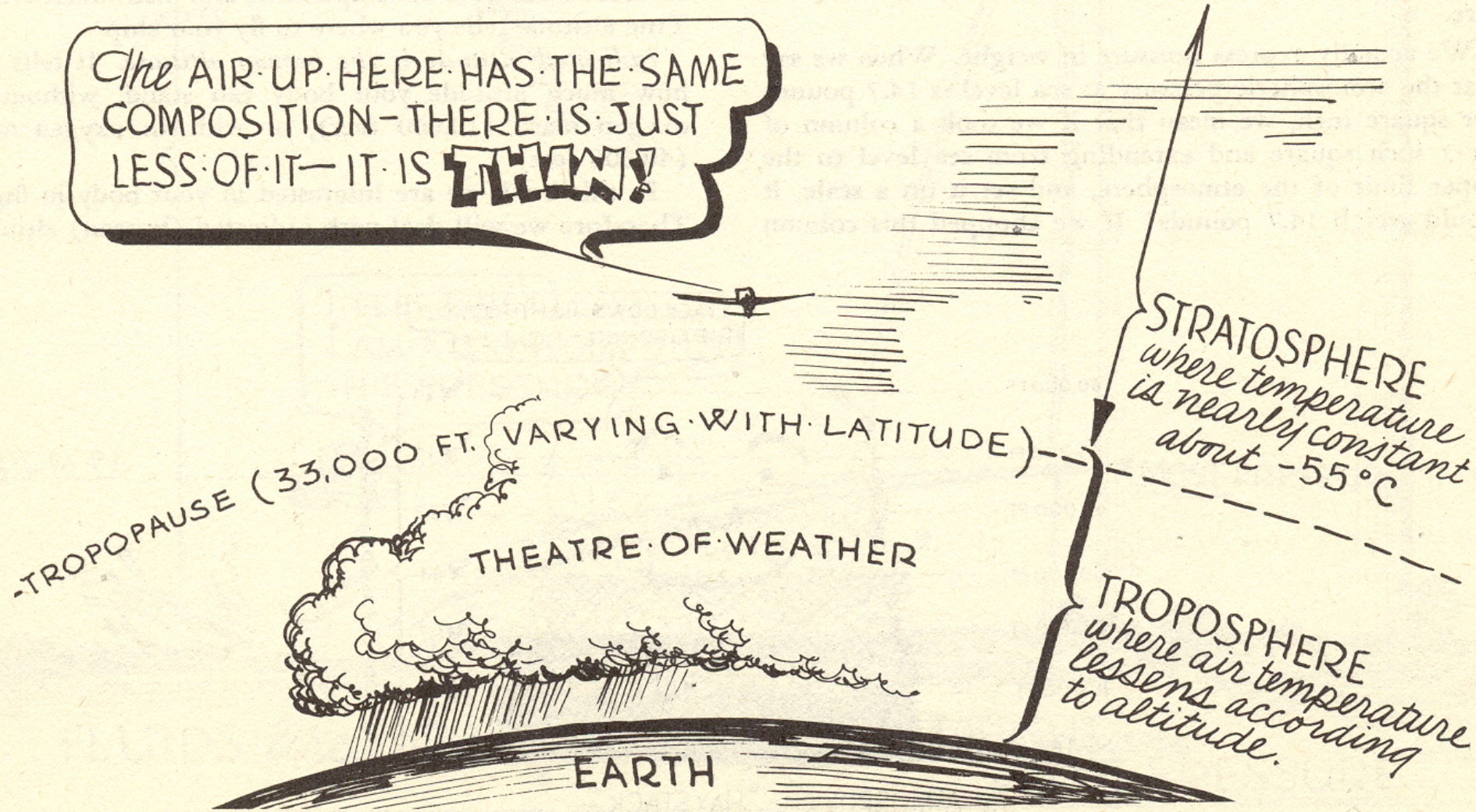
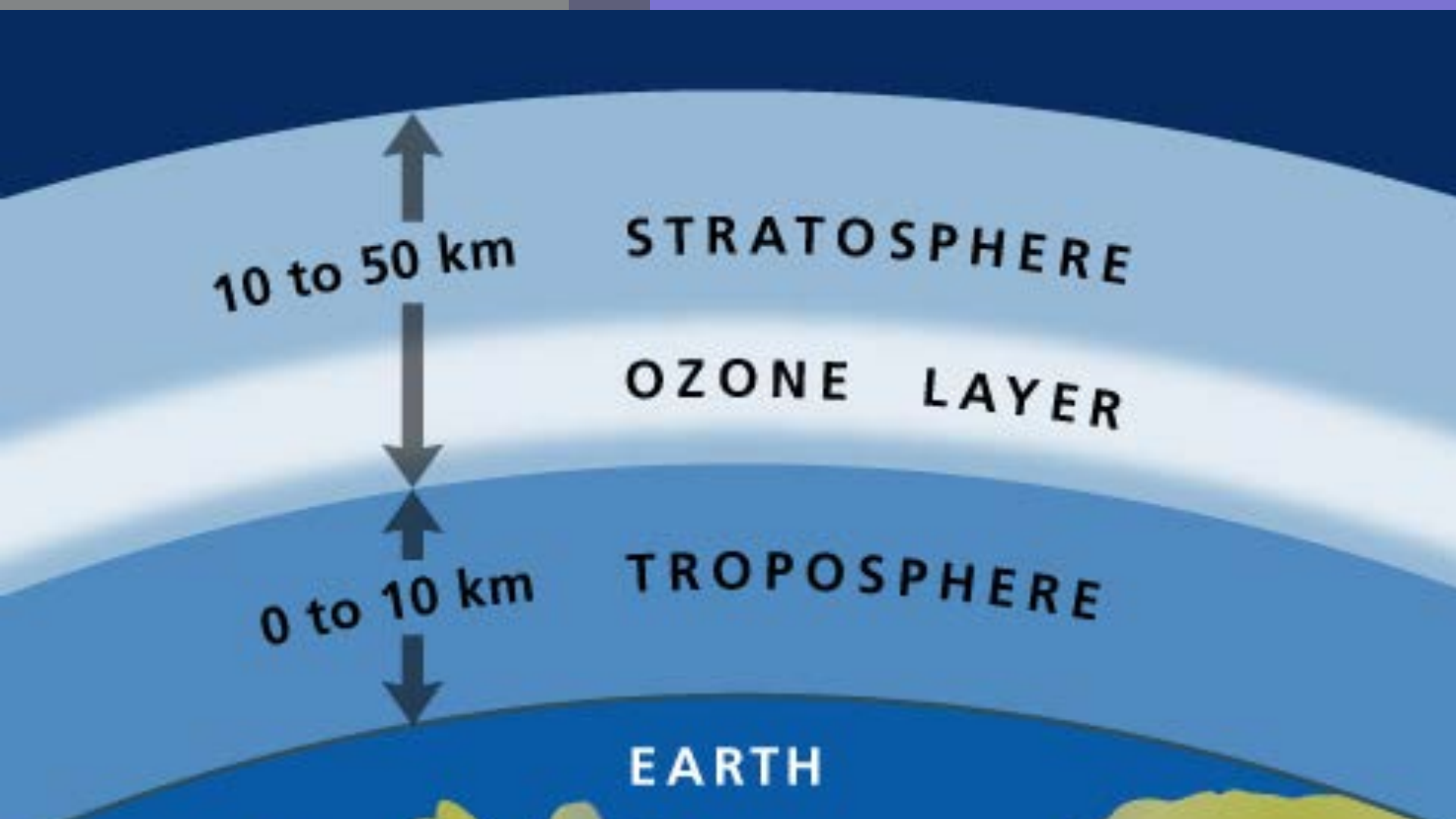
E. Cannot calculate at that altitude

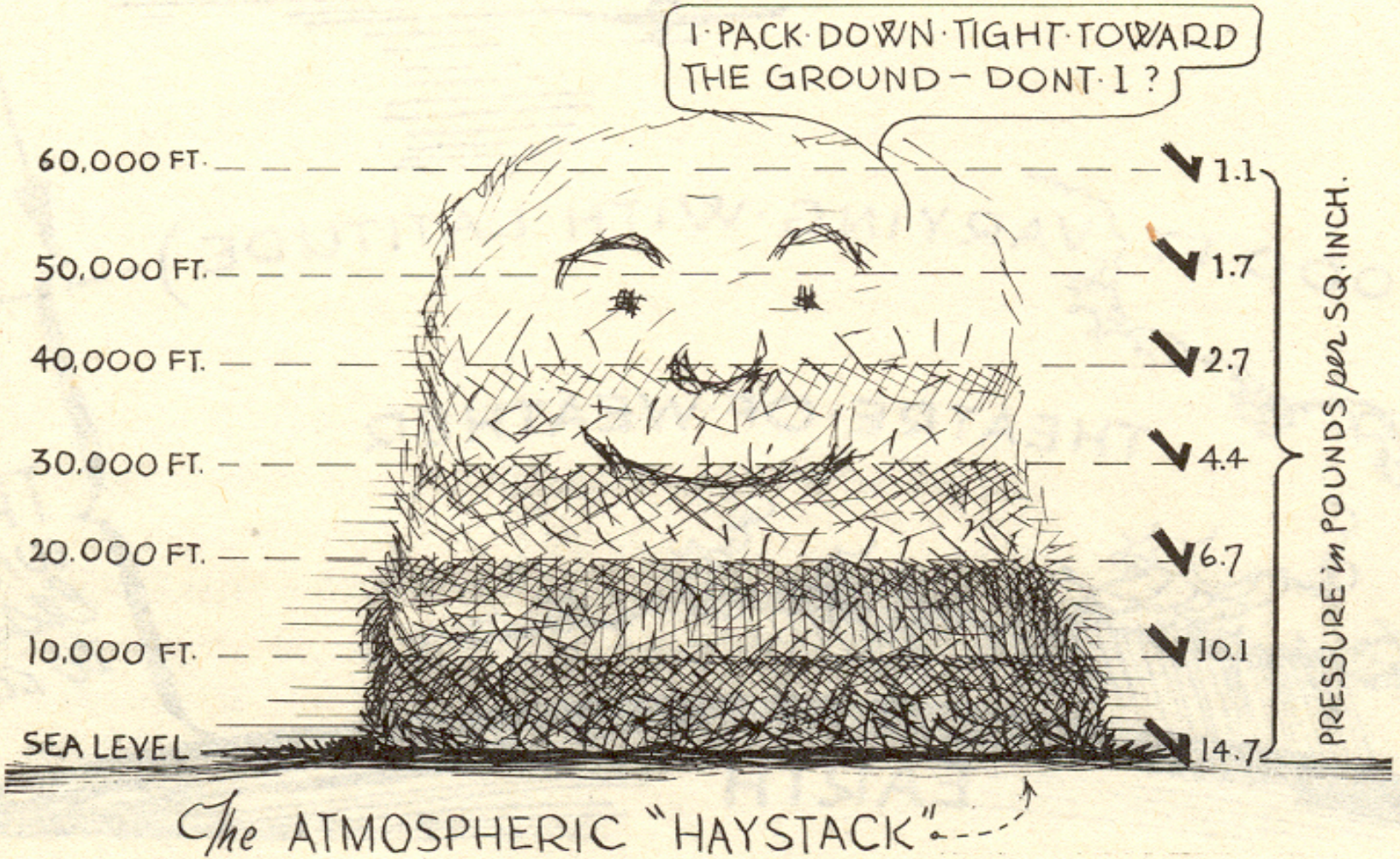
78%
Nitrogen

21%
Oxygen

1% Other
Gasses


The AIR UP HERE HAS THE SAME COMPOSITION - THERE IS JUST LESS OF IT — IT IS THIN!
STRATOSPHERE where temperature is nearly constant about -55°C
TROPOPAUSE (33,000 FT. VARYING WITH LATITUDE)
THEATRE OF WEATHER
TROPOSPHERE where air temperature lessens according to altitude.
EARTH


10 to 50 km
STRATOSPHERE
OZONE LAYER
0 to 10 km
TROPOSPHERE
EARTH

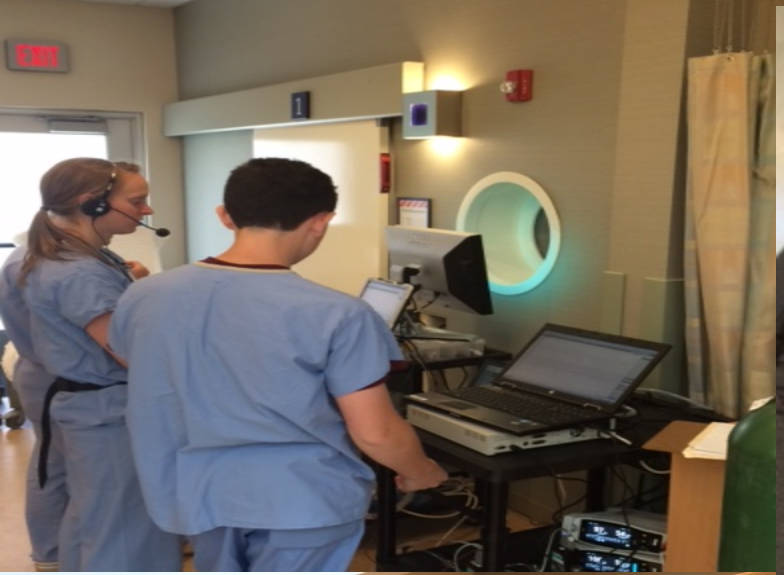


The ATMOSPHERIC "HAYSTACK"

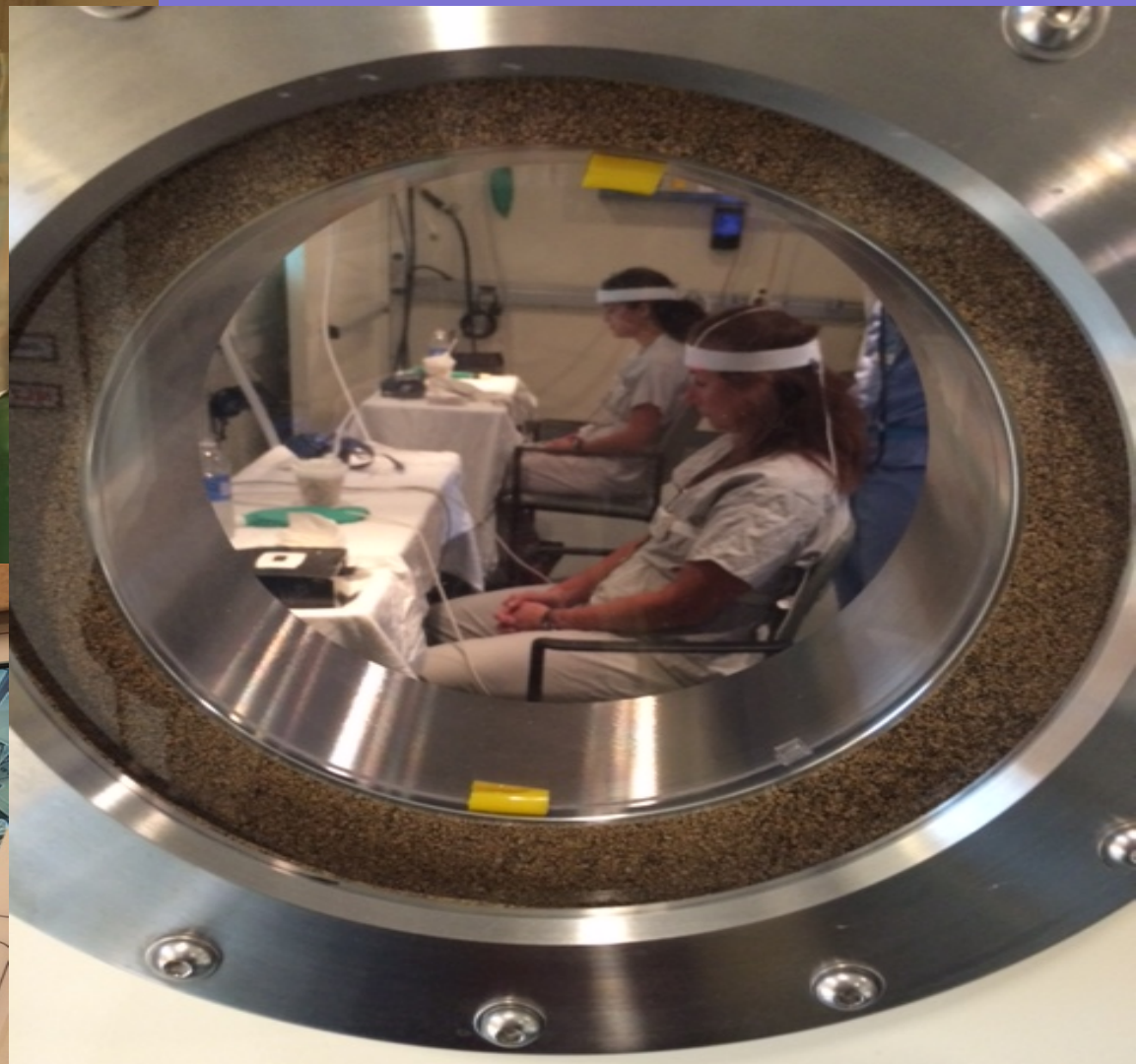
ALTITUDE		PRESSURE		
feet	meters	mm Hg	in Hg	lb/in^2
0	0	760	29.92	14.69
5,000	1,525	632	24.9	12.23
10,000	3,048	523	20.58	10.11
15,000	4,572	429	16.88	8.29
20,000	6,096	349	13.74	6.75
25,000	7,620	282	11.09	5.45
30,000	9,144	226	8.87	4.36
35,000	10,668	179	7.04	3.46
40,000	12,192	141	5.53	2.72
45,000	13,716	111	4.35	2.14
50,000	15,240	87.3	3.44	1.69
55,000	16,764	68.8	2.71	1.33
60,000	18,288	54.1	2.14	1.05
65,000	19,812	42.3	1.66	0.8164
70,000	21,336	33.3	1.32	0.6494
75,000	22,860	26.2	1.03	0.5057
80,000	24,384	20.7	0.82	0.4028
85,000	25,908	16.4	0.644	0.3165
90,000	27,432	13	0.508	0.2496
95,000	28,956	10.3	0.404	0.1988
100,000	30,480	8.2	0.315	0.1549

Time of Useful Consciousness

Feet (thousands)	*Kilometers*	*Time*
50	15.2	9 – 12 sec
43	13.1	9 – 12 sec
40	12.2	15 – 20 sec
35	10.7	30 – 60 sec
30	9.1	1 – 2 min
28	8.5	2.5 – 3 min
25	7.6	4 – 6 min
22	6.7	8 – 10 min
18	5.5	20 – 30 min


EXIT


MAIN LOCK 1
MAIN LOCK 1

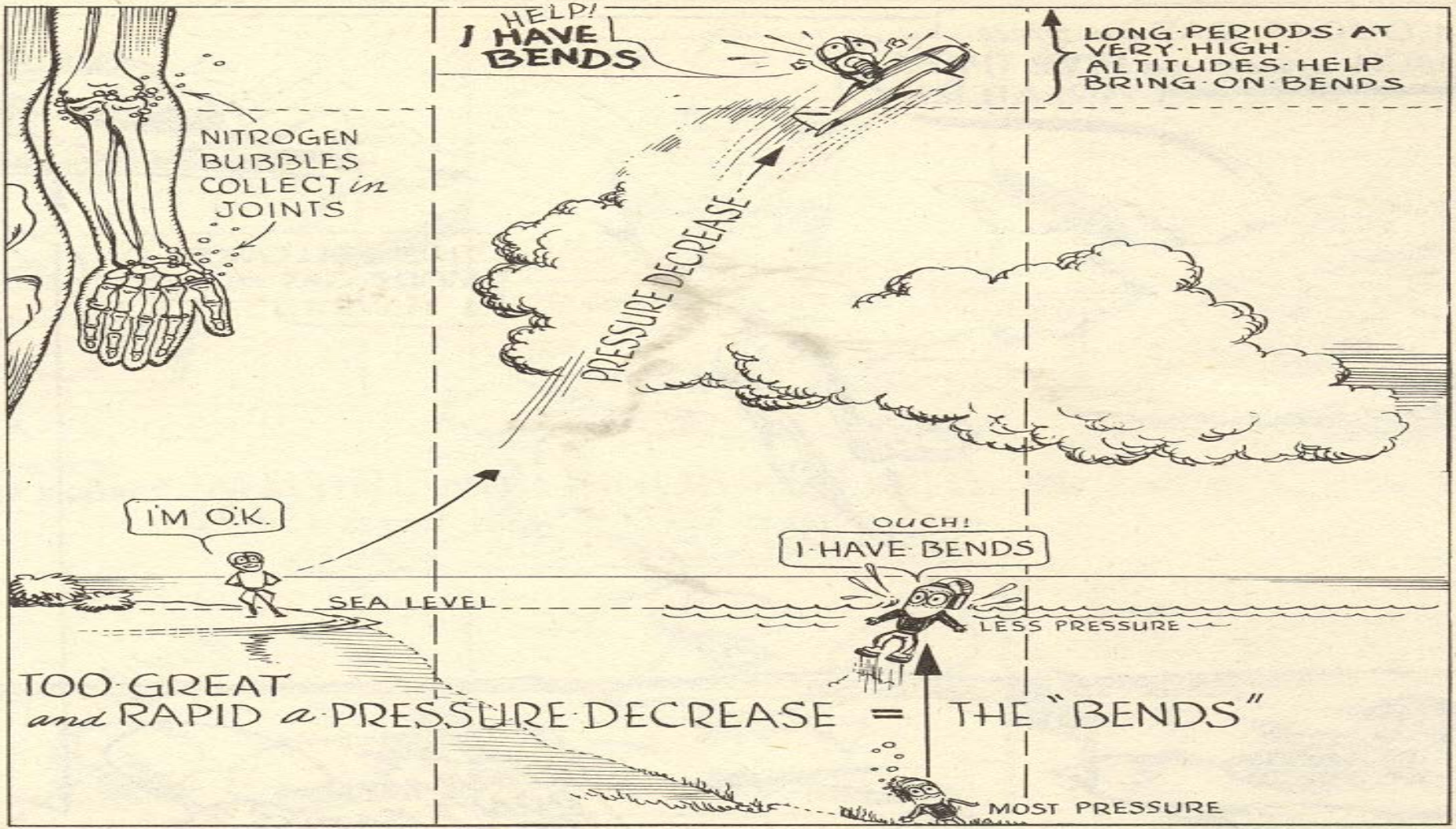



DREAMLINER

What do aviators, divers and soft drinks have in common?

"Liquid systems saturated with a dissolved gas"

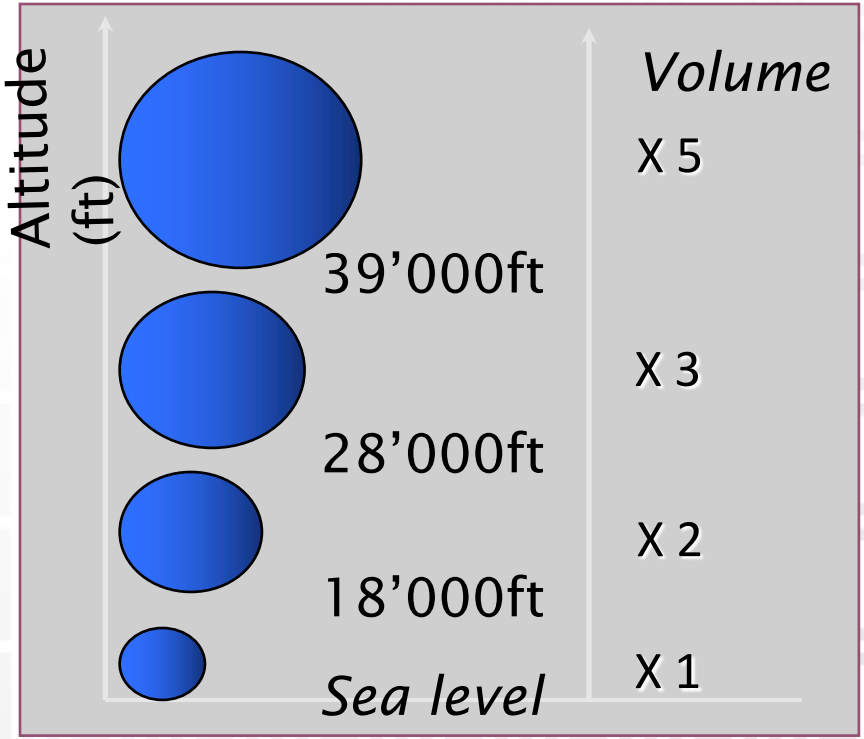
- Henry's Law
  - Amount of dissolved gas in solution varies directly with pressure of that gas over the solution
  - $P_1/P_2=A_1/A_2$
- Decompression Sickness (DCS)
  - Dissolved nitrogen equalizes with the surrounding environment as pressure changes
  - If the pressure change is too rapid it comes out of solution rapidly forming bubbles in the blood and tissues


HELP! I HAVE BENDS
LONG PERIODS AT VERY HIGH ALTITUDES HELP BRING ON BENDS
NITROGEN BUBBLES COLLECT in JOINTS
PRESSURE DECREASE
I'M O.K.
OUCH! I HAVE BENDS
SEA LEVEL
LESS PRESSURE
MOST PRESSURE
TOO GREAT and RAPID a PRESSURE DECREASE = THE "BENDS"

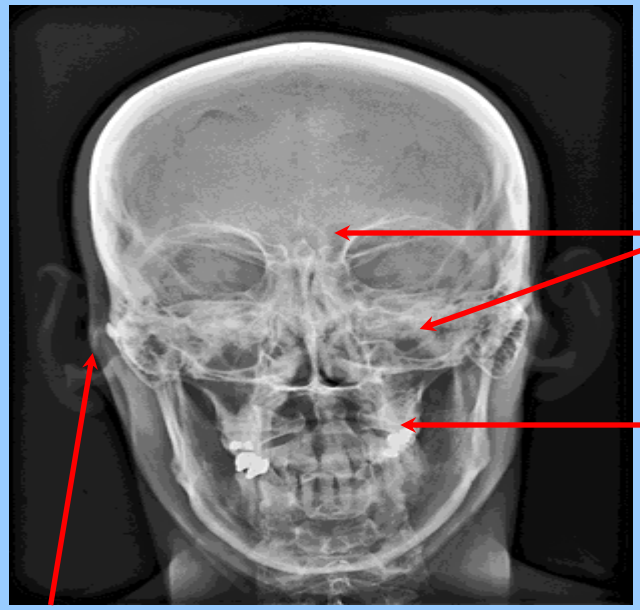
Law of Boyle-Mariotte

$$p_1 \times V_1 = p_2 \times V_2$$

A given mass (volume) of a gas is inversely proportional to the pressure to which it is subjected.



Boyle's Law & Physiology

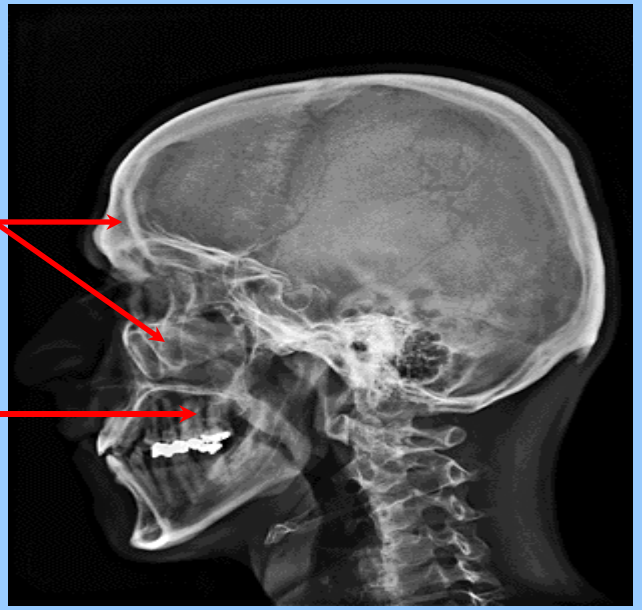


Trapping of gas

Paranasal Sinus
(Sinus block)

Carious Teeth

(Aerodontalgia)



Middle Ear
(Earblock)

Result: Pain with pressure changes (descent)

Ambient Air Pollution

Which of the following compounds are NOT considered one of the regulated ambient air pollutants?

A. Ultrafine particles (PM 2.5)
B. Sulfur dioxide
C. Nitrogen dioxide
D. Carbon dioxide
E. Ozone

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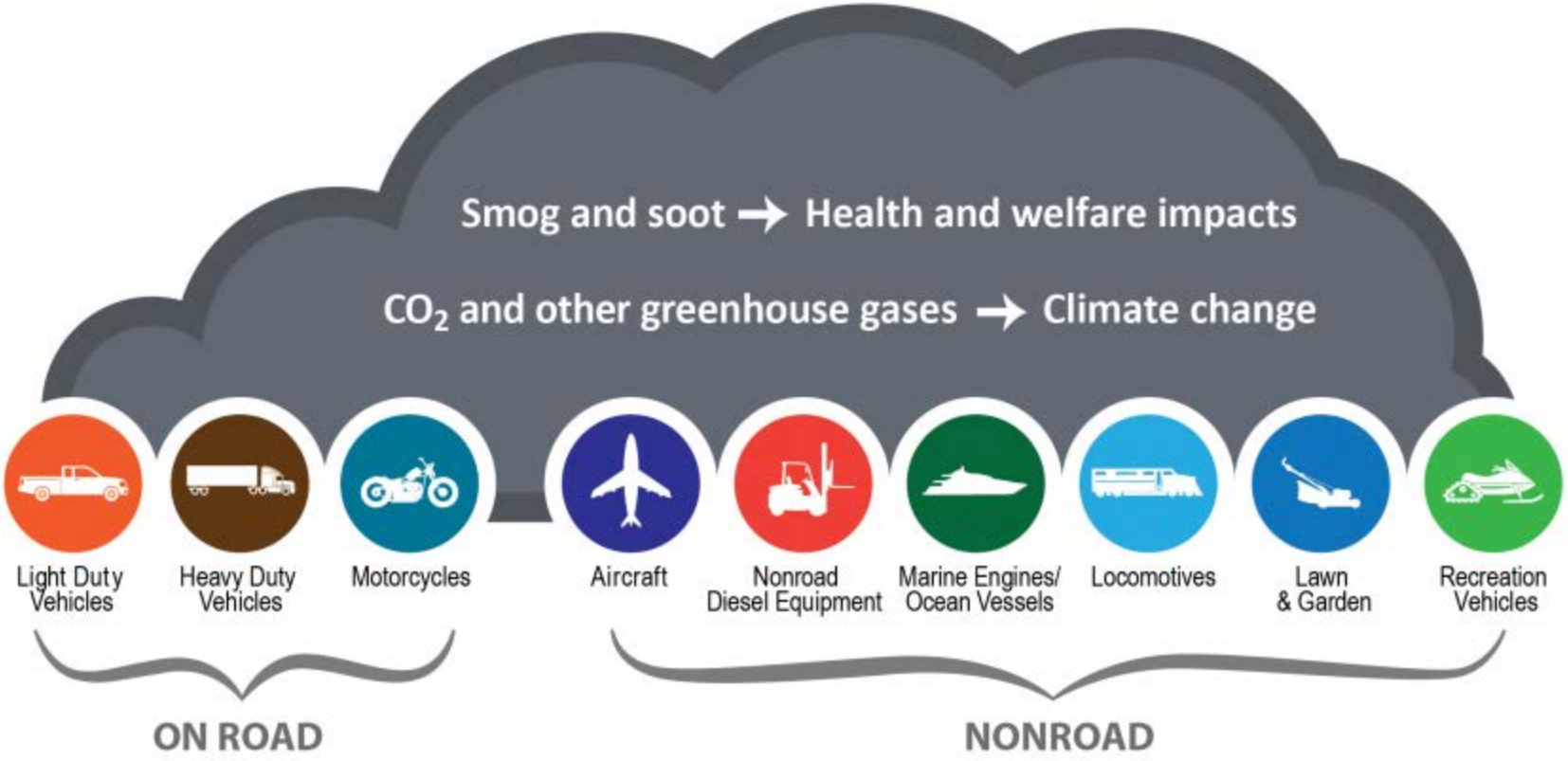
Sources of Transportation Air Pollution



Source: US EPA

Solutions for Transportation Air Pollution

Catalytic converters in conjunction with unleaded gasoline and low sulfur levels significantly reduce hydrocarbon & nitrogen oxide emissions

Fuel standards reduce exposure to pollutants like lead and benzene

Renewable fuels reduce CO_2 emissions

Engine technologies like computer controls, variable valve timing, multi-valve engines, turbo charging & gasoline direct injection improve fuel economy & reduce CO_2 emissions

Transmission technologies like 7+ speeds, dual clutch transmissions (DCTs), & continuously variable transmissions (CVTs) improve fuel economy & reduce CO_2 emissions

Diesel filters reduce particulate matter from on road & off road diesel engines

Alternative vehicle technologies like plug-in electric vehicles & fuel cells = zero tailpipe emissions

Better transportation planning for passengers & freight reduce emissions & fuel use

EPA United States Environmental Protection Agency

Table 1. National Ambient Air Quality Standards for Criteria Air Pollutants

Pollutant	Primary standard		Measuring method
Ozone (O_3, ppm)	1-hr average	≤0.1 ppm	Ultraviolet photometric method
	8-hr average	≤0.06 ppm	
PM_{10} (μg/m^3)	Annual arithmetic mean	≤50 μg/m^3	β-Ray absorption method
	24-hr average	≤100 μg/m^3	
$PM_{2.5}$ (μg/m^3)	Annual arithmetic mean	≤25 μg/m^3	Gravity concentration method
	24-hr average	≤50 μg/m^3	
Sulfur dioxide (SO_2, ppm)	Annual arithmetic mean	≤0.02 ppm	Pulse ultraviolet fluorescence method
	24-hr average	≤0.05 ppm	
	1-hr average	≤0.15 ppm	
Nitrogen dioxide (NO_2, ppm)	Annual arithmetic mean	≤0.03 ppm	Chemiluminescent method
	24-hr average	≤0.06 ppm	
	1-hr average	≤0.10 ppm	
Carbon monoxide (CO, ppm)	8-hr average	≤9 ppm	Non-dipersive infrared method
	1-hr average	≤25 ppm	

People residing in regions with air pollutant concentration above the primary standards may experience adverse health effect from poor air quality.
PM, particulate matter.

Source: *Korean J Pediatr* 2012;55(6):185-192.

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Air Pollution and Noncommunicable Diseases

A Review by the Forum of International Respiratory Societies' Environmental Committee, Part 1: The Damaging Effects of Air Pollution

Dean E. Schraufnagel, MD; John R. Balmes, MD; Clayton T. Cowl, MD; Sara De Matteis, MD, MPH, PhD; Soon-Hee Jung, MD, PhD; Kevin Mortimer, MB, BChir, PhD; Rogelio Perez-Padilla, MD; Mary B. Rice, MD, MPH; Horacio Riojas-Rodriguez, MD, PhD; Akshay Sood, MD, MPH; George D. Thurston, ScD; Teresa To, PhD; Anessa Vanker, MBChB, PhD; and Donald J. Wuebbles, PhD

5th leading risk factor of death worldwide
(Global Burden of Disease Report)

Air pollution poses a great environmental risk to health. Outdoor fine particulate matter (particulate matter with an aerodynamic diameter < 2.5 μm) exposure is the fifth leading risk factor for death in the world, accounting for 4.2 million deaths and > 103 million disability-adjusted life years lost according to the Global Burden of Disease Report. The World Health Organization attributes 3.8 million additional deaths to indoor air pollution. Air pollution can harm acutely, usually manifested by respiratory or cardiac symptoms, as well as chronically, potentially affecting every organ in the body. It can cause, complicate, or exacerbate many adverse health conditions. Tissue damage may result directly from pollutant toxicity because fine and ultrafine particles can gain access to organs, or indirectly through systemic inflammatory processes. Susceptibility is partly under genetic and epigenetic regulation. Although air pollution affects people of all regions, ages, and social groups, it is likely to cause greater illness in those with heavy exposure and greater susceptibility. Persons are more vulnerable to air pollution if they have other illnesses or less social support. Harmful effects occur on a continuum of dosage and even at levels below air quality standards previously considered to be safe.

CHEST 2019; 155(2):409-416

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Air Pollution not only affects the respiratory system but also other organ systems in the body – however, it is controllable and therefore, health effects preventable.

Although air pollution is well known to be harmful to the lung and airways, it can also damage most other organ systems of the body. It is estimated that about 500,000 lung cancer deaths and 1.6 million COPD deaths can be attributed to air pollution, but air pollution may also account for 19% of all cardiovascular deaths and 21% of all stroke deaths. Air pollution has been linked to other malignancies, such as bladder cancer and childhood leukemia. Lung development in childhood is stymied with exposure to air pollutants, and poor lung development in children predicts lung impairment in adults. Air pollution is associated with reduced cognitive function and increased risk of dementia. Particulate matter in the air (particulate matter with an aerodynamic diameter $< 2.5\ \mu m$) is associated with delayed psychomotor development and lower child intelligence. Studies link air pollution with diabetes mellitus prevalence, morbidity, and mortality. Pollution affects the immune system and is associated with allergic rhinitis, allergic sensitization, and autoimmunity. It is also associated with osteoporosis and bone fractures, conjunctivitis, dry eye disease, blepharitis, inflammatory bowel disease, increased intravascular coagulation, and decreased glomerular filtration rate. Atopic and urticarial skin disease, acne, and skin aging are linked to air pollution. Air pollution is controllable and, therefore, many of these adverse health effects can be prevented.

CHEST 2019; 155(2):417-426

Which of the following statements are most correct regarding tobacco abuse and smoking cessation?

A. In the U.S., tobacco addition has risen to the second most common drug addiction behind use of marijuana.

B. Women who stop smoking during pregnancy increase their risk of having a low birth weight baby.

C. Counseling and medication are both effective for treating tobacco dependence, and using them together is more effective than using either one alone.

D. People of low SES are less likely to make quit attempts but are more successful in quitting smoking cigarettes than those in higher SES groups.

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D. People of low SES are less likely to make quit attempts but are more successful in quitting smoking cigarettes than those in higher SES groups.

- Tobacco use can lead to tobacco/nicotine dependence and serious health problems including coronary artery disease, lung and other cancers, strokes, peripheral vascular disease, and other conditions
- Smokers can and do quit smoking. Since 2002 there are more former smokers than current smokers.
- More people in the world are addicted to nicotine than to any other drug. Research suggests that nicotine may be as addictive as heroin, cocaine, or alcohol.
- Quitting smoking is hard and may require several attempts. People who stop smoking often start again because of withdrawal symptoms, stress, and weight gain.

Disparities in tobacco use

People with low SES tend to smoke cigarettes more heavily

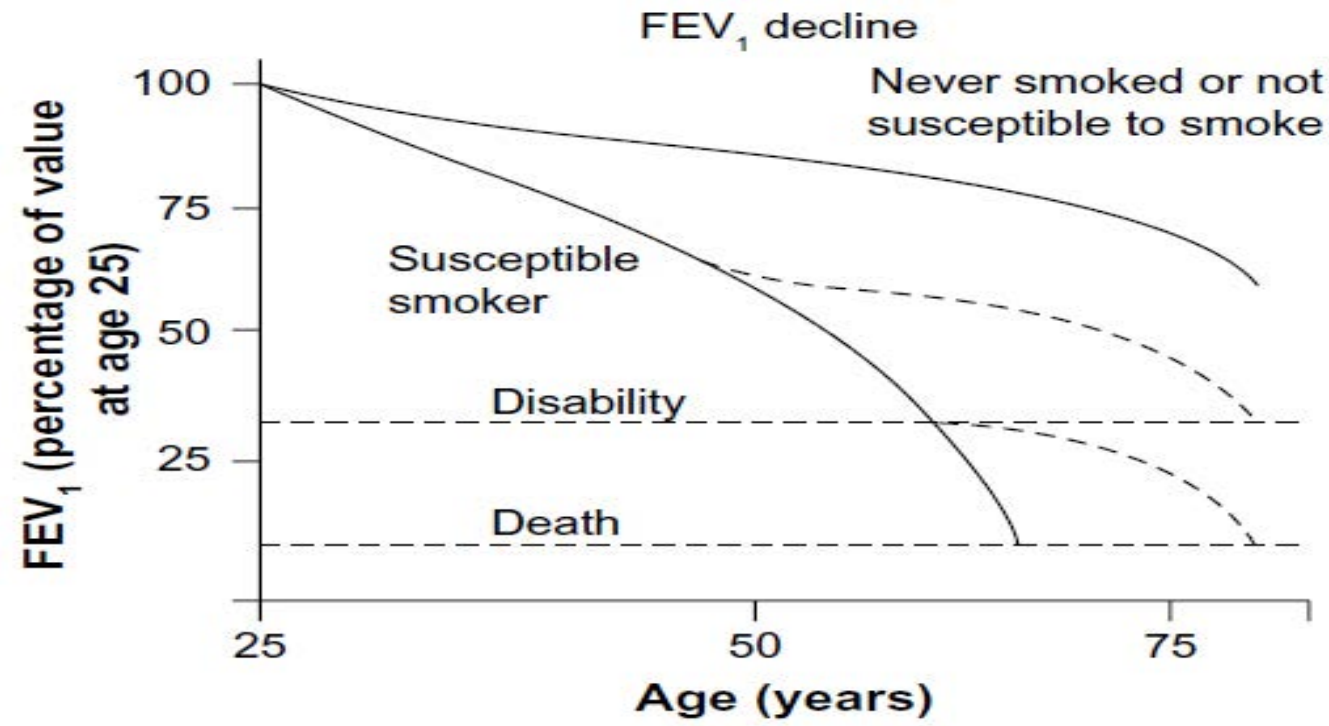
- Individuals living in poverty smoke cigarettes for a duration of nearly twice as many years as people with a family income of three times the poverty rate and with at least a Bachelor's degree.
- "Blue-collar" workers are more likely to start smoking cigarettes at a younger age and to smoke more heavily than white-collar workers.

Secondhand smoke exposure is higher among people living below the poverty level and those with less education

People of low SES are just as likely to make quit attempts but are less likely to quit smoking cigarettes than those who are not

Tobacco use treatment and smoking cessation

- Among all current U.S. adult cigarette smokers, nearly 7 out of every 10 (68.8%) reported in 2010 that they wanted to quit completely
- Reduced heart disease risk realized within 1 to 2 years of quitting smoking (for those smoking more than 1 pack per day)
- Women who stop smoking during pregnancy also reduce their risk of having a low birth weight baby



Am J Resp Crit Care Med 2002;166:675-679.

Tobacco use treatment and smoking cessation

Quitting without assistance ("cold turkey" or cut down then quit)

Medications for quitting that have been found to be effective include the following:

- Nicotine replacement products
  - Nicotine patch [which is also available OTC or by prescription], gum, lozenge, inhaler, nasal spray
- Prescription non-nicotine medications
  - bupropion SR (Zyban®),varenicline tartrate (Chantix®)

Counseling and medication are both effective for treating tobacco dependence, and using them together is more effective than using either one alone.

Use of eCigarettes ("Vaping")

- eCigarettes may be less harmful than cigarette smoking
- eCigarettes still contain nicotine and are highly addictive
- "Vaping" may actually involve more nicotine delivery than traditional cigarettes
- If recommending smoking cessation, eCigarettes are NOT the ideal mechanism for doing so
- Prevalence of nicotine dependence has increased dramatically with a 900% increase in rates of e-Cigarette use reported in U.S. high school students ages 14-18

Toxic Inhalations

CHEST Supplement

DIAGNOSIS AND MANAGEMENT OF WORK-RELATED ASTHMA: ACCP CONSENSUS STATEMENT

Diagnosis and Management of Work-Related Asthma*

American College of Chest Physicians Consensus Statement

Susan M. Tarlo, MBBS, FCCP; John Balmes, MD, FCCP; Ronald Balkissoon, MD; Jeremy Beach, MD; William Beckett, MD, MPH, FCCP; David Bernstein, MD; Paul D. Blanc, MD, FCCP; Stuart M. Brooks, MD; Clayton T. Cowl, MD, MS, FCCP; Feroza Daroowalla, MD, MPH, FCCP; Philip Harber, MD, MPH; Catherine Leniere, MD, MSc; Gary M. Liss, MD, MS; Karin A. Pacheco, MD, MSPH; Carrie A. Redlich, MD, MPH, FCCP; Brian Rowe, MD, FCCP; and Julia Heitzer, MS

Background: A previous American College of Chest Physicians Consensus Statement on asthma in the workplace was published in 1995. The current Consensus Statement updates the previous one based on additional research that has been published since then, including findings relevant to preventive measures and work-exacerbated asthma (WEA).
Methods: A panel of experts, including allergists, pulmonologists, and occupational medicine physicians, was convened to develop this Consensus Document on the diagnosis and management of work-related asthma (WRA), based in part on a systematic review, that was

CHEST September 2008; Vol. 134(3): Suppl 1S-41S.

Eur Respir J 2012; 39: 529–545
DOI: 10.1183/09031936.00096111

ERS TASK FORCE REPORT

Guidelines for the management of work-related asthma

X. Baur, T. Sigsgaard, T.B. Aasen, P.S. Burge, D. Heederik, P. Henneberger, P. Maestrelli, J. Rooyackers, V. Schlünssen, O. Vandenplas and D. Wilken on behalf of the ERS Task Force on the Management of Work-related Asthma

ABSTRACT: Work-related asthma, which includes occupational asthma and work-aggravated asthma, has become one of the most prevalent occupational lung diseases. These guidelines aim to upgrade occupational health standards, contribute importantly to transnational legal harmonisation and reduce the high socio-economic burden caused by this disorder.

A systematic literature search related to five key questions was performed: diagnostics; risk factors; outcome of management options; medical screening and surveillance; controlling exposure for primary prevention. Each of the 1,329 retrieved papers was reviewed by two experts, followed by Scottish Intercollegiate Guidelines Network grading, and formulation of statements graded according to the Royal College of General Practitioners' three-star system.

Recommendations were made on the basis of the evidence-based statements, which comprise the following major evidence-based strategic points. 1) A comprehensive diagnostic approach considering the individual specific aspects is recommended. 2) Early recognition and diagnosis is necessary for timely and appropriate preventative measures. 3) A stratified medical screening strategy and surveillance programme should be applied to at-risk workers. 4) Whenever possible, removing exposure to the causative agent should be achieved, as it leads to the best health outcome. If this is not possible, reduction is the second best option, whereas respirators are of limited value. 5) Exposure elimination should be the preferred primary prevention approach.

KEYWORDS: Diagnostics, occupational asthma, occupational exposure, prevention, risk factors, surveillance

AFFILIATIONS
Author affiliation details and a list of the Task Force members can be found in the Acknowledgements section.

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Nov 28 2011

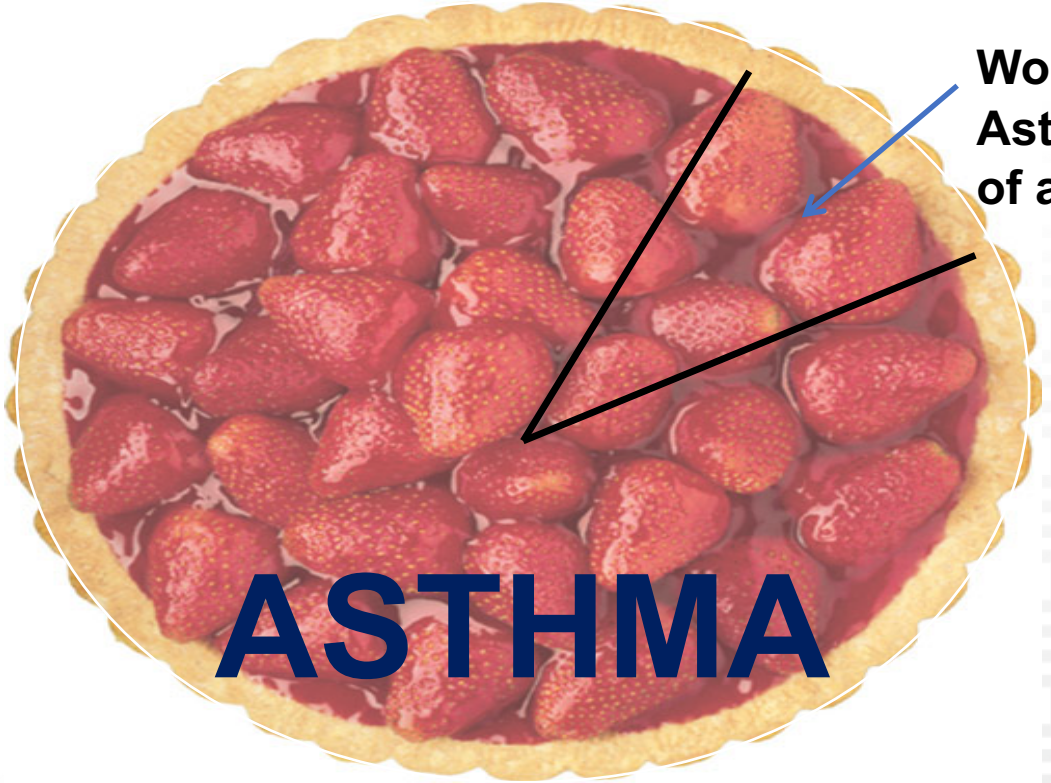
Consensus reached on several topics on Work-Related Asthma (WRA)

- Take a history to screen for WRA in all new onset or worsening asthma patients
- In all patients suspected with WRA, obtain a history of job duties, exposures, use of protective devices, presence of respiratory disease in co-workers, etc.
- For individuals with suspected sensitizer-induced occupational asthma (OA), carefully document history and use objective testing to improve diagnostic probability (e.g. serial peak flow readings, serial methacholine challenge, immunological assessments, induced sputum testing, etc.)

Consensus reached on several topics on WRA(cont.):

- In patients suspected with WRA who are continuing to work, record serial measurements of peak flow as part of the diagnostic evaluation (minimum 4x/day for at least 2 weeks)
- Focus on exposure control and remove patients from exposure in sensitizer-induced asthma
- An individual diagnosed with OA represents a potential sentinel event, so the workplace may need to be evaluated to identify and prevent other cases of OA -- and if sensitizer present, implement secondary prevention (e.g. questionnaires, screening spirometry, etc.)

Work-related asthma epidemiology



Work-related
Asthma has a prevalence of 9-15% of all forms of asthma

Balmes J. *Am J Respir Crit Care Med. 2003; 167(5):787-97.*

Work-related asthma

Immunologic-induced asthma

- **High-Molecular Weight Antigens**
- **Low-Molecular Weight Antigens**

Asthma with latency

Asthma without latency

Irritant-induced asthma

(RADS)

Inhalation of irritants, gases, fumes

Reactive Airways Dysfunction Syndrome (RADS)

Reactive Airways Dysfunction Syndrome (RADS)

- ***An asthma-like illness that occurs after a single exposure to high levels of a respiratory irritant (vapor, fume, smoke) frequently occurring after a workplace accident or spill.***
- Symptoms develop within hours of exposure and are associated with methacholine challenge responsiveness.
- Symptoms and airway responsiveness often persist longer than one year and may be permanent.

Brooks SM, Lockey J. *Am Rev Respir Dis* 1981;123:A11.

Assessment and treatment of acute toxic inhalations

Clayton T. Cowl

Purpose of review
Acute toxic inhalation exposures affect thousands of individuals worldwide each year. The acute evaluation of these inhaled exposures is often fraught with difficulty in identifying a specific agent, may involve multiple compounds, and a wide variety of responses are seen depending on the physical properties of the specific toxicant, the length of time of inhalation, and the concentration of the exposure. Recognizing key aspects of the most common acute toxic inhalations is useful in developing a diagnosis and treatment strategy.

Recent findings
Use of sequential observations with flexible bronchoscopy has been the standard of care for assessing airway injury, and virtual bronchoscopy using computed tomographic images in a three-dimensional reconstructed image can now better identify airway narrowing. Use of [^{18}F]-fluorodeoxyglucose uptake, as measured by PET, has the potential for early recognition of delayed acute lung injury in toxic inhalation exposures. Development of a standardized respiratory injury grading system is ongoing with a recent multicenter trial nearly complete, allowing for more accurate estimates of eventual outcomes and guide levels of intensity of care for patients with acute inhalation injury. Removal from the source of exposure and airway support remain the first critical aspect of treatment, and additional therapies have been studied recently that focus on altering molecular mechanisms of acute cellular injury, expanding potential treatments beyond other pharmacotherapeutic strategies utilized previously such as mucolytics, bronchodilators, and inhaled anticoagulants.

Summary
Although a prevalent source of airway injury, exposure to acute toxic inhalants is often difficult to assess and prognosticate, and challenging to treat.

Keywords
acute inhalation injury, acute toxic inhalants, gaseous inhalation, inhaled irritants, toxic inhalations

Smoke inhalation injuries

- Smoke inhalation injury is generally defined as the inhalation of thermal or chemical irritants with more than 23,000 injuries and 5,000–10,000 U.S. deaths per year
- According to the WHO, more than 1 billion people develop airway and pulmonary inflammation as a result of inhaled smoke from indoor cooking fires, forest fires and burning of crops.
- Smoke toxicity is increasing because industrial products have shifted from woods and natural materials towards lighter construction materials, synthetics and petrochemicals, which ignite and burn 2x- to 3x-times hotter and faster.

Smoke inhalation injuries (cont.)

- Thermal injury, which is mostly restricted to the upper airway (exception: blast injury or steam inhalation)
- Chemical irritation of the respiratory tract
- Systemic toxicity from toxic gases

Smoke inhalation injuries (cont.)

Contact irritants -- particulates

- Cause cellular damage and massive edema
- Include particulate matter such as soot with particles larger than five microns lodging in the upper airways, causing mechanical obstruction
- Particles smaller than one micron are inhaled distally, where the carbonaceous soot is toxic to the macrophages. Heavy metals coating the surface of soot cause direct lung damage by forming free oxygen radicals which damage cilia and alveolar surfaces

Aldehydes and acrolein -- released when wood and cellulose burn

- Cause intense tearing, coughing, and choking with acrolein

What Things Do I Need to Consider in Assessing the Patient?

- Physical Properties of Gas
- Acute Clinic Findings as an Assessment of Injury Severity
- **Common Types of Toxic Inhalations**
  - Ammonia
  - Cadmium
  - Mercury
  - Zinc chloride
  - Mace & Tear Gas
  - Hydrogen sulfide
  - Ozone
  - Sulfur dioxide
  - Chlorine Derivatives
  - Phosgene
  - Nitrogen oxides

Smoke inhalation injuries (cont.)

Degradation of plastics creates most of the corrosive gases found in fires

- Plastics containing a chlorine molecule (e.g. polyvinyl chloride)
- Burning forms hydrogen chloride, phosgene, and HCl
- If superheated air has also been inhaled, swelling can be severe and cause rapid, significant airway obstruction.

Central systemic poisons (carbon monoxide or CO) and cyanide

Physical Properties of Toxic Irritants

- Size of particles
- Water solubility
- Concentration of substance in ambient air
- Density of substance
- Duration of exposure
- Presence or absence of ventilation
- Host factors
  - Age, smoking status, co-morbidities
  - Respiratory protection

Water Solubility and Site of Initial Impact of Toxic Irritants

Water Solubility	Initial Level of Impact	Inhalant
High	Nose Pharynx Larynx	Ammonia Chlorine Sulfur dioxide
Medium	Trachea Bronchi	Ozone
Low	Bronchioles Alveoli	Nitrogen dioxide Phosgene

From Balkisson R: In Occupational Upper Airway Disease. Clinics Chest Med 2002; 23:717-725.

Summary

- The Atmosphere, Hypobaric Hypoxia and Dysbarisms
- Air pollution
- Smoking
- Toxic Inhalations

Thank you for your attention!

Ευχαριστώ για την προσοχή σας

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