

History of Hyperbaric Medicine

ROBERT S. MICHAELSON, DO, MPH
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How Did We Get From Here



To Here

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History of Hyperbaric Medicine

- ▶ Discuss history of diving
- ▶ Discovery of the atmosphere
- ▶ Five major milestones in the development of hyperbaric medicine
 - ▶ Triger's caisson
 - ▶ Eads and Brooklyn Bridge
 - ▶ Haldane and staged decompression
 - ▶ Rescue of the USS Squalus
 - ▶ Donnell and Norton

Diving as a Profession

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- ▶ Salvage Operations
 - ▶ From as early as 9th century BC
 - ▶ Pay scale based on depth of dive
- ▶ Military Operations
 - ▶ Early attempts to bore into hull of ships or attach crude explosives to vessels
 - ▶ Confined to shallow waters and for short duration dives
- ▶ Very Hard to be Stealthy and Effective



Gourd Breathing About 375 AD



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Diving Hood by Flavius Vegetius Renatus about 375 AD in
Eptome Institutionum Rei Militaris



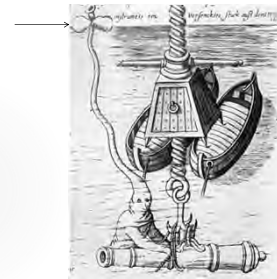
Leonardo's (1452-1519) Design For Swim Fins



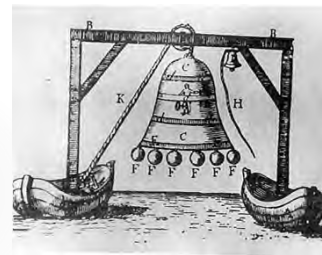
Diving Rig of Niccolo Tartaglia
about 1551



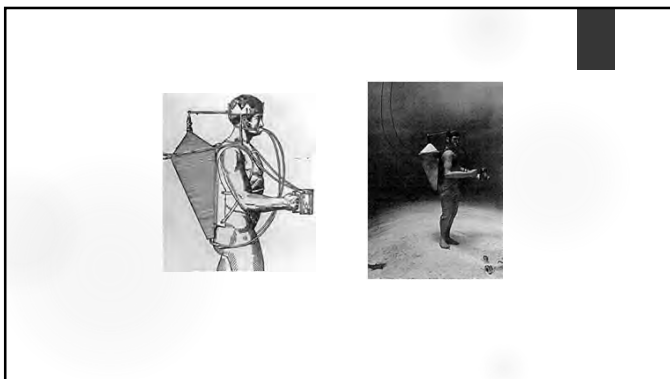
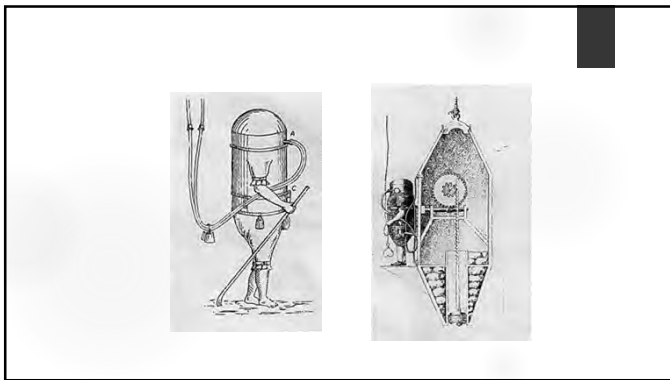
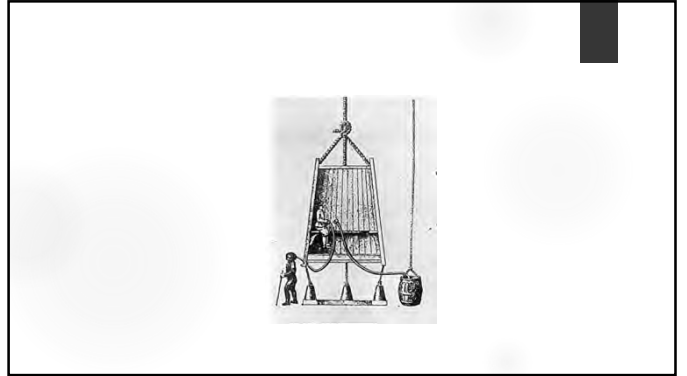
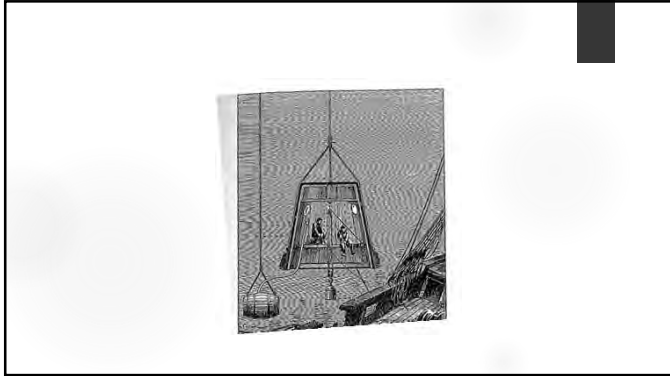
Canon Recovery Mid-1600's



Probably First Diving Bell Mid-1600's



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Diving as a Profession

- ▶ Salvage Operations
 - ▶ From as early as 9th century BC
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Diving Bell-1664



- ▼ The Vasa, a Swedish ship sunk within a mile of her maiden voyage in 1628.
- ▼ In 1658, Hans Albrecht von Treileben went to Stockholm and presented his knowledge of using a diving bell. But not until late 1663, did he obtain salvage rights.

Klingert's Diving Suit -1797



- ▶ This equipment is the first to be called "diving suit". It consists of a jacket and trousers made of waterproof leather, a helmet with a porthole, and a metal front. It is linked to a turret with an air reservoir.

Triton-1808



- ▶ Freiderich von Drieberg designed an apparatus that was worn on the diver's back and was surface-supplied with compressed air. This device, called "Triton", was of no practical use but it gave the idea of compressed air being applied in diving

"Aqua Lung" - Self Contained Underwater Breathing Apparatus- 1943



- ▼ Jacques-Ives Cousteau and Emile Gagnan invented their "Aqualung" and revolutionized underwater exploration. They designed a self-contained underwater breathing apparatus (SCUBA) with two or three cylinders with compressed air.

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The Grecian Bend

The Grecian Bend was a dance move introduced to polite society in America just before the American Civil War

The "Bend" was considered very daring at the time



Discovery of the Atmosphere

- ▶ First written record of air as a quality was in 16th century BC Egyptian Ebers papyri
- ▶ Distinction made between



Discovery of the Atmosphere

- ▶ Homeric Greeks thought air was the conveyor of life
 - ▶ Want of good air was called asma
 - ▶ Bad air called miasma



Discovery of the Atmosphere

- Thales of Miletus (7th century BC) observed water evaporated into air.
 - Thought all life must be



Discovery of the Atmosphere

- ▶ Anaximander (7th Century BC) called it to apeiron or substance which made up everything



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Discovery of the Atmosphere

- Leucippus and Democritus (5th century BC) developed the to *apeiron* into the atomic theory
 - All things made up of indivisible units or atoms



Discovery of Atmosphere

- Aristotle disagreed and supported Empedocles of Sicily (5th century BC) who divided all substances into fire, water, earth, and air.



Discovery of Atmosphere

- Hippocrates developed this into the four humors
 - Yellow bile, black bile, phlegm, and blood
 - Ruled medicine for the next 1000 yrs
 - Opposing forces, which determined health and illness overlook atomic theory



Discovery of Atmosphere

- ▶ Newton re-established the atomic concept



Discovery of Atmosphere

- Development of a vacuum was critical to understanding atmosphere
- The concept of "vacuum" was first proposed by the Greek, Democritus who thought an empty space must exist between atoms, which made up all things
- Aristotle disagreed, thought light would not pass through such a void and this idea, the *horror vacui*, i.e. "Nature abhors a vacuum", lasted for 1000 years.

Discovery of Atmosphere

- ▶ True mechanical vacuums were created by pumps invented by Otto von Guericke in 1646-1647



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Discovery of Atmosphere

- ▶ Magdeburg Hemispheres of von Guericke



Discovery of Atmosphere

- ▶ Robert Boyle and Robert Hooke collaborated on further development of the air pump and vacuum
- ▶ Boyle identified the pressure of an air chamber was exactly inversely proportional to the volume of air added or removed from the chamber (held at constant temperature).
- ▶ $P \times V = k$ or $P_1V_1 = P_2V_2$



Discovery of Atmosphere

- ▶ Robert Hooke exposed himself to a vacuum in 1621. He developed ear pain and noted a candle went out in the vacuum



Discovery of Atmosphere

- Gasparo Berti (1600-1643) developed an experiment where he put bell inside a flask
 - Flask attached to a 40 ft pipe and tube
 - Flask was opened and water flowed down the tube until it was about 8 feet below the bell or about 32 feet high



Discovery of Atmosphere

- ▶ Torricelli used mercury and this rose only about 3 feet
- ▶ He grasped the idea the weight of the atmosphere was pressing down on the mercury
 - ▶ The same as 32 ft column of water



Discovery of Atmosphere

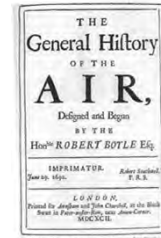
- ▶ Pascal (Torricelli's student) demonstrated effect of weights of air by using a barometer in church steeples and mountains in Auvergne France



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Discovery of Atmosphere

- Boyle first noted that removing an organism from it's normal atmosphere could be deadly
- In 1661 Boyle noted gas bubbles forming in the eye of a viper he exposed to a vacuum
- Credited as the first description of decompression sickness



Discovery of Atmosphere

- Combustion was an area of great interest
- Philosophers developed the idea that all burnable things contained the substance phlogiston which did the burning

Discovery of Atmosphere

- ▶ In August 1774, Joseph Priestley used a magnifying glass to concentrate the sun's rays on a flask of the red oxide of mercury.
- ▶ A gas was evolved burning 5 times the intensity of ordinary air
- ▶ He stated " this species of air may not improperly be called dephlogisticated air"
- ▶ What he actually "discovered" was of course, oxygen



Discovery of the Atmosphere



- ▶ Lavoisier in 1777, named the gas Priestley's discovered - oxygen, from the Greek *oxus* (*acid*) and *gennao* (*to beget*).
- ▶ He thought the gas expelled from the mercuric oxide was an acid.
- ▶ Also naming oxygen would avoid the word "air" as he believed oxygen could not be regular air

Discovery of Atmosphere

- ▶ Lavoisier, his wife Marie, and colleagues were able calculate the first values for oxygen consumption in experiments in bell chambers in 1780.
- ▶ Sadly, this was the end of the phlogiston theory

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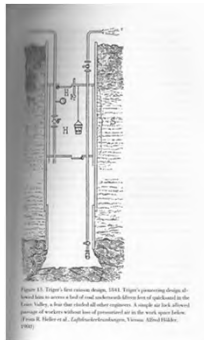
Discovery of Atmosphere

- ▶ William Henry (1744-1836) recognized he could dissolve more gas in a solution if he increased the pressure on the liquid.
- ▶ Concentration = Pressure x gas solubility = Henry's law



Triger's Caisson

- ▶ In 1830's James Watt developed the steam engine capable of developing pressures of 30 psi (g)
- ▶ Allowed water to be pumped out of mines to a pressure equivalent of 3 ATA. There is one atm increase in pressure for each 33 fsw
- ▶ In 1841 Charles-Jean Triger developed an iron shaft or caisson for mining
- ▶ Through a series of inlet and outlet valves and air locks, he was able to pressurize the caisson to about 3ATA
- ▶ His first caisson was used at a depth of about 62 feet (19 meters)



Triger's Caisson

- ▶ Worker shifts were 7-10 hours at 3 ATA
- ▶ USN no-decompression limit at 62 feet is 50 minutes
- ▶ Triger reported that 2 workers became ill with severe arm and leg pains about 30 minutes after exiting the pressurized caisson
- ▶ Many reported breathlessness after exiting
- ▶ He called this *mal de caisson*
- ▶ He hired two physicians B Pol and CJJ Watelle

Triger's Caisson

- ▶ Pol and Watelle did very meticulous research on the ill workers
- ▶ First to realize the illness occurred only after the workers left the caisson and loss of compressed air caused some effect on the body
 - ▶ Pol himself developed severe DCS
- ▶ Concluded "the harmful effects of decompression were directly related to their rapidity of the decompression itself"
- ▶ They realized the quickest and safest means of restoration was immediate return to the compressed air

The St Louis (Eads) Bridge

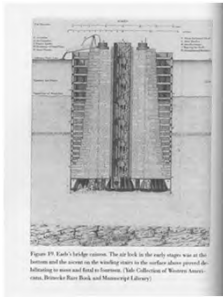
- ▶ Bridge designed to cross the Mississippi in St Louis
- ▶ There was no exposed bedrock so Eads designed a bridge that would have to penetrate river depth of at least 100 feet to hit bedrock
- ▶ Construction began in 1868



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St Louis Bridge

- ▶ Caisson required



St Louis Bridge

- ▶ On Feb 28, 1869 the caisson hit bedrock at 93.5 feet
- ▶ Pressure almost 4 ATA with shifts more than 2 hours
- ▶ Decompressing workers in 3 ½ minutes
 - ▶ USN decompression schedule > 4 hours
- ▶ First fatality on March 19th
- ▶ Six fatalities in 10 days
- ▶ He hired his personal physician Alphonse Jaminet
- ▶ Jaminet's important contribution was to add elevator so men didn't have to walk up stairs
- ▶ Similar events occurred during building of the Brooklyn Bridge

Paul Bert

- ▶ French physiologist 1833-1886
- ▶ He recognized that a practice of fisherman in the Mediterranean practiced piercing the swim bladders of fish caught very deep
- ▶ Prevented rupture of other visceral organs and prevented spoilage
- ▶ He was able to deduce that fish, like humans were normally confined to a particular ambient pressure and expansion of gas was the mechanism of injury
- ▶ He identified nitrogen bubble formation as the cause of decompression sickness
- ▶ Boyle's furiously tortured viper occurred nearly 200 years earlier

Staged Decompression John Scott Haldane(1860-1936)

- ▶ Scottish physiologist first became interested in gas physiology as a schoolboy
 - ▶ He reported effects of non-circulating air in in rooms of his first boarding school in 1879
- ▶ He then became interested in and was tasked to investigate accidents involving carbon monoxide in coal miners
- ▶ He developed an assay that allowed him to demonstrate how CO and oxygen bind to hemoglobin
- ▶ He took advantage of the reversible equation describing displacement of covalently bound CO to hemoglobin by oxygen
- ▶ Treated first CO poisoning by pure oxygen in 1919

Staged Decompression John Scott Haldane(1860-1936)

- ▶ Haldane and his colleague Guybon Damant a Royal Navy diver performed hundreds of experiments on decompression
- ▶ Two critical concepts
 - ▶ Identified the concept of tissue saturation
 - ▶ The longer a tissue was allowed to saturate the longer it to desaturate
- ▶ Developed the concept of tissue half-times
- ▶ Developed staging decompression
 - ▶ First mathematical models of decompression
 - ▶ Concept that you can reduce pressure by about ½ and not develop decompression sickness
- ▶ Experience shows not exactly true but decompression tables in use today are still based on Haldane and Damant's original work

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THE PREVENTION OF COMPRESSED-AIR ILLNESS.

By A. E. BOYCEUT, D.M.,
G. C. DAMANT,
Lieut. and Surgeon of Royal N. F.,
and J. S. HALDANE, M.D., F.R.S.
(From the State Institute of Preventive Medicine.)
(With 3 Figures and 3 Plans.)

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Sinking of USS Squalus

- ▶ On May 23rd Squalus left home to test point 13 SE of Portsmouth NH
- ▶ Commanded by Lt (jg) Oliver Nanquin
- ▶ Test ability to dive while at running speed in 60 second or less
- ▶ Lights indicated all hull openings were closed
- ▶ False indication and soon 4/7 compartments filled with water, sinking to seabed at 240 feet
- ▶ 26 drowned immediately

Sinking of USS Squalus

- ▶ Swede Momsen and Momsen Lung
- ▶ The Momsen Lung was an oblong rubber bag that recycled exhaled air. The lung contained a canister of soda lime, which removed poisonous carbon dioxide from exhaled air and then replenished the air with oxygen. Two tubes led from the bag to a mouthpiece: one to inhale oxygen and the other to exhale carbon dioxide



Sinking of USS Squalus

- ▶ Swede Momsen was finishing a 10 year series of tests using a breathing gas mixture including helium when the Squalus went down.
- ▶ He also had devised a diving bell that could couple with a submarine to remove submariners from a stricken submarine



Sinking of USS Squalus

- ▶ Swede Momsen was called to use the Momsen Bell in an attempt to rescue the submariners
- ▶ Squalus was found and known that survivors were on board
- ▶ His first call was to Navy physicians Albert Behnke, who had been working with him on decompression procedures using helium mixed gas diving and Charles Shilling, senior medical officer

Sinking of USS Squalus

- ▶ Sub was located
- ▶ US Navy Boatswain's mate Matrin Sibitsky was lowered and able to attach a cable to the Squalus hatch
- ▶ 22 minute dive with 40 minutes of decompression
- ▶ First dive using helium
- ▶ 33 survivors were saved by the Momsen Bell
- ▶ Only known successful rescue of submariners from a sunken sub
- ▶ Momsen lung was used in October 1944, when eight submariners used it to reach the surface after Tang sank in 180 feet (55 m) of water in the East China Sea

Squalus survivor and Momsen Bell



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Donnell and Norton

- ▶ Alonzo Donnell, Maj, USAF, and Perry Norton Lt, USNR were first physicians to treat an aviator with decompression sickness in a hyperbaric chamber
- ▶ Case report in 1960
- ▶ Pt was a 6000 hr + pilot
- ▶ Altitude chamber exposure to FL430
- ▶ Immediately post flight, subject had difficulty using left hand
- ▶ Placed on 100% oxygen
- ▶ Rapid progression of severe weakness, dizziness and nausea

Donnell and Norton

- ▶ Transported to Langley AFB to Little Creek. Va five hours after initial presentation
- ▶ BP less than 90 mmHg
- ▶ Left hemiplegia
- ▶ Blindness
- ▶ Disoriented to person, time, and place
- ▶ Recompressed to 165 fsw with improvement at 14 minutes
- ▶ 38 hour treatment time
- ▶ Full recovery except on careful neuro testing had mild difficulty in dealing with symbolic abstractions
- ▶ Adler in 1943 reported 150 cases of DCS with seven deaths in one million exposures



Questions?

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