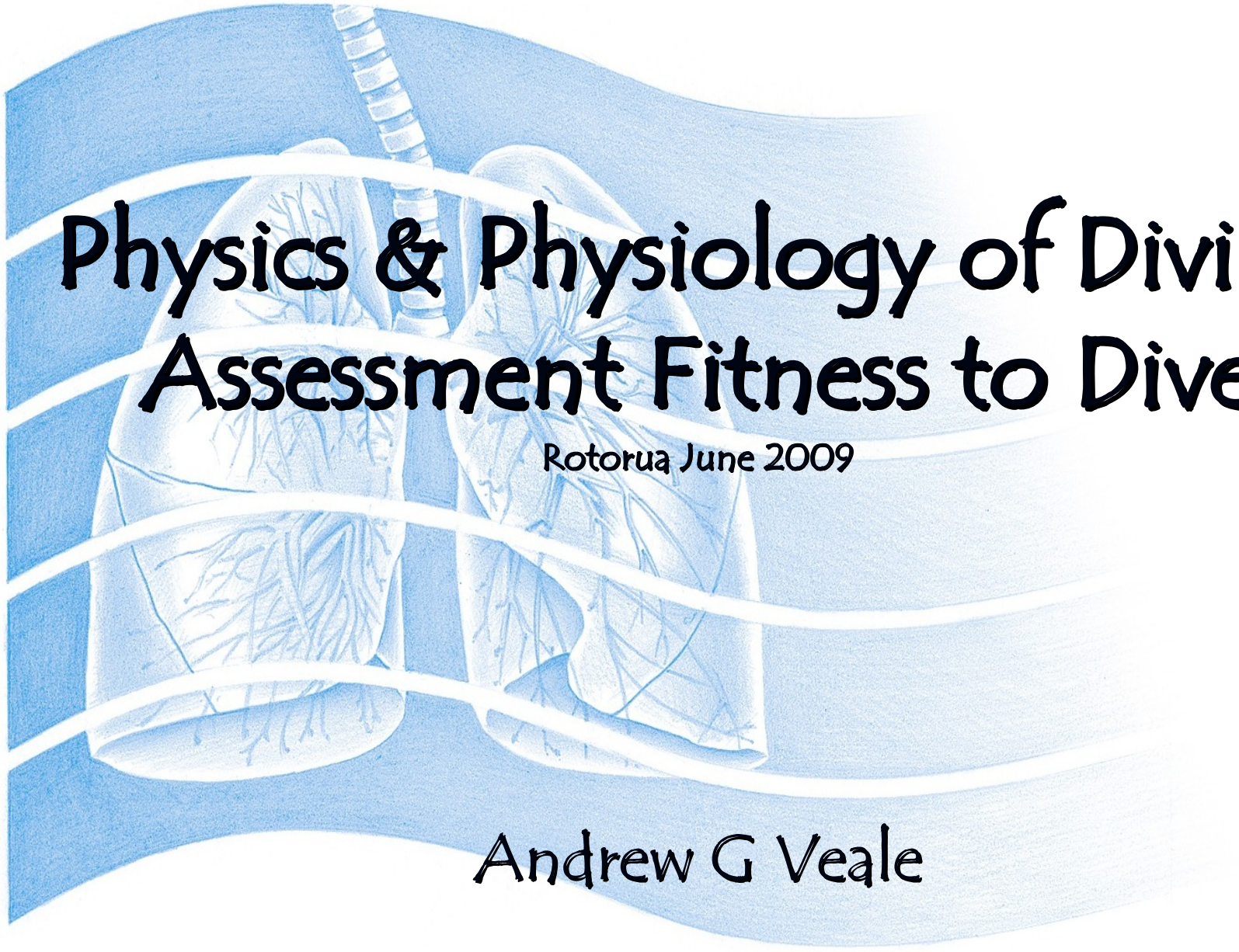


Physics & Physiology of Diving Assessment Fitness to Dive

Rotorua June 2009

Andrew G Veale

Diving Fitness

- No-one is fit to dive!

Diving Fitness

- Everyone can be helped to dive!

Diving Fitness

- No-one is fit to dive!
- What is our role?
  - Assess the risks of diving in this individual
  - Advise methods by which these risks might be minimised
  - Assist the intending diver to reach an informed decision with regards to their risks
  - Assist the intending diver make a risk benefit choice
  - Monitor likely risks which change over time
  - Notify the coroner
  - Comfort the living

A Retrospective Analysis of Diving-related Deaths in New Zealand 2000-2006

Andrew McClelland
Auckland

Diving Fatalities

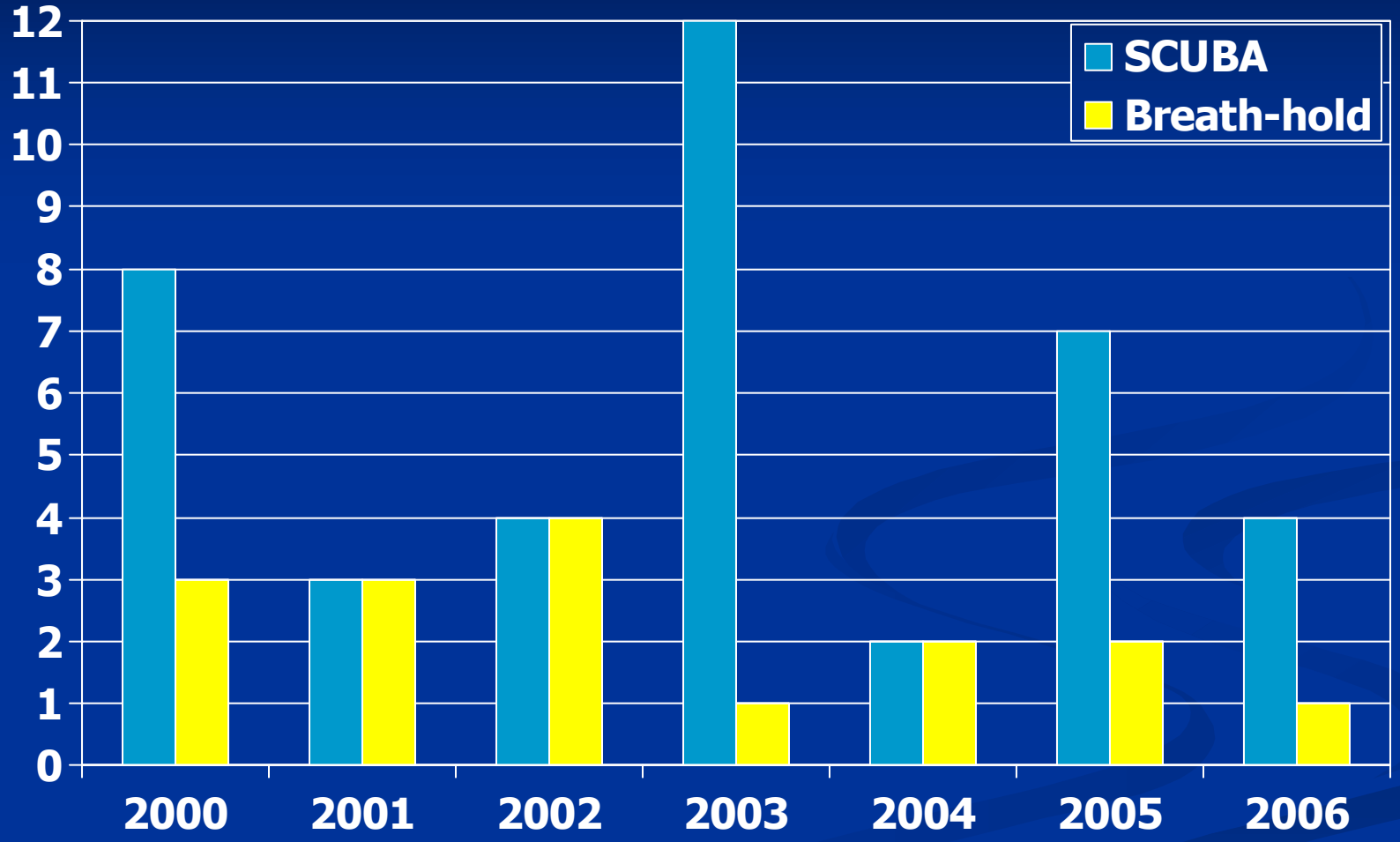
- Diving-related deaths are rare
- 5-10 deaths per year (5%) of the total number of drowning deaths in NZ
- 1980 to 2000 estimated scuba death rate 5.8 per 100 000 per year

(Davis, Warner & Ward - SPUMS 2002)

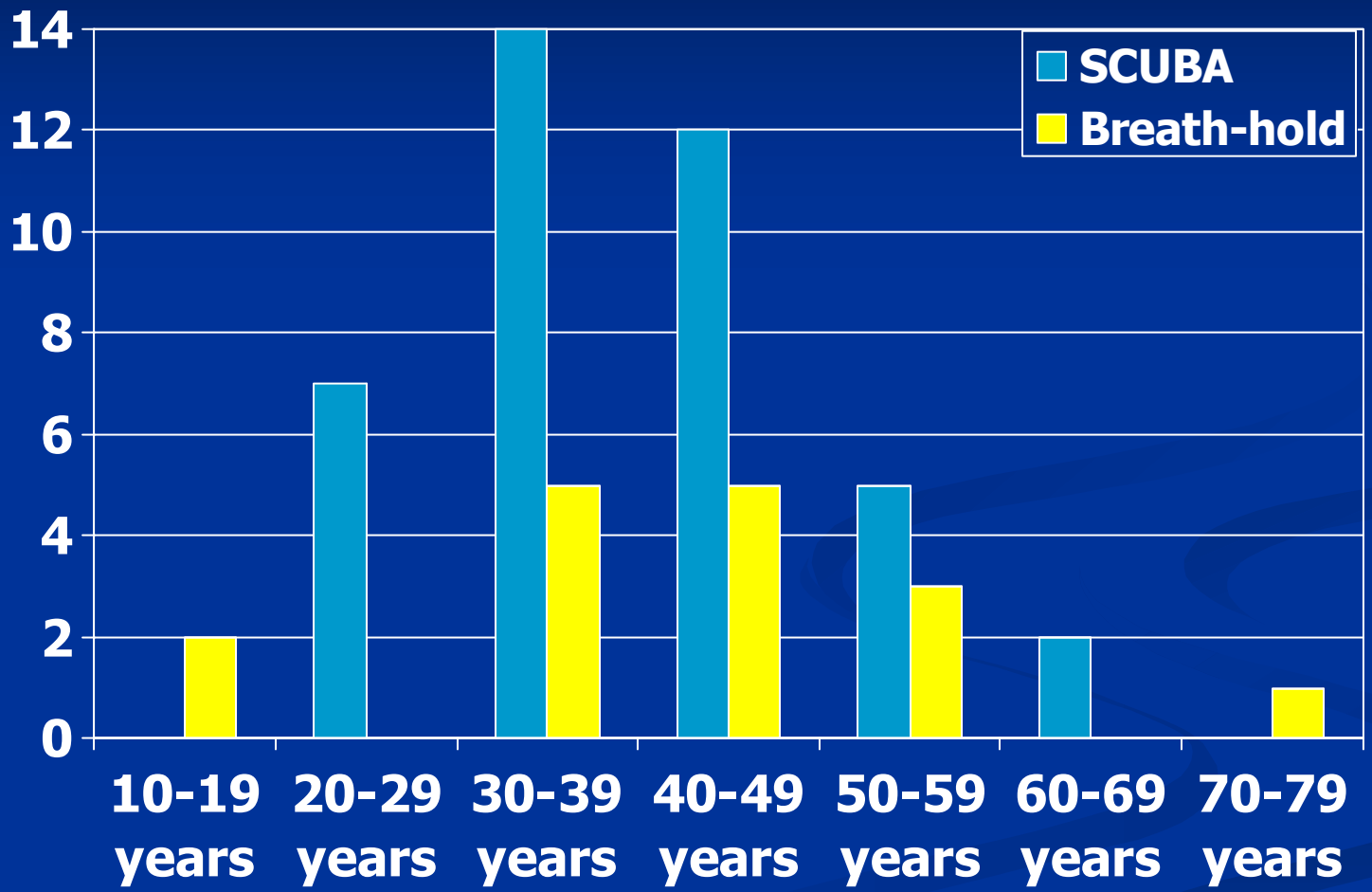
Diving Fatalities 2000-2006

- 40 SCUBA divers
  - Mean age 39.6 years, range 21 to 69 years
  - 5 were female
  - 75% Caucasian, 17.5% Maori
- 16 breath-hold divers
  - Mean age 42.9 years, range 18 to 78 years
  - All male
  - 53% Maori

Annual NZ Diving Fatalities



Fatalities by Age Group and Type



SCUBA divers

- Certification
  - 31 certified
  - 6 of unknown certification
  - 3 never certified
- Experience
  - 21 (52.5%) were inexperienced (< 2 years)

SCUBA divers

- 11 solo divers
- 13 buddy separation

- At least 3 divers had run out of air

- 4 divers were over weighted
- Only 1 diver had released his weight belt

AGE/SEX	MEDICAL CONDITIONS
29M	Old Tb, pleural adhesions
58F	Unexplained syncope, chest pains
47M	Massive CVA; 2 years TIA's, uncontrolled HT
68M	Coronary artery disease (CAD), DM type 2
34M	Myocarditis, cardiomegaly, CAD, BMI=33
69M	CAD
30M	Crohn's disease – immunosuppressive meds
34M	Severe symptomatic CAD, pulmonary oedema
41M	CAD (no dive medical)
53F	Migraine meds (gastric rupture)
55M	Symptomatic CAD
53M	Pleural adhesions, PFO

Causes of Death

- Gas embolism - 9 deaths
- Adverse sea conditions
- CO poisoning - 1 death
- Head injury from boat
  - 2 deaths (1 breath hold)
- Trauma – hit by a whale tail

Introduction

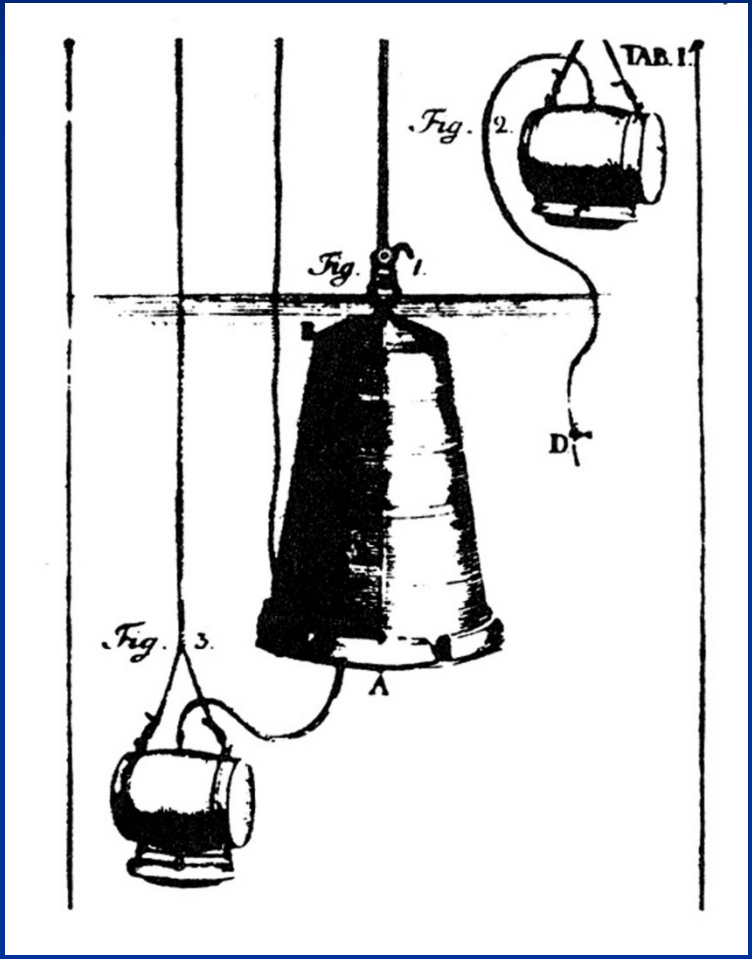
- History
- Transition from air to water
- Diving Environment
- Physics of depth
- Physiology of Depth (Pressure)
- How Humans (try) and cope
- How Marine Mammals do

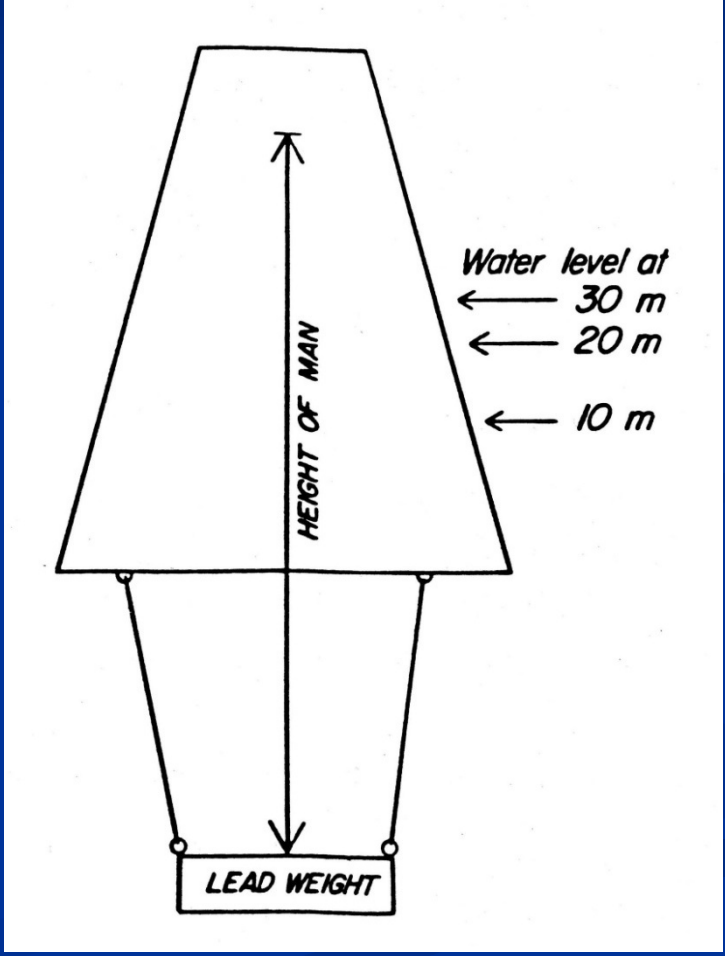
History

- Food (diving Ama)
- Salvage
- Construction (Caissons)
- Military
- Sport diving
- Scientific diving

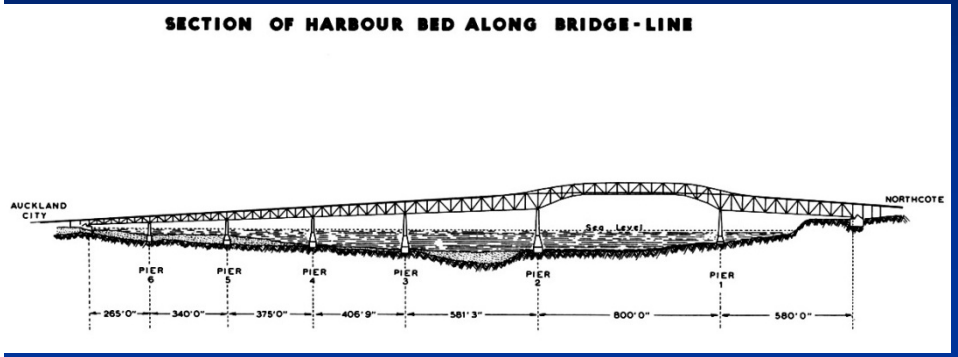
Diving Ama

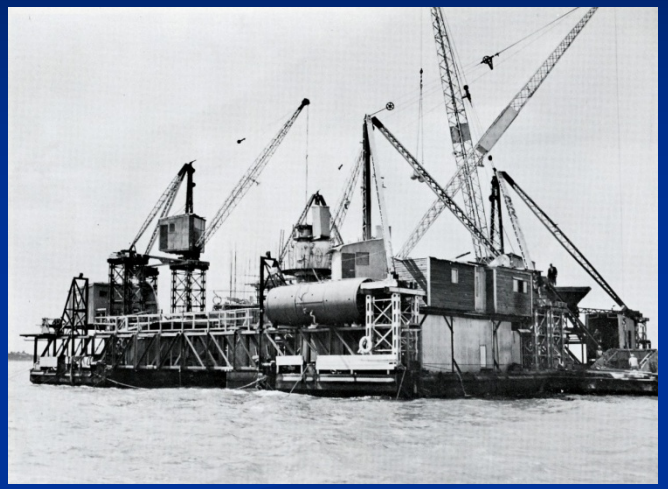
Bell diving - 1720

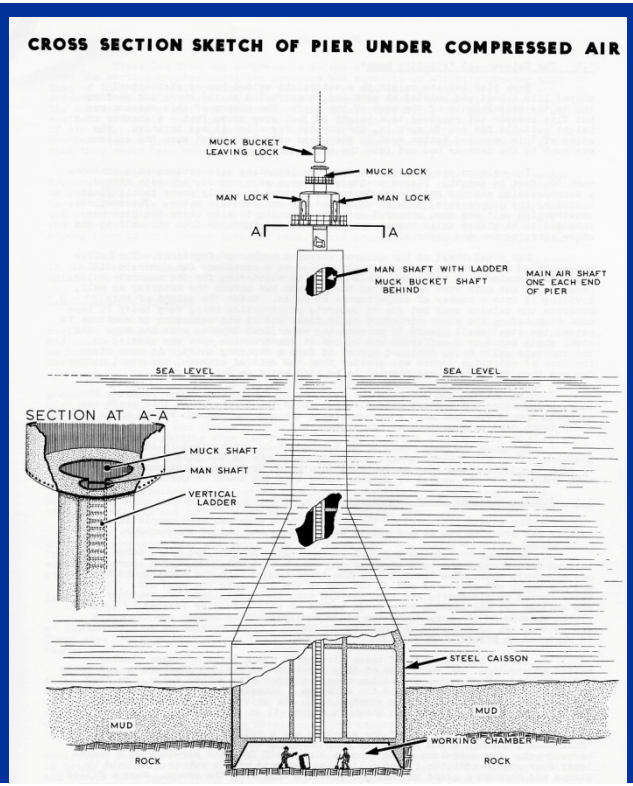




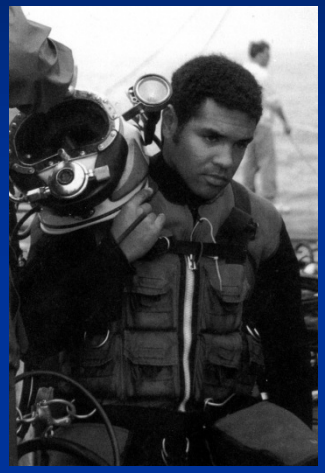
Auckland Harbour Bridge 1958







Military



Sport Diving

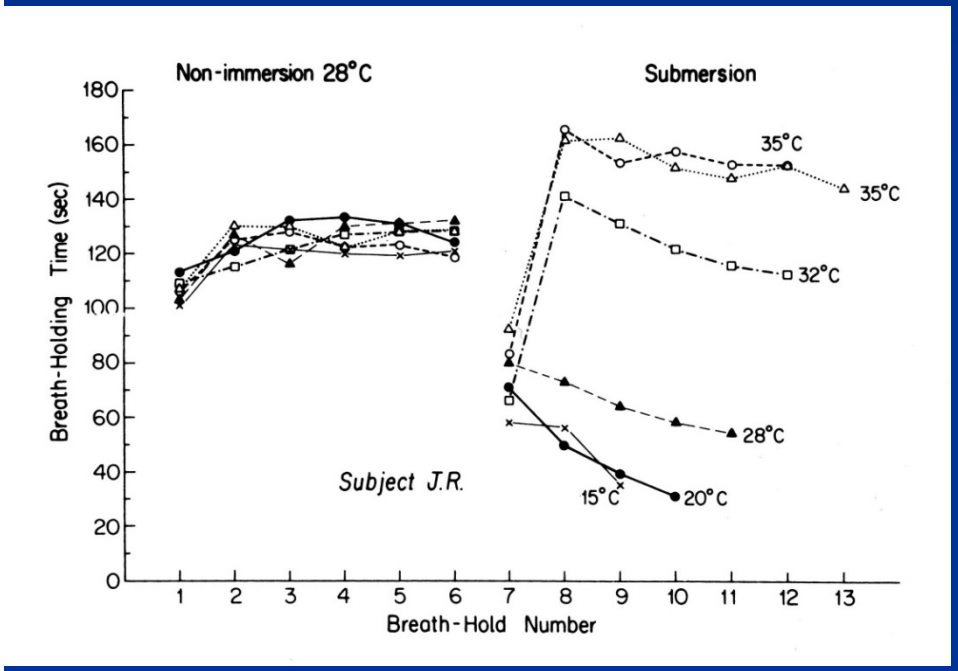
Environmental Factors

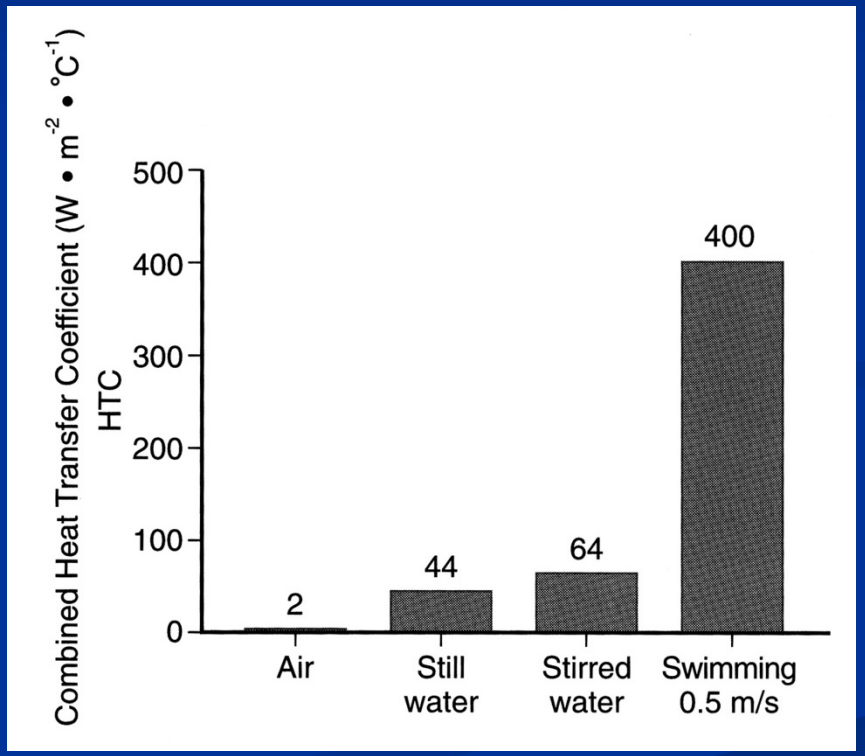
- Self Contained Underwater Breathing Apparatus (SCUBA)
  - Equipment heavy and awkward
  - Bottled gases (gas toxicities & contamination with CO, Diesel)
  - Runs out!!
- Wet
- Cold
- Unstable
- Distant from help
- Specialist help

Transitions

- Thermal
- Noise
- Light
- Density of the medium

Temperature





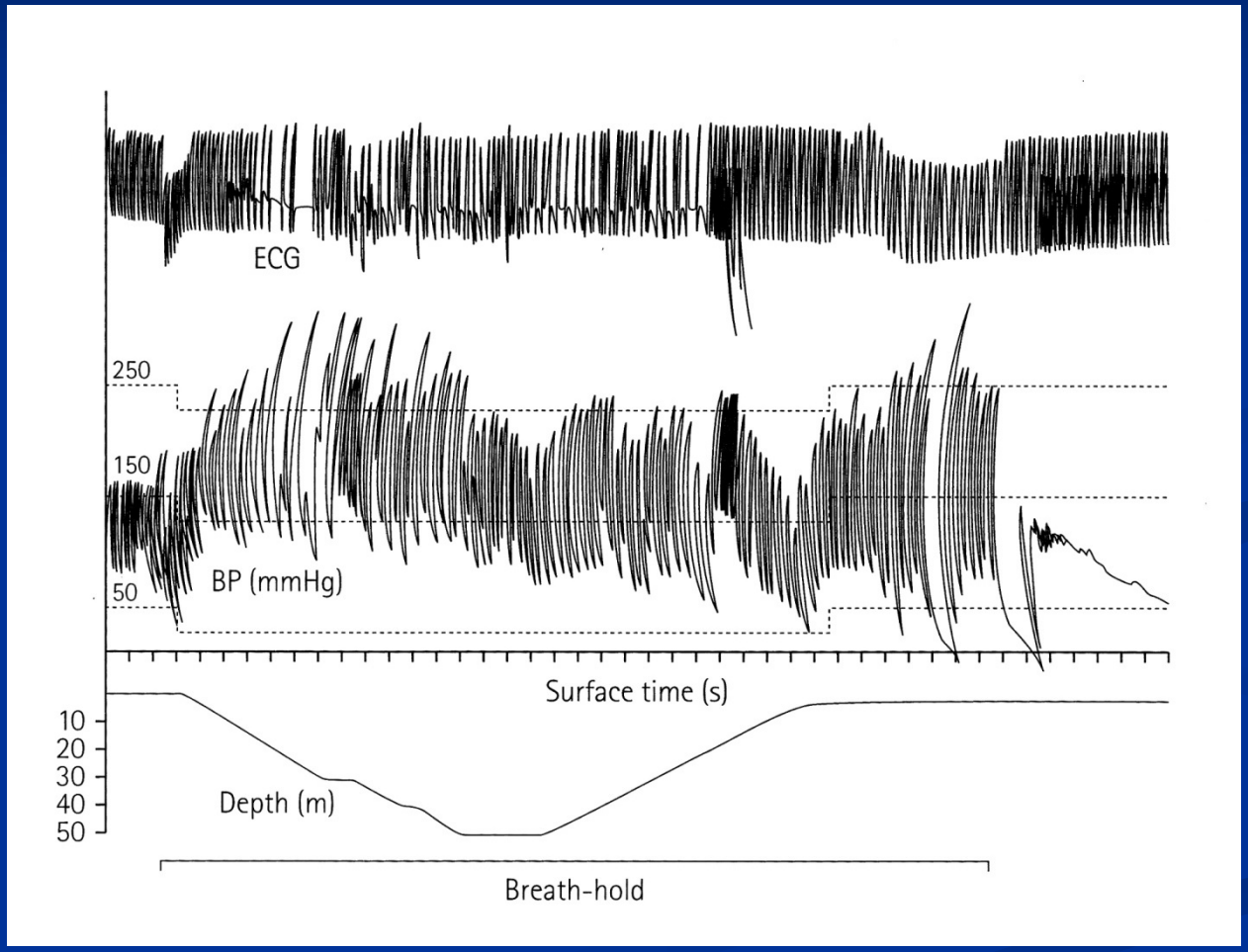
Physics

- Pressure (1 Bar, 2 ATA, 10msw, 33fsw, 34ffw)
  - Boyles Law:- $P \times V = K$
    - If pressure doubles volume must halve
- Solubility
  - Henry's Law:- $Q = k \times P_{gas}$
    - If Pressure doubles then dissolved gas doubles (over a time)
    - Diffusion into tissue depends on solubility in that tissue and perfusion
- Gas Density
  - If pressure doubles gas density doubles
  - Gas movement will become turbulent rather than laminar
- Pascals Principle
  - Pressure is transmitted through incompressible liquid

Immersion

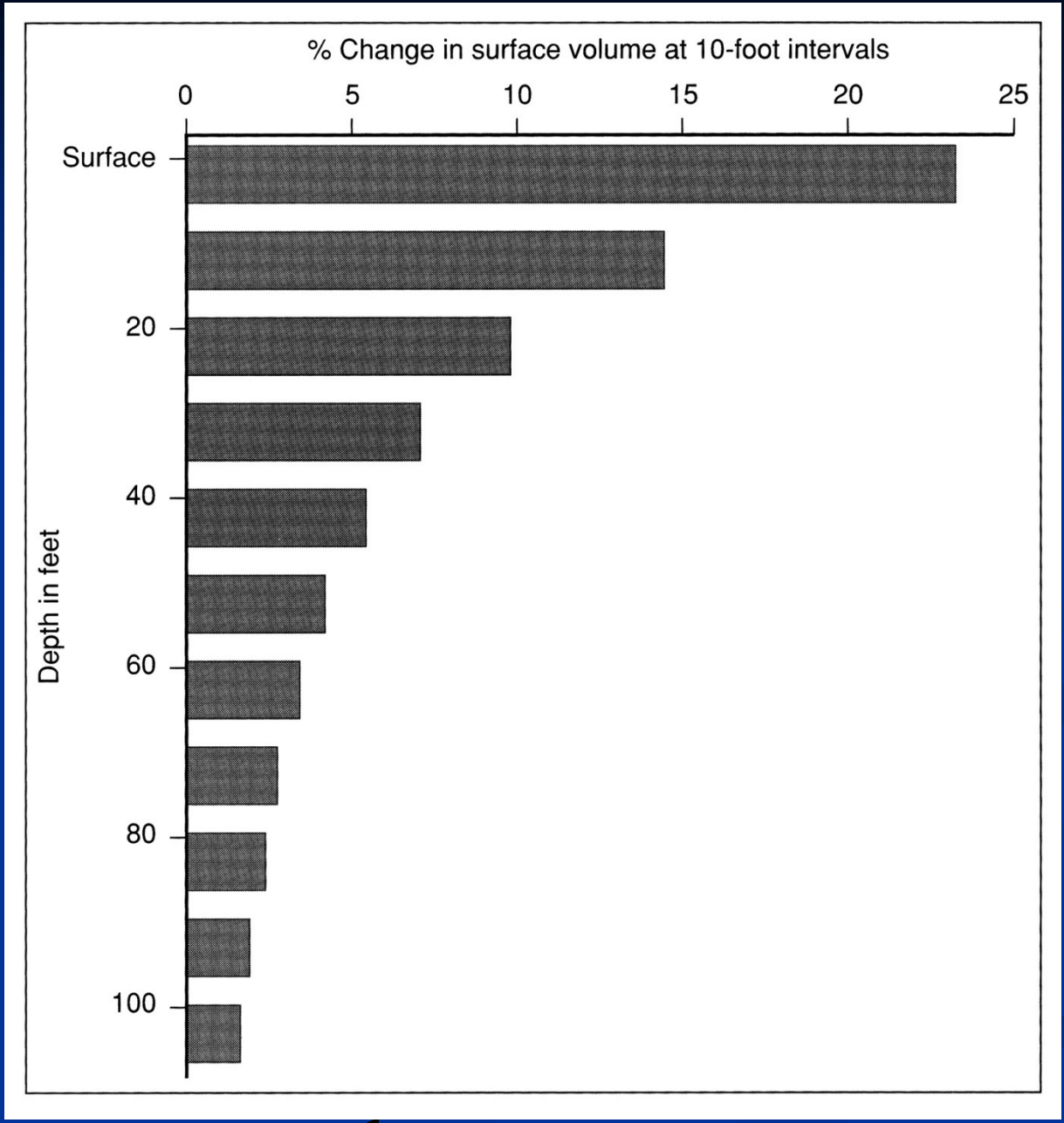
- Gravity reversed
- Dead space
- FVC decreased
- Compliance reduced
- 30% increased CO
- Bradycardia
- Vasoconstriction increased SVR and BP
- Diuresis

Hypertension



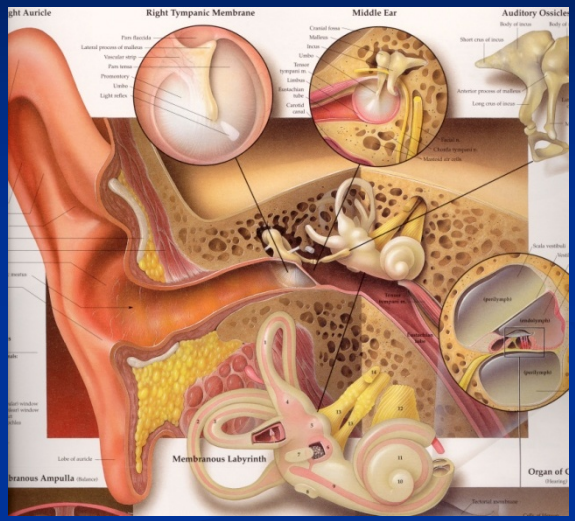
Boyles Law

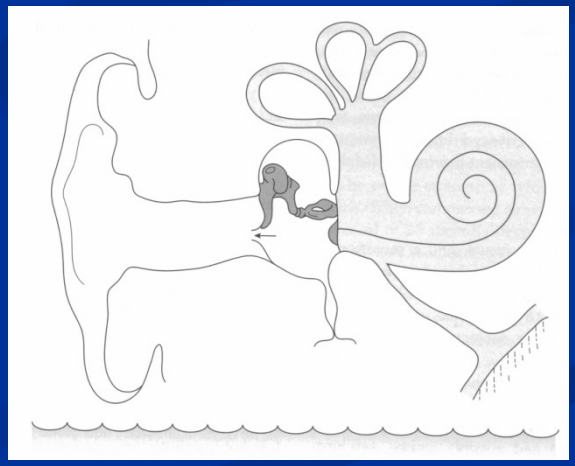
Depth Meters	ATA	Volume	Volume
0	1	1	1000
10	2	1/2	500
20	3	1/3	333
30	4	1/4	250
40	5	1/5	200


% Change in surface volume at 10-foot intervals
0
5
10
15
20
25
Surface
20
40
60
80
100
Depth in feet

The Ear

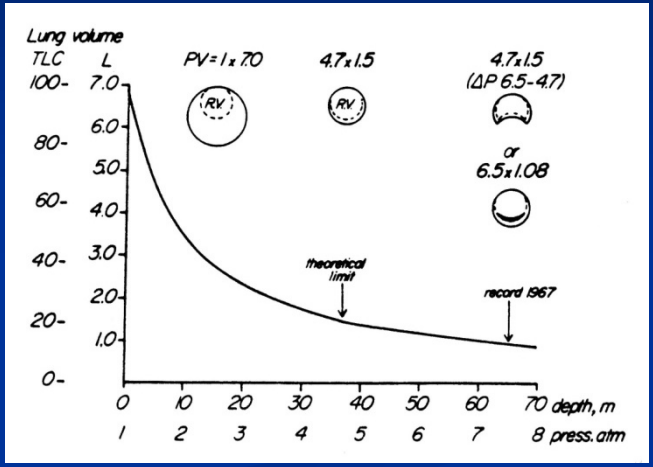
- Ear squeeze
- Tympanic membrane
- Middle ear
- Round window
- Labyrinth

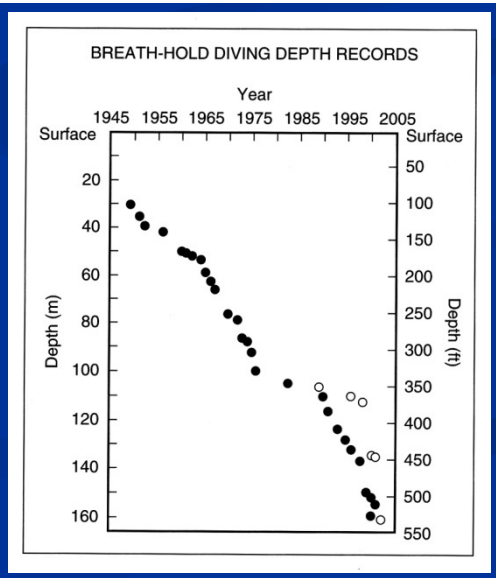




The Lung – free diving

- Compresses with depth to RV
- Becomes stiffer and less compliant
- Engorges with blood
- Fills with fluid

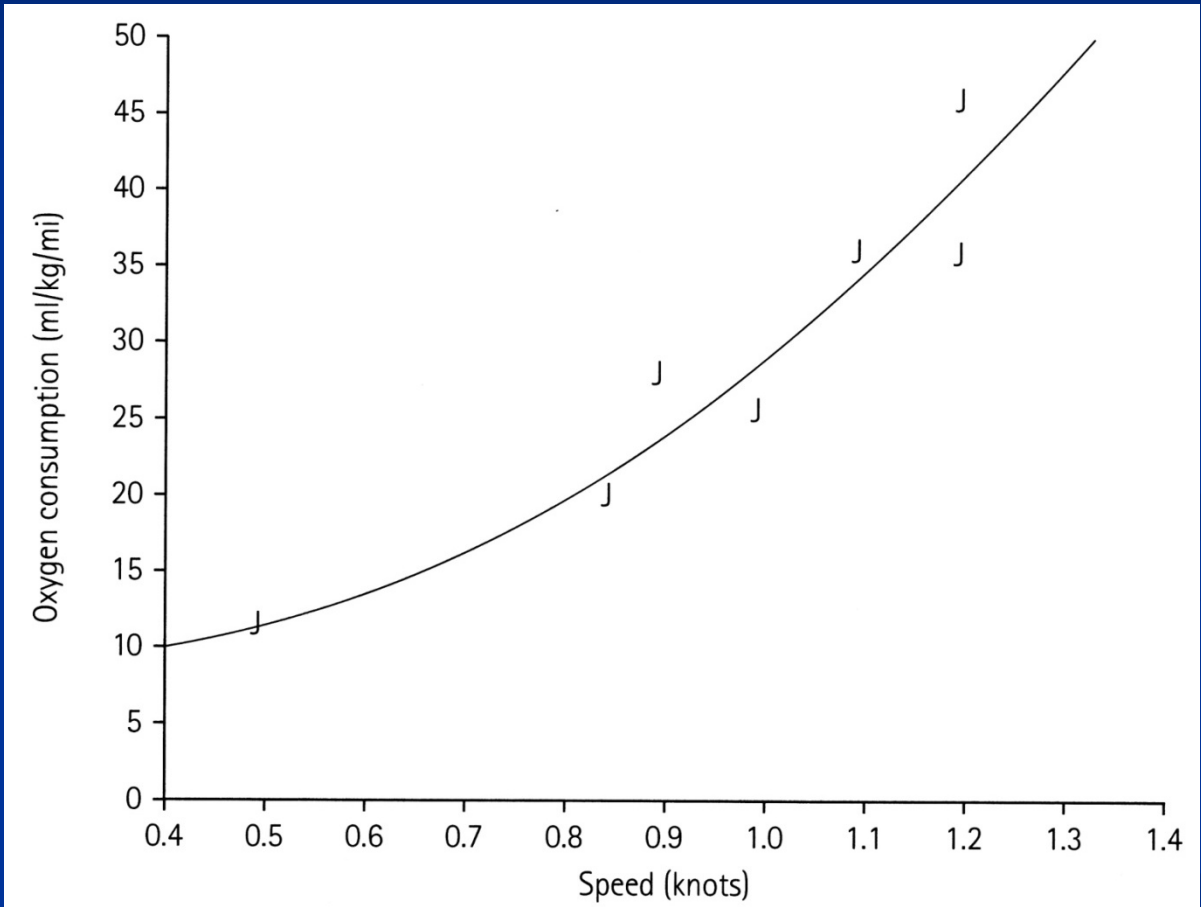




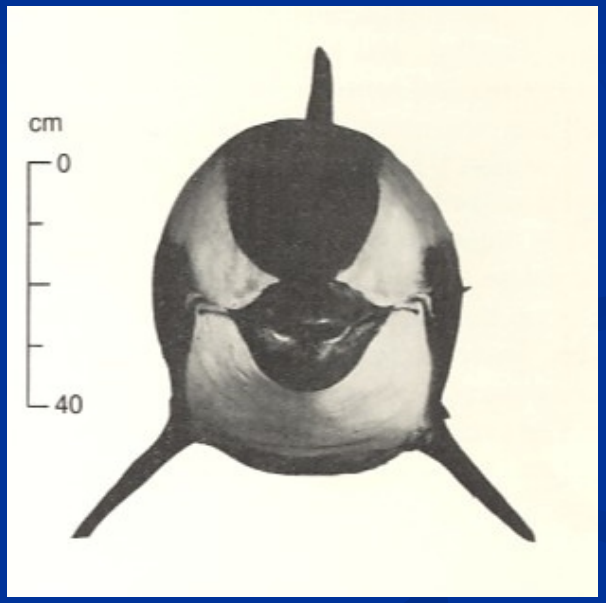
Exercise

- Hardwork
  - due to fluid density
  - Equipment
  - Poor technique
  - Poor training
- Work of breathing
  - Regulator resistance
  - Increased deadspace (increased Vd/Vt)
  - Decreased chest wall compliance due to wetsuit
  - Increased gas density
  - Increased turbulent flow
  - Decreased compliance (blood and fluid)

Swimming Work

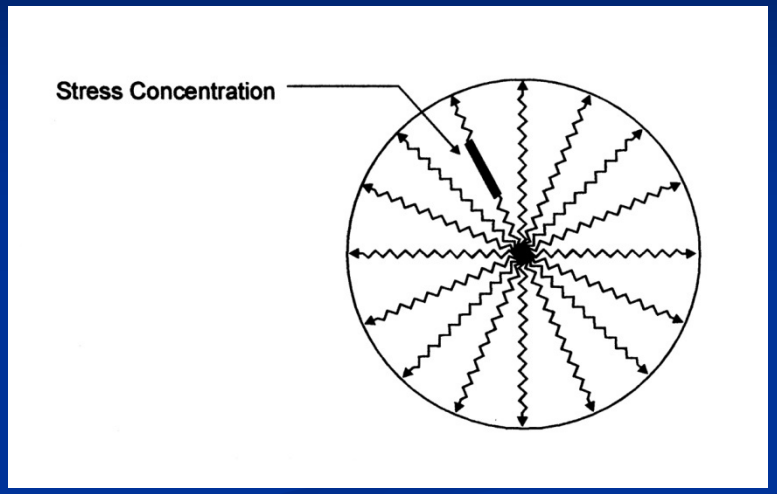


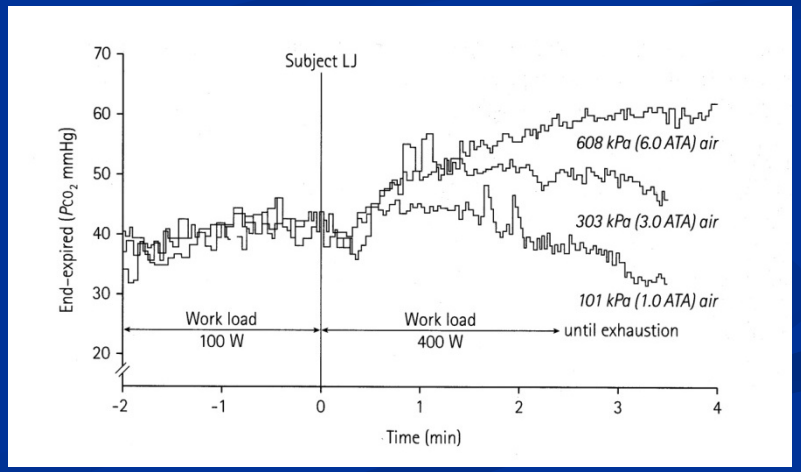
Diver technique


cm
0
40

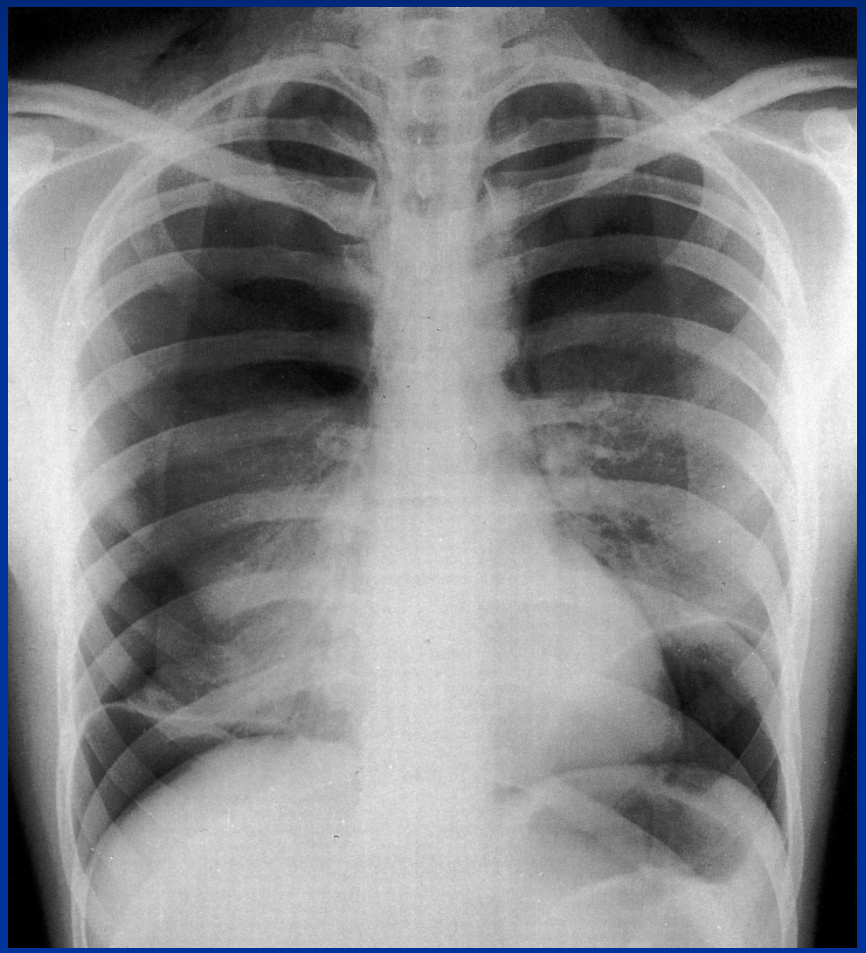
The Lung - SCUBA

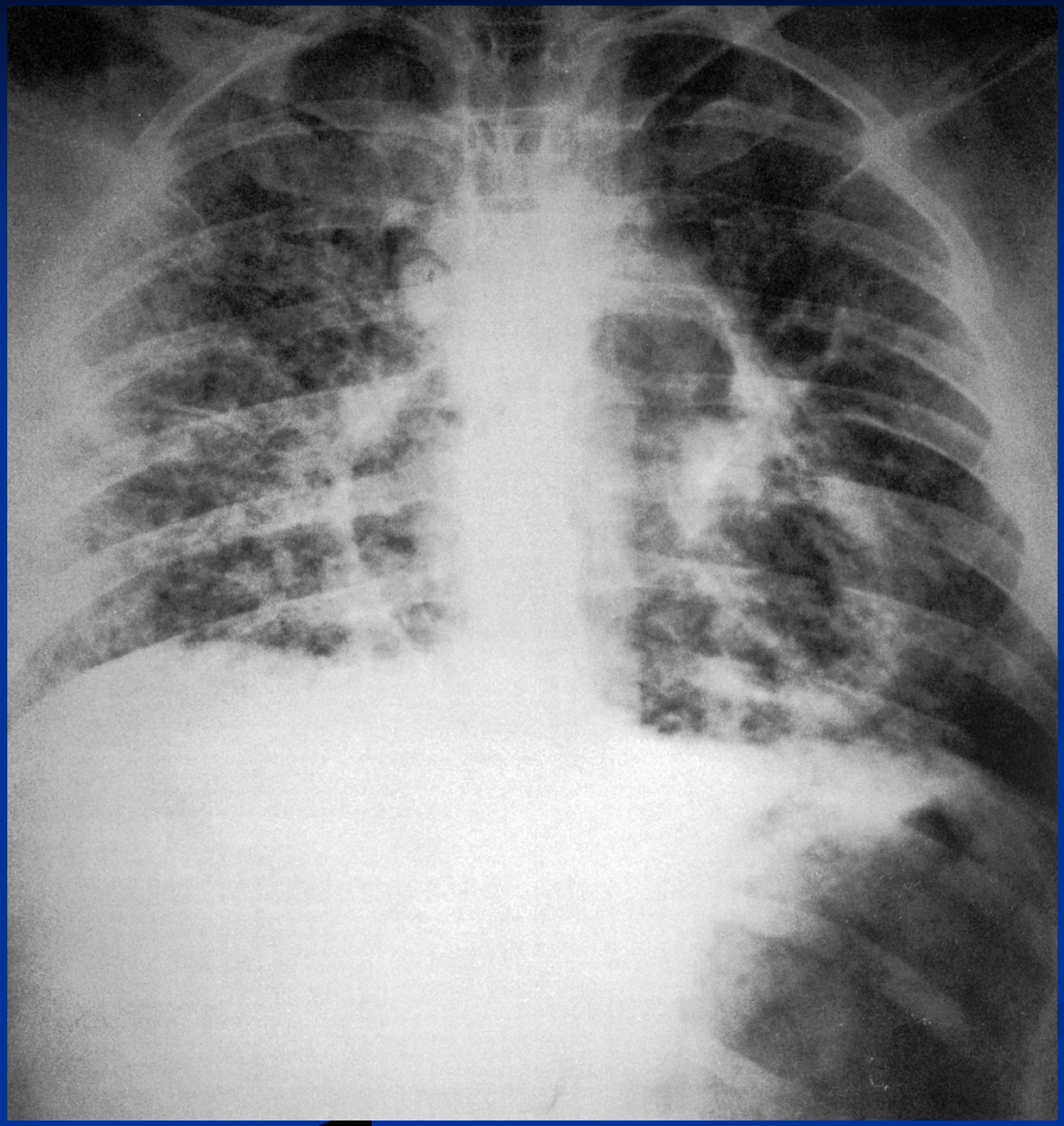
- Increased density increases WOB
- VCO2 increases as VO2 increases
- Increased resistance (equipment and wetsuit
- The reduction in FRC may increase CV
- MVV falls
- V_ECO2 falls
- Reduced response to rising CO2
- Different time constants
- Differential compliance



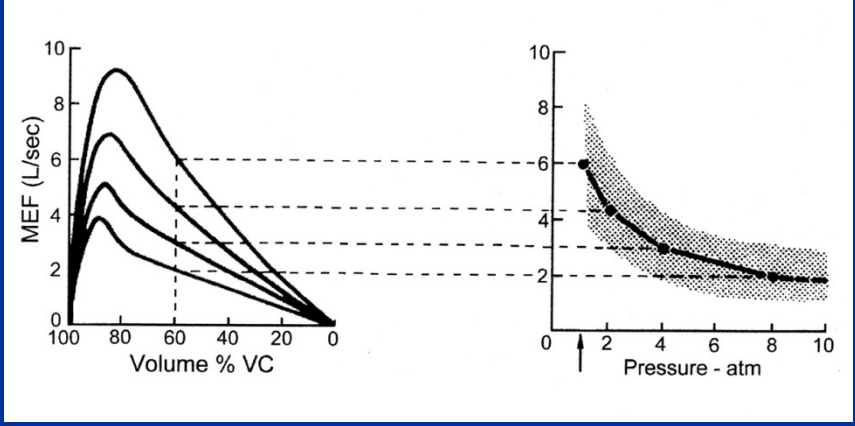


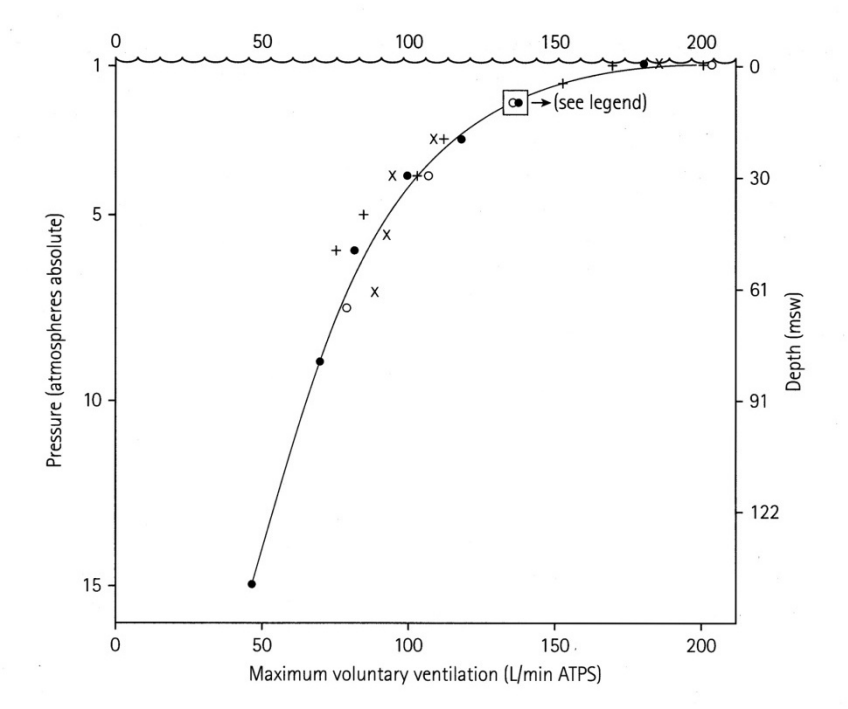
Barotrauma





Decreased ventilation with increased depth





Case 1

- 38 year old experienced diver instructor
  - Mitral regurgitation due to MVPS
  - Past history of hayfever and asthma

Case 2

- 30 year old experienced scientific diver
  - Past hayfever and asthma

Case 4

- 33 year old intending diver
  - with past hyperthyroidism

Case 5

- 55 year old intending diver
  - Well

Case 6

- 55 year old diver
  - CAVG 4 mths ago

Case 7

- 40 year old intending diver
  - Hypertension

Case 8

- 25 year old intending diver
  - Doing a course with 3 flatmates
  - Last to submerge
  - First to ascend
  - Ascends with half the air of others in his group

Summary I

- Will the condition increase risk of a diving related injury
- Will treatment of the condition increase diving injury risk
- Could diving make an existing condition worse
- Is the consequence of the medical condition serious
- Could the condition make diagnosis retrieval/treatment of a diving injury more difficult

Summary II

- GP best to determine normality
- Diving trained doctor best to determine diving relevance of a condition
- Specialist best to evaluate severity and correctability of a medical condition
- Individual is best to determine if the risk is worth it