MATH AND SCIENCE @ WORK

AP* BIOLOGY Student Edition

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PREVENTING DECOMPRESSION SICKNESS ON SPACEWALKS

Background

Neutral buoyancy is the term used to describe an object that has an equal tendency to float as it does to sink. In water, items can be made neutrally buoyant using a combination of weights and flotation devices. In such a state, even a heavy object can be easily manipulated.

Because of the similarities to microgravity (weightlessness), NASA uses neutral buoyancy to help astronauts train for spacewalks. NASA's training facility is the Neutral Buoyancy Laboratory (NBL) located inside the NASA Sonny Carter Training Facility in Houston, Texas. The NBL is a pool large enough to hold full-sized mockups of the International Space Station (ISS), and flight payloads (like the Hubble telescope). The dimensions of the pool are 62 m (202 ft) long, 31 m (102 ft) wide, and 12 m (40 ft) deep, allowing two different training activities to be performed at either end of the pool simultaneously. For astronauts, the facility provides important pre-flight training in becoming familiar with planned crew activities and with the dynamics of body motion under weightless conditions.

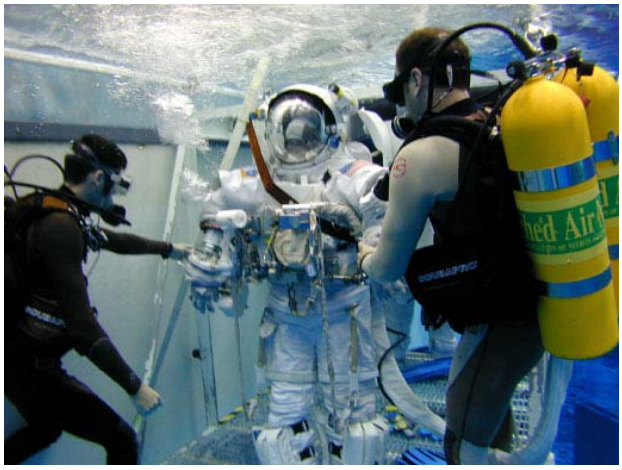

Figure 1: Astronaut Barbara Morgan participating in an underwater simulation of extravehicular activity (EVA) with diver assistance at the NBL

Figure 2: Hyperbaric chamber located at the NBL used to treat diving-related decompression illness

Astronauts wear pressurized Extravehicular Mobility Unit (EMU) suits, weighing approximately 280 lbs (127 kg), while training in the NBL. They are assisted by at least four professional SCUBA divers wearing regulation SCUBA gear. For every hour the astronaut plans to spend on a spacewalk, the team will spend seven hours training in the water. On a training day at the NBL, astronauts normally spend up to six consecutive hours in the pool. For safety reasons, the SCUBA divers are limited to five hours of dive time per day and this time is broken into at least two different dives. A fully staffed and equipped medical team is on site to provide emergency medical treatment and to monitor the health of

astronauts and divers participating in NBL operations.

One medical condition that can occur while training in the NBL is decompression sickness (DCS). DCS is the result of inadequate decompression following exposure to increased pressure. During a dive, body tissues absorb nitrogen in proportion to the surrounding pressure. As long as the diver remains at pressure, the dissolved nitrogen in tissues and blood presents no problem. If the pressure is reduced too quickly, however, the nitrogen comes out of solution and forms bubbles in the tissues and bloodstream. For divers, DCS is a condition that could occur at the end of a dive when ascending to the surface. To avoid DCS, divers do not ascend too quickly and are required to take decompression stops after long and/or deep dives. A hyperbaric chamber is available at the NBL for the immediate treatment of a diving-related DCS.

Astronauts must also take precautions to avoid DCS that could occur when going on spacewalks. The pressurized spacesuits astronauts wear on spacewalks is significantly lower than the ambient pressure of the International Space Station (ISS). For this reason, astronauts go through a denitrogenation process prior to all spacewalks.

Problem

AP Biology Lab 12 allows students to investigate and evaluate the physical and biological factors that affect the solubility of dissolved oxygen and subsequent effects on aquatic ecosystems of Earth. The concentration of dissolved oxygen in an aquatic environment is an important indicator of the environment's water quality. Some organisms, such as salmon, require high concentrations of dissolved oxygen. Other organisms, like catfish, can survive in environments with lower concentrations of dissolved oxygen.

A. Aquatic and terrestrial vertebrates both depend on gas exchange mechanisms for the absorption of dissolved oxygen and release of carbon dioxide.

   I. Compare and contrast the respiratory systems of a fish and a mammal.

   II. Explain how each is adapted to make efficient use of oxygen in its environment.

III. Discuss two factors that would affect dissolved oxygen availability in aquatic environments.

At the Neutral Buoyancy Laboratory (NBL), astronauts breathe a special mixture of 46% oxygen and 54% nitrogen, known as “nitrox”. The increased oxygen level allows the crewmembers and divers to stay under water for long periods of time with a reduced risk of developing decompression sickness (DCS). DCS is most commonly associated with deep sea divers who ascend too quickly from a dive, or do not carry out the required decompression stops after a long and/or deep dive.

B. Data collected from a deep sea dive is shown in Table 1.

Table 1: Data from a Deep Sea Dive (Breathing 21% O_2, 78% N_2, 1% Trace Gases)

Depth (meters)	**Amount of Dissolved N_2 in Lean Tissue (ml $_{STPD}$)**	**Atmospheric Pressure (kPa)**	**N_2 Partial Pressure (kPa)**
0	510	101	79.8
10	1021	202	159.6
20	1532	303	239.4
30	2043	404	319.2

I. Using the data in Table 1, identify and discuss the factor(s) that affect nitrogen solubility in human tissues.

II. Explain what will happen to the nitrogen in a diver's body as he ends the dive and returns to the surface.

Currently, astronauts wear pressurized spacesuits in order to work in space environments. The pressure of these suits (29.65 kPa) is significantly lower than the ambient pressure of the International Space Station (101.3 kPa). Therefore, astronauts must go through a denitrogenation process prior to all spacewalks. The denitrogenation process, called an "oxygen prebreathe", will decrease nitrogen partial pressure in lean tissue and blood before depressurization to avoid subsequent DCS.

C. DCS is a condition that both astronauts and SCUBA divers must take precautions to avoid.

Table 2: Prebreathe Conditions for the ISS "Campout" Decompression Protocol

Prebreathe Protocol Steps	Ambient Pressure (kPa)	Start Time (min)	End Time (min)	Breathing Gas (% of O_2)
1. O_2 mask is put on to start denitrogenation	101.3	0	30	100
2. Decompression from 101.3 to 70.3 kPa	70.3	30	60	100
3. 8 hrs and 40 min living at 70.3 kPa, mostly sleeping in the ISS airlock	70.3	60	580	26.5
4. Recompression from 70.3 to 101.3 kPa	101.3	580	590	100
5. Stay at 101.3 kPa for hygiene break and to collect breakfast	101.3	590	620	100
6. Decompression from 101.3 to 70.3 kPa	70.3	620	650	100
7. Eat breakfast in the airlock, don the spacesuit	70.3	650	710	26.5
8. 50 min of in-suit prebreathe with 100% O_2	70.3	710	760	100

I. Determine when the symptoms of DCS would most likely occur for an astronaut who is scheduled for a spacewalk.

II. Define contributing factors leading to the onset of DCS and evaluate the potential health effects of DCS.

III. Review the data in Table 2 and discuss how the four steps in the “prebreathe” protocol serve as countermeasures for the astronauts against DCS.