



# Decompression Procedures

# Course Introduction

- ✓ Welcome
- ✓ Introductions
- ✓ Prerequisite Review
- ✓ Paperwork
  - Training Record
  - Release
  - Medical History

# Course Overview

- ✓ Course Objectives
- ✓ Lecture & Discussion Topics
  - Part A — Technical Foundations
  - Part B — Decompression Procedures
- ✓ Equipment Counseling Session
- ✓ Equipment Configuration Session
- ✓ Confined Water Skills Development Section
- ✓ Open Water Sessions



# Advanced Nitrox / Technical Foundations

# Course Introduction

- ✓ Welcome
- ✓ Introductions
- ✓ Paperwork
  - Training Record
  - Release
  - Medical History

# Course Overview

## ✓ Course Objectives

- Extended Range (Depth & Time)
- Optimized Nitrox Blends
- Advanced Dive Planning
- EAN50 & Oxygen Procedures
- Enhanced Skills
- Increased Confidence
- Limited Decompression (Foundations)

# Course Overview cont'd

- ✓ Lecture & Discussion Topics
- ✓ Equipment Counseling Session
- ✓ Equipment Configuration Session
- ✓ Water Skills Development
- ✓ Open Water Dives
  - 4 Minimum for Advanced Nitrox
  - 6 Minimum for Technical Foundations

# The Diver at Depth

## ✓ Pressure Terminology

- Atmospheric
- Hydrostatic
- Absolute

## ✓ Partial Pressure

- Henry's Law (Absorption)
- Dalton's Law (Gasses in a Blend)

## ✓ Calculating Partial Pressure

- For EAN50 at 66 fsw (20 m)

$$ppO_2 = FO_2 \times ATA$$

$$ppO_2 = 0.5 \times 3$$

$$ppO_2 = 1.5$$

## ✓ Boyle's Law

- Pressure / Volume Relationships
- Absolute Pressure / Gas Density / Partial Pressure

Boyle's Law						
Depth fsw	Depth msw	ATA	PO <sub>2</sub>	PN <sub>2</sub>	Volume	Density
Surface	Surface	1	.21	.79	1	1x
33 fsw	10 msw	2	.42	1.58	1/2	2x
66 fsw	20 msw	3	.63	2.37	1/3	3x
99 fsw	30 msw	4	.84	3.16	1/4	4x
132 fsw	40 msw	5	1.05	3.95	1/5	5x
165 fsw	50 msw	6	1.26	4.74	1/6	6x

## ✓ Inert Gas Absorption

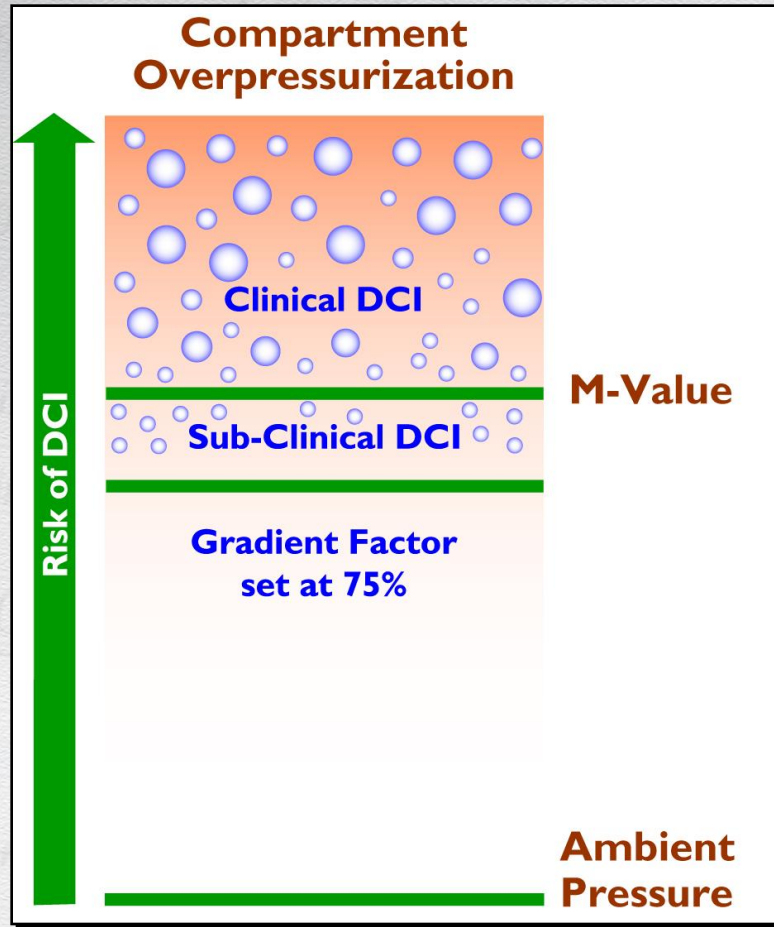
- Inspired Partial Pressure
- Absorption Gradients (Diagram p. 1-7)
- Role of Perfusion
- Gas Solubility in Tissues
- Tissue Saturation

## ✓ Inert Gas Elimination

- Desaturation Gradients
- Controlling the Desaturation Process
- Proper Ascent Rates

- ✓ Inert Gas Elimination (cont'd)
  - Stage Decompression
  
- ✓ The Saturation / Desaturation Model
  - Role of Dive Tables and Computers
  - Mathematical Models
  - Half-time Concept
  - Saturation Model Diagram (p. 1-8)
  - Saturation / Desaturation Times
  - M-value

# M-Value Diagram

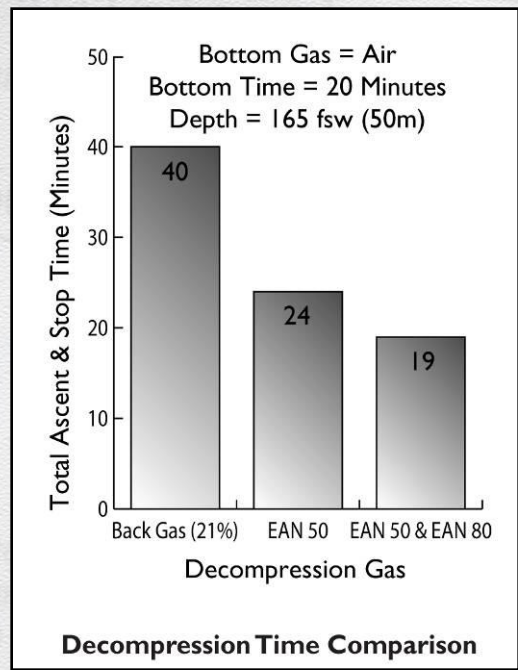


## ✓ The Saturation / Desaturation Model (Cont'd.)

- Managing M-Values on Ascent
- Current Day M-Value Models
- Free-Phase and Seed Bubbles

## ✓ Accelerated Decompression

- Utilizing Decompression Gasses
- Maximizing the Desaturation Gradient



*Utilizing EAN50 can reduce ascent times by nearly 50%*

## ✓ Accelerated Decompression (Cont'd.)

- EAN50 for Simulated Decompression (Advanced Nitrox Course)
- EAN50 for Stage Decompression (Technical Foundations Course)
- MOD = 70 fsw (21m)

## ✓ Deep Stops

- Richard Pyle's Accidental Discovery
- Pyles Emperical Procedure
- Flaws in Early Decompression Models
- Lessons for TechXR Divers

## ✓ Decompression Illness

- The effects of gas bubbles in the blood and/or tissues that may form on ascent
- Inert gas that comes out of solution when critical tensions are exceeded
- Arterial gas embolisms resulting from mechanical lung overexpansion
- DCI risk is minimized by:
  - Controlling ascent rate
  - Making safety stops
  - Completing prescribed decompression schedules

# Signs & Symptoms of DCS

- Tingling or Itchy Skin
- Joint Pain
- Loss of Coordination
- Numbness
- Shortness of Breath
- Visual Distortion
- Chest Pain
- Bloody/Frothy Sputum
- Respiratory Failure
- Blotchy Skin Rash
- Dizziness
- Fatigue or Weakness
- Paralysis
- Coughing Spasms
- Unconsciousness
- Personality Change
- Convulsions

*Refer to Decompression Procedures, pages 2-16 through 2-18 for additional information on DCI.*

## ✓ Oxygen and the Diver

- $ppO_2 = 0.10$  Minimum to sustain life
- $ppO_2 = 0.12$  Unconsciousness likely
- $ppO_2 = 0.16$  Lethargy and reduced mental process
- $ppO_2 = 0.21$  Normal  $ppO_2$  (Normoxic)
- $ppO_2 = 1.10$  Threshold for CNS oxygen toxicity
- $ppO_2 = 1.40$  Recommended maximum for recreational and technical dives (bottom phase)
- $ppO_2 = 1.60$  Substantial risk of CNS oxygen toxicity, maximum  $ppO_2$  for decompression

## ✓ Hypoxic Mixes

## ✓ Normoxic Mixes

## ✓ Hyperoxic Mixes

## ✓ Oxygen Toxicity

- Pulmonary Oxygen Toxicity
- Central Nervous System (CNS) Oxygen Toxicity

C	Convulsion
V	Visual Distortion
E	Ear (Hearing Abnormalities)
N	Nausea
T	Twitching Muscles
I	Irritability
D	Dizziness

## ✓ Establishing ppO<sub>2</sub> Limits

- 1.4 for bottom phase of the dive
- Up to 1.6 max for decompression
  - 70 fsw (21 m) for EAN50
  - 30 fsw (9 m) for EAN80
  - 20 fsw (6 m) for Oxygen

## ✓ Nitrogen Narcosis

- Cause (Diagrams p.1-13)
- Symptoms
  - Slowed performance of mechanical tasks
  - Reduced capacity to think and reason
  - Short term memory loss
  - False sense of well being & concern for safety
  - Inability to focus on tasks

## ✓ Nitrogen Narcosis (Cont'd.)

- Euphoria
- Paranoia
- Divers do not become tolerant, they “adapt”

**Tolerance:** *The capacity to absorb a drug continuously or in large doses without adverse effect; diminution in the response to a drug after prolonged use.*

**Adapted:** *To make suitable to or fit for a specific use or situation.*

- Most divers affected when  $ppN_2 = 3.18$

## ✓ Equivalent Narcosis Depth

- Predicting diver performance
- The END Formula

$$\text{END} = \left[ \frac{\text{FN}_2 \times (\text{Depth} + 33)}{.79} \right] - 33$$

$$\text{END} = \left[ \frac{\text{FN}_2 \times (\text{Depth} + 10)}{.79} \right] - 10$$

Equivalent Narcosis Depth NTx 21/30 (Imperial)	
DEPTH (ft)	END
100	46
110	56
120	62
130	68
140	74
150	81
160	87
170	93
180	99

Equivalent Narcosis Depth NTx 21/30 (Metric)	
DEPTH (m)	END
30	15
33	17
36	18
39	20
42	22
45	24
48	26
51	28
54	30

*Refer to Normoxic Trimix, pages 3-3 through 3-4 for additional information on END.*

## ✓ Hypercapnia & Vasodilation

- Condition that occurs whenever lung ventilation is inadequate and CO<sub>2</sub> levels in the body tissues are abnormally high.
- Symptoms include:
  - Drowsiness
  - Inability to think / concentrate
  - Unconsciousness
  - Convulsion
  - Headaches
- Arteries in brain dilate and may contribute to the onset of CNS Oxygen Toxicity

## ✓ Hypothermia

- Condition where the body experienced excessive heat loss
- Implications for extended range divers

## ✓ Hydration

- One of the *most significant factors* that predispose a diver to DCI
- Drink sufficient fluids so that urine remains clear

## ✓ Patent Foramen Ovale

- Failure of the Foramen Ovale to seal completely
- Blood shunts from venous to arterial circulation
- Divers may experience DCI
- Diagnosed by bubble contrast echocardiography

## ✓ Physical Conditioning

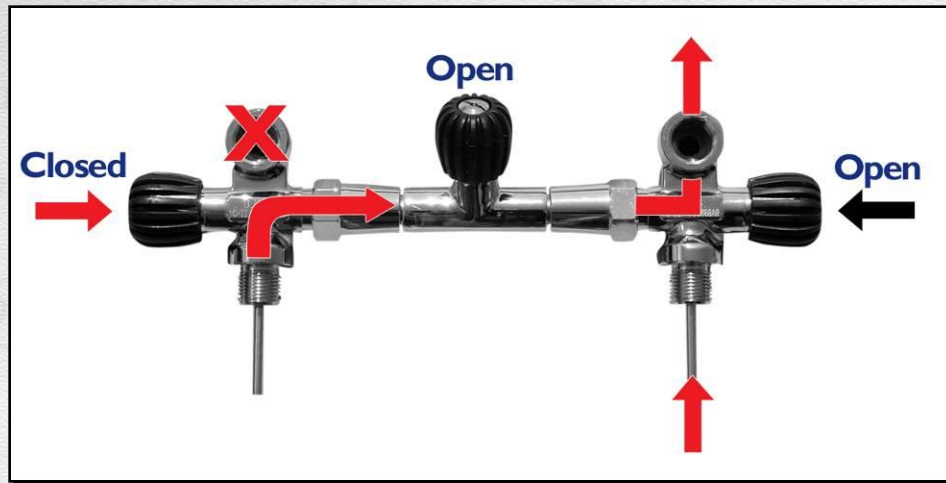
- Aerobic exercise and strength training
- Special concerns
  - smoking
  - medications
  - respiratory ailments
  - physical injuries
  - drug or alcohol abuse

# Equipment for Extended Range Diving

- ✓ **Simplicity**
  - Match equipment to dive objectives
  - Proper fit and streamlining
  - Ease of use
- ✓ **Consistency**
  - Change one element at a time
  - Test equipment before critical dives
  - “Team” considerations
- ✓ **Reliability & Redundancy**
  - Accidents resulting from unfamiliar equipment
  - Importance of maintenance
  - Need for redundancy

- ✓ **Back Gas Cylinders**
  - Match cylinders to dive requirements
  - Steel vs. Aluminum
- ✓ **Single Cylinder Configurations**
  - Simplicity
  - Redundancy (H-valve or “pony bottle”)
  - Sizes
- ✓ **H-valves (or Y-valves)**
  - Features and function
  - Gas flow during isolation
- ✓ **Pony Bottles**
  - Configuration
  - Contents and use
  - Methods of mounting and rigging

- ✓ **Doubles or Twinsets**
  - Manifolds vs. “independent doubles”
  - Weight & buoyancy characteristics
  - Special precautions
- ✓ **Manifolds**
  - Isolation vs. non-isolation designs



- Dive termination upon isolation

- ✓ **Stage Cylinders**
  - Use
  - Selection criteria
  - Popular sizes and materials
- ✓ **Rigging Stage Cylinders**
  - Selecting hardware
  - Positioning
- ✓ **Nitrox and Oxygen Service Ratings**
  - Responsibilities of cylinder ownership
  - “Oxygen Clean” and “Oxygen Service”
  - Government regulations
  - Manufacturer specifications

## ✓ Cylinder Identification

- Back gas labels
- Deco gas labels
- “O<sub>2</sub> Clean” / “O<sub>2</sub> Service”
- Visual Inspection Stickers

## ✓ Regulators for Deep Diving

- The regulator as “life support” equipment
- Selection criteria
- WOB diagrams (p. 1-22)
- Design features
- Warranty and service programs

## ✓ Regulators for Decompression

- Selection criteria

- ✓ **Regulators for Decompression (cont'd)**
  - Use with high oxygen percentages
  - Maintaining O<sub>2</sub> Clean Rating
- ✓ **Full Face Masks**
  - Applications
  - Features
  - Training
- ✓ **Backplates & Harnesses**
  - Construction materials
  - Design
  - Accessories
- ✓ **Wings**
  - Design
  - Capacity
  - Redundancy

- ✓ “Tech-reational” BC’s
  - Dual purpose design
  - Features
- ✓ Submersible Pressure Gauge
  - For back gas cylinders
  - For stage cylinders or “pony bottles”
- ✓ Digital Gauges and Computers
  - Information displayed
  - Depth Gauge / Timers
  - Computers in “gauge mode”
  - Ascent rate indicator required
  - Multi-gas computers
- ✓ Compasses
  - Features
  - Uses

## ✓ Exposure Suits

- Importance of thermo-regulation
- Wetsuits
- Dry suits
- Managing buoyancy on ascent

## ✓ Weight systems

- Integral system weight vs. added weight
- Options
- Hazards and risks of releasing weight with a decompression obligation

## ✓ Cutting Devices

- Primary and redundant
- Designs and applications

- ✓ **Reels**
  - Applications
  - Designs and Capacities
- ✓ **Surface Marking Bag (SMB)**
  - Applications
  - Designs
  - Diver Identification
- ✓ **Jon Lines**
  - Applications
  - Designs
- ✓ **Lights**
  - Primary light designs
  - Back-up lights
  - Burn times

# Equipment Configuration

1. *Discussion:* Adaptability
2. *Discussion:* Configuration Options
3. *Discussion:* Specific Recommendations or Team Requirements
4. *Schedule:* Individual Equipment Counseling Session
5. *Schedule:* Equipment Configuration / Assembly Session

# Dive Planning

- ✓ **General Considerations**
  - Need for careful attention to detail
  - Primary and Contingency Plans
  - Plan your dive then dive your plan
  
- ✓ **The Extended Range Dive Day**
  - Limit the number of dives per day
  - Extend the duration of surface intervals
  - Multi-day Extended Range diving
  
- ✓ **Establishing Dive Objectives**
  - Assessment
  - Organization and simplification

- ✓ **Deciding What to Breathe**
  - Consider depth, conditions, and objectives
  - Nitrox use to extend time and avoid decompression
- ✓ **Calculating the Optimized Nitrox Blend**
  - Establish limiting  $ppO_2$
  - Formula to determine Max  $O_2$
  - Example calculation
  - TechXR Reference Slate
- ✓ **Calculating Maximum Operating Depths (MOD)**
  - Establish limiting  $ppO_2$
  - Formula to determine MOD
  - Example calculation
  - MOD Calculations Worksheet (Appendix)

- ✓ **Managing Inert Gas Absorption**
  - Dive Planning Software
  - DPS operating procedures
  - “User Profile” or preferences
  - Setting “Risk Management Factors”
  - The TechXR Dive Plan slate
  - Dive Plan Example 1 Worksheet (Appendix p. A-2)
  - Terminology: Run Time and Stop Time
  - Dive Plan Example Worksheets 2 - 4 (Appendix p. A-3)
  
- ✓ **Safety Stops and the Extended Range Diver**
  - Traditional safety stops
  - Deeper safety stops
  - The “+5 Rule”
  - Table vs DPS generated profile comparison

- ✓ **Making Repetitive Dives Using DPS Programs**
  - Planning a sequence of dives
  - Entering Surface Interval Time
  - Dive Plan Example Worksheets 5 - 6  
(Appendix p. A-6 & A-7)
  
- ✓ **Managing Exposure to Oxygen**
  - Establishing ppO<sub>2</sub> limits
  - NOAA Limits (TechXR Reference Slate)
  - TechXR CNS Exposure Tracking Chart
  - CNS Exposure Example Worksheets 1 - 2  
(Appendix p. A-8 & A-9)
  - Recommendations for Single Dive Limits,  
Daily Limits and Minimum SIT

## ✓ Beyond the NDL

- Contingency Plan requiring stage Decompression for emergency use only. Primary Plan must fall within the
- NDL limits of the SSI Combined Air / EANx Dive Tables (Advanced Nitrox Course)
- Dive Plan Example Worksheets 7 - 8 (Appendix p. A-10 & A-11)

## ✓ Improving Off-gas Efficiency

- Using high FO<sub>2</sub> gas on ascent
- Gas switching at the safety stop
- Observing the MOD
- Safety stops planned using back gas

## ✓ Managing Your Gas Supply

- Rule of 1/3's for Extended Range dives
- SAC Rates and Work Factors

- ✓ **Managing Your Gas Supply (cont'd)**
  - TechXR Gas Planning Chart
  - TechXR Gas Planning Example Worksheets 1-2  
(Appendix p. A-12 & A-13)
  
- ✓ **Gas Planning with Stage Cylinders**
  - Planning the requirements for back gas plus a stage cylinder
  - TechXR Gas Planning Example Worksheets 3 - 4  
(Appendix p. A-14 & A-15)
  
- ✓ **Calculating Your SAC Rate(s)**
  - Measure consumption during a timed swim at a constant depth
  - The SAC Rate Formula, TechXR Reference Slate
  - TechXR SAC Rate Example Worksheet  
(Appendix p. A-17)

- ✓ Turn Time, Turn Pressure and Ascent Pressure
  - Turning the dive based on time
  - Calculating turn pressure
  - Calculating ascent pressure
  - TechXR Turn Time,/Turn Pressure/Ascent Pressure Worksheet Appendix page A-16)

# Diving Procedures

- ✓ **The Dive Team**
  - Team Members
  - Responsibilities
- ✓ **Dive Briefings**
  - Personnel to include
  - Information to communicate
  - “Dirt Dives” or dry rehearsals
  - Completing the TechXR Dive Plan Slate
- ✓ **Making Entries and Exits**
  - Types of entries
  - Special concerns for entries
  - Types of exits
  - Special concerns for exits

- ✓ **S-drills**
  - Pre-entry checks
  - In-water checks
  
- ✓ **Descents**
  - “Modified free-fall”
  - Descending on lines
  - Maintaining “near neutral” buoyancy
  
- ✓ **Propulsion Techniques**
  - Energy conservation
  - Avoid substrate contact / anti-silting
  - Modified flutter kick
  - Frog and “modified frog” kicks
  - Pull and glide technique

- ✓ **Ascents**
  - Maintaining the proper ascent rate
  - Importance of buoyancy control
  - Monitoring the ascent rate indicator
  
- ✓ **SMB Deployment**
  - When to deploy
  - Controlling buoyancy
  - Managing the reel and SMB
  - Prepare for entanglement emergency
  
- ✓ **Surface Procedures**
  - Rest following Extended Range Dives
  - Effect of exercise on doppler bubble “scores”

## ✓ Emergency Procedures

- Gas Loss
- Total Gas Loss
- Decompression Gas Loss
- Loss of Buoyancy
- Power Inflator Malfunction
- Lost Team Member(s)
- Primary Light Malfunction
- SMB Reel Jam
- Missed Decompression Stop
- Blow-up Ascent
- Immediate Assistance Required

- ✓ **Decompression Illness Watch**
  - Recognition
  - Importance of oxygen first aid and early treatment
- ✓ **Accident Management Plan**
  - Preparing the team with First Aid, CPR & Oxygen Administration training
  - Having emergency equipment and supplies on hand
  - Preparing a written emergency management Plan\

## QUESTIONS

## SUMMARY

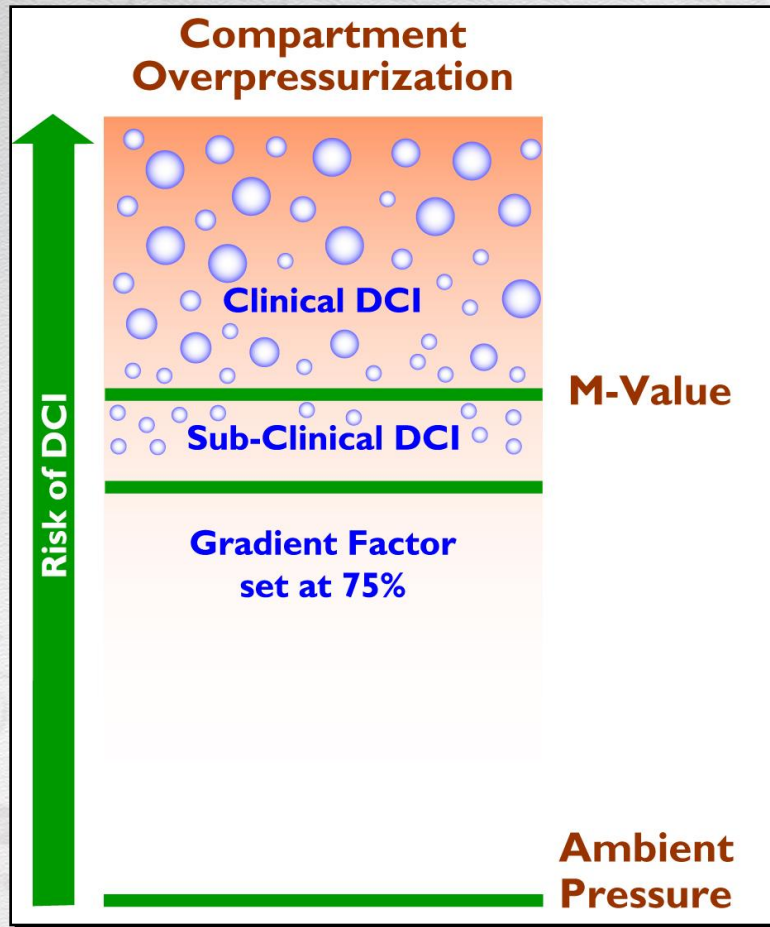


# Decompression Procedures

# Decompression Theory

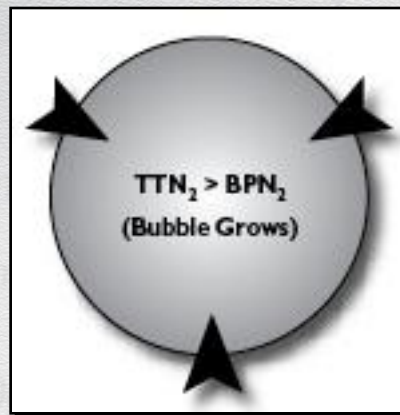
- ✓ **The Origin of M-values**
  - Haldane experiments
  - Supersaturation ratio
  - Experiments at NEDU
  - Workman proposes M-value concept
- ✓ **Evolution of M-value models**
  - Bühlman ZH-L16
  - Concept of “leading” compartment
- ✓ **Free Phase Mechanics**
  - Definition of “free phase”
  - “Bubble seeds”

# M-Value Model



## ✓ Free Phase Mechanics

- Definition of “free phase”
- “Bubble seeds”
- Bubble dynamics
- Bubble growth



## ✓ Bubble Models

- Concept understood by Haldane
- Staging deeper (Pyle revisited)
- Brian Hill's thermodynamic model
- Yount & Hoffman propose VPM model
- Wienke develops the RGBM

## ✓ Model Conflict

- Overpressurization Model
- Gradient factors
- Adjusting DPS programs

- ✓ **Planning a Decompression Dive**
  - Calculating the profile with EAN50 as the decompression gas
  - Decompression Plan Worksheet 1 (Appendix page A-18)
- ✓ **Real World vs. Desktop Ascents**
  - Impact of variable ascent rate
  - Ascending ahead of plan to arrive at stop on time
- ✓ **Making Stops Below the Deco Gas MOD**
  - Making deep stops on back gas
  - Decompression Plan Worksheet 2 (Appendix page A-19)

- ✓ **Multi-level Decompression Dives**
  - Inputting multi-level data
  - “Floor” and “ceiling” depths
  - Decompression Plan Worksheet 3 (Appendix page A-20)
- ✓ **Managing CNS Exposure on Multi-level Dives**
  - Entering data on the planning chart
  - Multi-level CNS Plan Worksheet (Appendix page A-21)

# Gas Planning for Decompression Dives

- ✓ **Preparing a Primary Gas Plan**
  - Planning for self sufficiency
  - Contingency gas planning
  - Decompression Gas Plan Worksheet 1  
(Appendix p. A-22)
- ✓ **Preparing a Back Gas Plan**
  - Generating the back gas profile
  - Decompression Gas Plan Worksheet 2  
(Appendix p. A-23)
- ✓ **Turn and Ascent Pressures**
  - Calculating
  - Back gas decompression requirements

# Decompression Procedures

- ✓ **Ascending With a Decompression Obligation**
  - Negotiating a series of “ceilings”
  - On-time gas switches
  - Switching at the deco gas MOD
  - Making an efficient stop
- ✓ **Communicating Decompression Status**
  - Signaling time and time remaining
  - Signaling stop depths
  - Signaling gas switches
- ✓ **The Role of Support Divers**
  - Avoiding decompression status
  - Topside communications
  - Monitoring bottom diver status
  - Retrieving extra gas/supplies

- ✓ **Advanced Dive Planning**
  - Preparing a DiveLine
  - DiveLine Worksheet (Appendix)
  
- ✓ **Responding to a DCI Emergency**
  - Preparation & problem recognition
  - Type I DCS
  - Type II DCS
  - Barotrauma
  
- ✓ **Signs & Symptoms of DCI**
  - Musculoskeletal
  - Cardio-respiratory
  - Skin
  - Gastrointestinal
  - Neurological

## ✓ First Aid for DCI

- Secure the area or move victim to a safe zone where first aid can be administered
- If, unconscious, place the diver in the lateral recumbent (recovery) position, left side down. (Backboard may be used to maintain a head down (30°) position)
- Ensure that airway is open
- Administer 100% oxygen
- Perform CPR if required
- Conduct the Rapid (Field) Neurological exam
- Activate the EMS system and follow instructions
- Protect against hypothermia
- Encourage diver to rest, remain calm, and be still
- Protect diver from excessive heat
- Provide fluids for re-hydration

- Do not leave victim alone, monitor changes, and notify EMS if condition worsens
  - Avoid perceptual narrowing when caring for an accident victim. Be aware of conditions that may affect safety or the quality of care
  - Continue to monitor other team members
  - Transport the victim to a medical care facility as directed
- ✓ **In-Water Recompression**
- Emergency field method for treatment of DCI
  - Controversial procedure requiring O<sub>2</sub> administration at 30 fsw (9m) for long periods
  - Requires specialized equipment and advanced preparation
  - May require an attending physician

- ✓ **Minimum SIT Between Dives**
  - Consult DPS program instruction manual
  - A minimum SIT of four hours is recommended following a decompression dive
- ✓ **Flying After Decompression**
  - Observe a minimum pre-flight surface interval of 24 hours

## QUESTIONS SUMMARY



# Advanced Decompression Procedures

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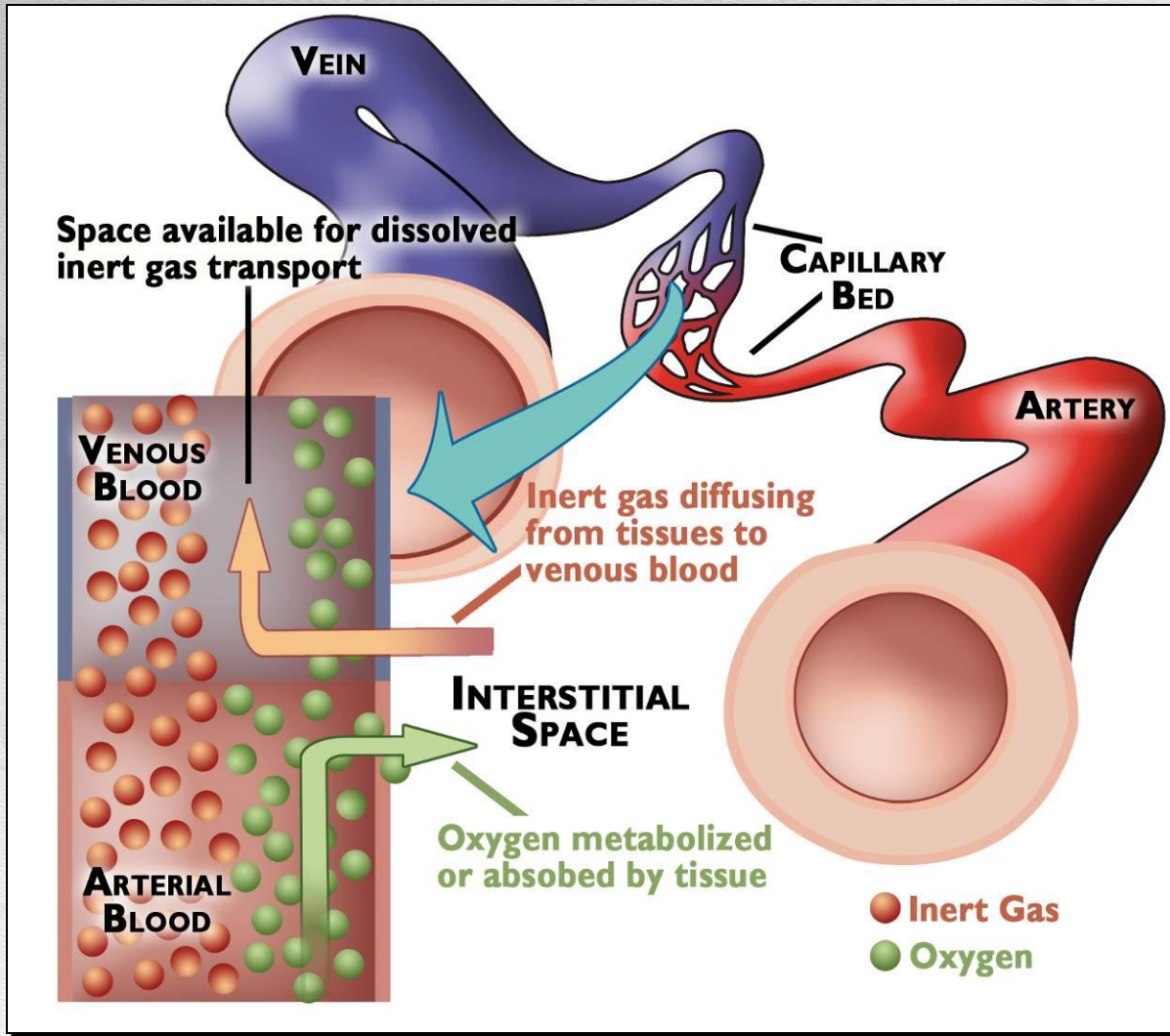
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# Decompressing with Oxygen

- ✓ The “oxygen window”
  - Increasing arterial ppO<sub>2</sub>
  - Capacity of venous blood to transport dissolved inert gas



- ✓ **EAN80 vs. Oxygen**
  - Oxygen provides maximum off-gas efficiency
  - O<sub>2</sub> range of application
  - O<sub>2</sub> advantage in heavy seas
  - O<sub>2</sub> vs. EAN80 stop time comparison
  - EAN80 switch at 30 fsw (9m)
  
- ✓ **Strategies for Advanced CNS Toxicity Management**
  - “Air Breaks”
  - Reducing times, depths, and/or deco gas FO<sub>2</sub>
  
- ✓ **Pulmonary Oxygen Toxicity**
  - Definition
  - Unit of measurement
  - Calculating
  - Implications for Normoxic Trimix divers

# Dive Planning With Multiple Decompression Gasses

- ✓ **Planning with EAN50 and oxygen**
  - Data entry and profile interpretation
  - Advanced Deco Plan Example 1 Worksheet (Appendix page A-28)
  
- ✓ **Planning with EAN50 and EAN80**
  - Data entry and profile interpretation
  - Advanced Deco Plan Example 2 Worksheet (Appendix page A-29)

- ✓ **Tracking CNS Exposure with Multiple Decompression Gasses**
  - Entering data on the CNS Exposure Tracking Chart
  - Advanced CNS Planning Example 2 Worksheet (Appendix page A-30)
  
- ✓ **Gas Planning with Multiple Decompression Gasses**
  - All deco cylinders lost
  - EAN 50 lost
  - EAN80 of oxygen lost

# Two Deco Gas Procedures

- ✓ Rigging and Carrying the Second Stage Cylinder
  - Rich Right
  - Methods for identification by feel
- ✓ Making the Switch
  - Valving on EAN50 at the MOD
  - Valving on EAN80 or O2 as you leave prior stop
  - Switch gasses immediately upon arrival at stop

## QUESTIONS

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