Information and opinions expressed by LT DiGeorge are not intended/should not be taken as representing the policies and views of the Department of Defense, its component services, or the U.S. Government.
History of Diving and Hyperbaric Medicine

http://historyofdivingmuseum.blogspot.com/2010/06/diving-bell.html
History of Diving and Hyperbaric Medicine

History of Diving and Hyperbaric Medicine

http://dev.nsta.org/evwebs/2270/PastTechnology.html
History of Diving and Hyperbaric Medicine

- Nathaniel Henshaw (1662)
  - Built sealed chamber called “Domicilium” with organ bellows to treat acute diseases

http://www.baromedical.hu/info/hbo-tortenete
History of Diving and Hyperbaric Medicine

- **Triger (1845)**
  - Noted pain in shoulders of French mine workers suspecting a link to the pressure at depth

- **Andrew Smith (1871)**
  - Coins the term “Caisson Disease” in workers during the construction of Brooklyn Bridge giving way to the “bends” given the appearance of individuals suffering from decompression sickness

- **Paul Bert (1878)**
  - Physiologic effects of air pressure and oxygen toxicity

- **Haldane (1908)**
  - Goat studies reveals parallel perfusion in limited compartments
  - Paved the way for the U.S. Navy Diving Tables and guidelines we use today
History of Diving and Hyperbaric Medicine

- Triger (1845) noted pain in shoulders of French mine workers
  - Noted pain in shoulders of French mine workers suspecting a link to the pressure at depth
History of Diving and Hyperbaric Medicine

http://www.brooklynbridgeaworldwonder.com/safety-design.html
\section*{Diving Physics}

\begin{itemize}
  \item**Boyle’s Law**
    \begin{itemize}
    \item For any gas at a constant temperature, the volume of the gas will vary inversely with the pressure
      \begin{itemize}
      \item Squeeze
      \item Pulmonary Over-Inflation Syndrome
      \item Air consumption
      \item Minimum manifold pressure
      \end{itemize}
    \end{itemize}
  \item **Charles’ Law**
    \begin{itemize}
    \item For any gas at a constant pressure, the volume of the gas will vary directly with absolute temperature
    \end{itemize}
  \item **Gay-Lussac’s Law**
    \begin{itemize}
    \item For any gas at a constant volume, the pressure of the gas will vary directly with the absolute temperature
      \begin{itemize}
      \item Charging of tanks
      \item Air storage
      \item Recompression chamber
      \end{itemize}
    \end{itemize}
\end{itemize}
Diving Physics

- **Dalton’s Law**
  - The total pressure exerted by a mixture of gases is equal to the sum of the pressure of each of the different gases making up the mixture with each gas acting as if it alone was present and occupied the total volume
    - Gas toxicity at depth
    - Partial pressures

- **Henry’s Law**
  - The amount of any given gas that will dissolve in a liquid at a given temperature is directly proportional to the partial pressure of that gas
    - Inert gas absorption
      - Depth
      - Time
      - Level of inert gas exposure
    - Decompression Sickness
    - Dive table development
Diving Medical Issues

- Decompression Sickness
- Arterial Gas Embolism
- Pulmonary Barotrauma
- Non-Pulmonary Barotrauma
- Abnormal Gases
- Environmental Exposures
Decompression Sickness (DCS) aka “The Bends”

- Pathologic response to bubble formation in the tissues from excess dissolved gas upon reduction in ambient pressure

  - **Type I**
    - Musculoskeletal joint pain
    - Skin (urticarial) and lymphatic (local edema)

  - **Type II**
    - Pulmonary “chokes”
    - Neurologic (paresthesia and numbness)
    - Vestibular “staggers”
    - Cutis Marmorata

http://www.aafp.org/afp/2008/0101/p47.html
Decompression Sickness

- Extravascular Bubbles (Autochthonous)
- Intravascular Bubbles
  - Usually venous unless:
    - Pulmonary impairment
    - AV shunts
    - Intracardiac shunts
- Mechanical effects
  - Blocked blood flow
  - Embolization
  - Compression of tissues
- Non-mechanical
  - Foreign body provoking inflammatory response
Decompression Sickness

• Risk Factors
  – Short deep dives
  – Omitted Decompression
  – Patent Foramen Ovale
  – Exercise
  – Cold
  – Older age
  – Obesity
  – Dehydration
  – Prior DCS
Arterial Gas Embolism (AGE)

- Occurs within 10 minutes of surfacing
- Symptomatic with obvious clinical manifestations

http://physiologyonline.physiology.org/content/17/2/77
Pulmonary Over-Inflation Syndrome (POIS)

- Expansion of gas trapped in lung causing increased alveolar pressure during decreasing ambient pressure with rupture of lung tissue
  - Caused by breath-holding during ascent
  - Risk factors include:
    - Asthma
    - Secretions
    - Granulomas
    - Cysts
    - Blebs

- Can lead to:
  - AGE
  - Pneumothorax
  - Mediastinal emphysema
  - Subcutaneous emphysema
  - Pneumopericardium
Non-pulmonary Barotrauma

- Membrane (vascular) lined space
- Ambient pressure change
- Rigid walls
- Gas filled space
- Enclosed space

http://scienceblogs.comstartswithabang/files/2010/05/Normal_ear_anatomy.jpg
Non-pulmonary Barotrauma

• Middle ear “squeeze” from blocked ET
  – Teed score
• Sinus “squeeze”
• Face “squeeze”

http://www.scuba.net.hk/medicine/volume001.htm
Vertigo

**Caloric**
- Unequal temperature
- Descent
- Transient

**Alternobaric**
- Unequal Pressure
- Ascent
- Transient

http://i1186.photobucket.com/albums/z371/rdmcampbell/Vertigo.gif
Abnormal Gas

- Hypoxia
- Oxygen Toxicity
- Hypercapnia
- Nitrogen Narcosis
- Carbon Monoxide Poisoning
- Hyperventilation
Hypoxia

- Lack of concentration
- Lack of muscle control
- Inability to perform fine motor skills
- Drowsiness
- Weakness
- Agitation
- Euphoria
- Loss of consciousness
CNS Oxygen Toxicity

- Vision
- Ears
- Nausea
- Twitching/Tingling
- Irritability
- Dizziness
- Convulsions
Hypercapnia

- Carbon Dioxide toxicity
  - Confusion
  - Euphoria
  - Headache
  - Dizziness
  - SOB
  - Tachycardia
  - Burning eyes
  - Loss of consciousness
Nitrogen Narcosis

Loss of judgment
False sense of well-being
Onset around 100 FSW
Carbon Monoxide Poisoning

• Headache
• Nausea
• Vomiting
• Tachycardia
• Mental status changes
• Loss of consciousness
• Neurologic symptoms
• “Bad tasting air”
• Onset of symptoms on ascent or surface
Excessively lowers the carbon dioxide levels in the blood
  – Decrease respiratory drive
Hypothermia

• Huddle and H.E.L.P maneuvers
• Passive rewarming for severe
  – Remove wet clothing
  – Wrap in insulating blanket
  – Protect from elements
• Active rewarming for mild
  – Heated space
  – Heat packs

http://www.doomandbloom.net/wp-content/uploads/2014/01/huddle.gif
Hyperthermia

http://www.maximizedlivingdrshaub.com/thermography-is-a-safe-alternative-to-mammography
Saturation Diving

http://www.maninthesea.org/tourexhibits.php

“Any disease or condition which causes chronic or recurrent disability for duty assignment or has the potential of being exacerbated by the hyperbaric environment or diving duty is disqualifying”
**MANMED Chapter 15, Article 15-102**

- **Special Studies (within 3 months of exam)**
  - Chest x-ray (PA and lateral)
  - Electrocardiogram
  - Audiogram
  - Dental Class (must be Class I or II)
  - PPD
  - Visual acuity and color vision
  - CBC
  - Urinalysis
  - Fasting blood glucose
  - Hepatitis C screening
  - Lipids

- **Any time prior to dive training**
  - Blood type
  - G6PD
  - Sickle Cell

- **Immunizations for both Hepatitis A and B**
Important Parts of Physical Exam

- Valsalva
- Neurologic Exam
• Chronic Eustachian tube dysfunction or inability to equalize middle ear pressure
• Maxillofacial anomaly precluding the comfortable fit of diving gear
• Persistent vertigo
• Hearing
• Vision standards vary by job duties
• LASIK and PRK acceptable as long as cleared 3 months out from surgery for initial appointment or 1 month out for designated divers
• Color vision
• Pneumothorax
  – Spontaneous – permanently disqualifying
  – Traumatic
    • 6 month healing time
    • Standard non-contrast CT chest
    • Pulmonary Function Testing
    • Pulmonologist and UMO consultations
  – Pulmonary Barotrauma
  – Latent Tuberculosis Infection
  – Asthma
• Gastric bypass
• Abdominal surgery within last 3 months
• Severe GERD
Genitourinary

- Pregnancy
Musculoskeletal

- Chronic or recurrent which predisposes to diving injury, limits the performance of diving duties, or may confuse the diagnosis of a diving injury
Psychiatric

- Any Axis I or II disorder
- Alcohol use disorders
Neurologic

• Idiopathic seizures (except febrile before age 5)
  – Known cause may be waived

• Syncope, if recurrent, unexplained, or not responding to treatment
Hematologic

- Sickle Cell Trait
- Thrombocytopenia
• Allergies
  – Medication allergies OK
  – Food and environmental allergies are disqualifying
Treatment of Diving Emergency

- ABCs
- Transport Supine on 100% $O_2$
- Monitor consciousness
- Obtain past medical history
- Obtain dive profile
- Medication use
- Perform serial neurologic exams along with physical exam
  - Mental Status
  - Cranial Nerves
  - Motor
  - Sensory
  - Reflexes
  - Coordination
- Recompression Treatment with $O_2$
**Indications For Hyperbaric Oxygen**

- Air or Gas Embolism
- Carbon Monoxide Poisoning
- Clostridial Myositis and Myonecrosis
- Crush Injury, Compartment Syndrome and other Acute Traumatic Ischemias
- Decompression Sickness
- Central Retinal Artery Occlusion
- Problem Wounds
- Severe Anemia
- Intracranial Abscess
- Necrotizing Soft Tissue Infections

- Osteomyelitis (Refractory)
- Delayed Radiation Injury (Soft Tissue and Bony Necrosis)
- Compromised Grafts and Flaps
- Acute Thermal Burn Injury
- Idiopathic Sudden Sensorineural Hearing Loss
Submarine Medicine


Submarine Medicine

http://www.americanspecialops.com/equipment/SEAL-diving-gear/
• Diving Medical Officer Course (A-6A-0010) 12-20-DMO
• Butler WP. Caisson disease during the construction of the Eads and Brooklyn Bridges: A review. UHM 2004; 31: 445-59.