Inhalational Injury

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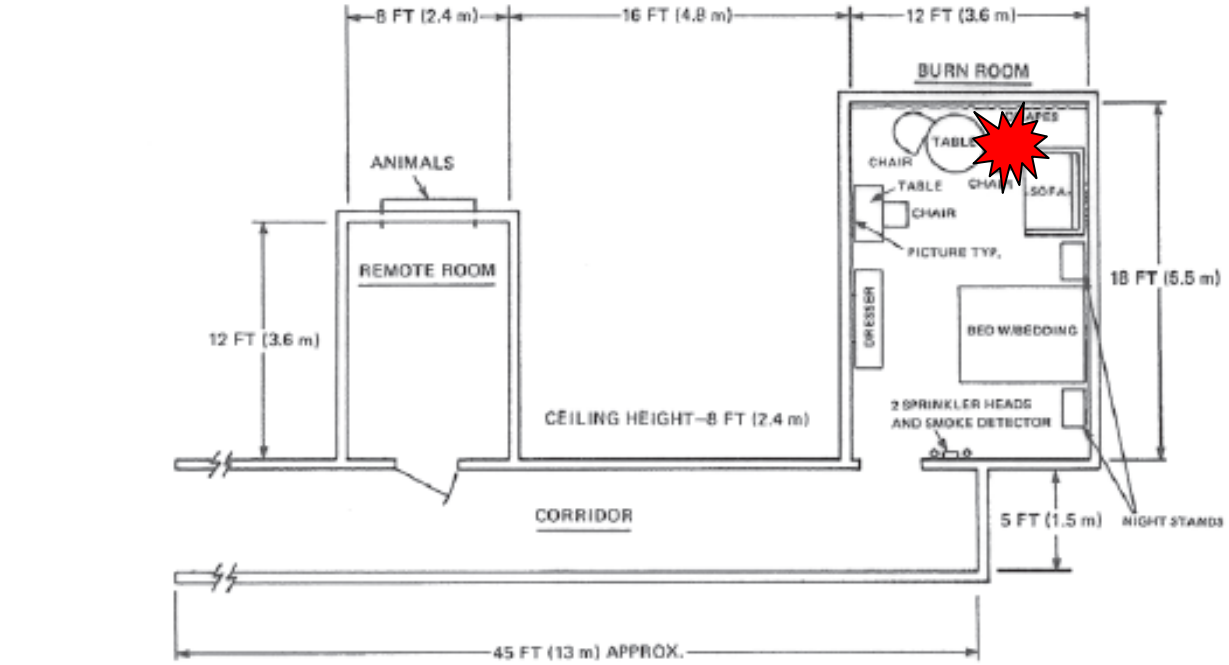
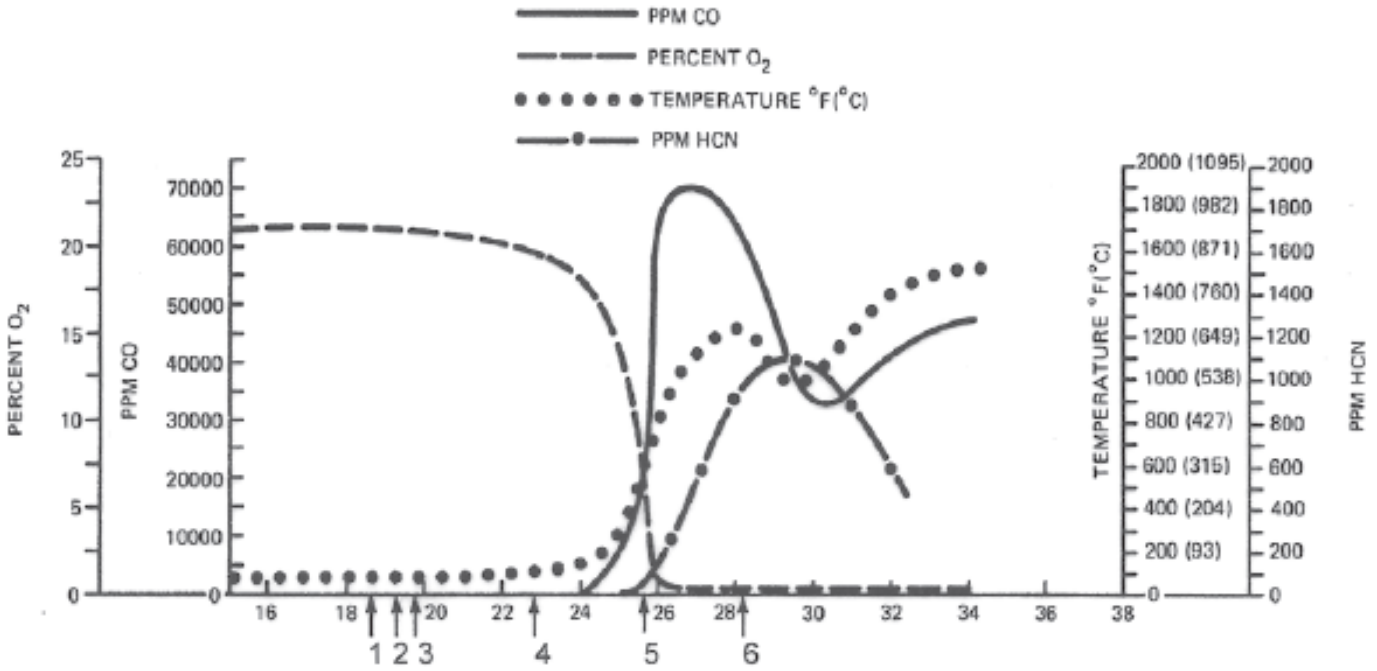
Conflict of interest

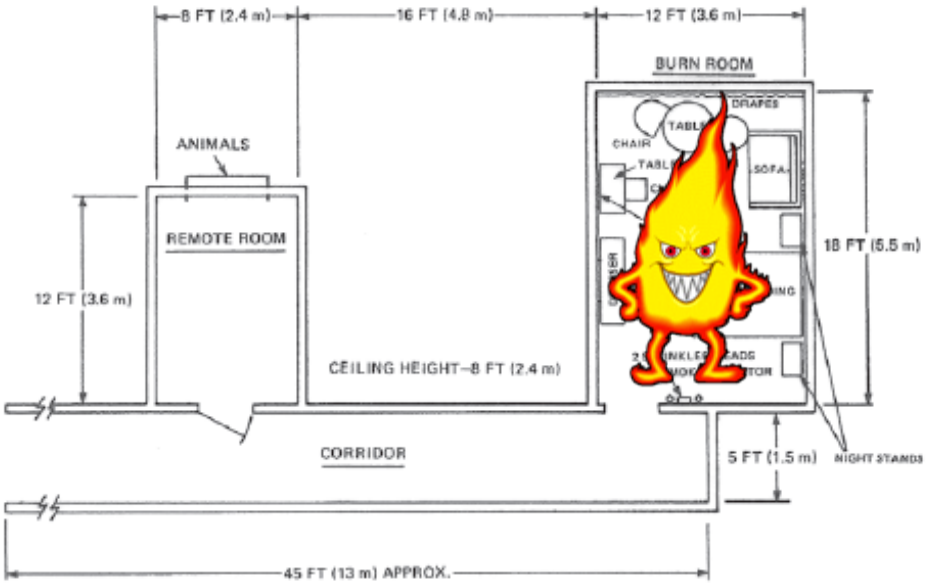
- No conflict of interest to declare

Objectives

- Understand different mechanisms of injury
- Anticipate types of injury based on clinical presentation
- Understand criteria for airway intervention
- Treat potential toxic exposures


8 FT (2.4 m)
16 FT (4.8 m)
12 FT (3.6 m)
BURN ROOM
ANIMALS
REMOTE ROOM
12 FT (3.6 m)
CEILING HEIGHT–8 FT (2.4 m)
CORRIDOR
CHAIR
TABLE
CHAIR
SOFA
CHAIR
PICTURE TYP.
DRESSER
BED W/BEDDING
18 FT (5.5 m)
2 SPRINKLER HEADS AND SMOKE DETECTOR
5 FT (1.5 m)
NIGHT STANDS
45 FT (13 m) APPROX.


PPM CO
PERCENT O_2
TEMPERATURE °F(°C)
PPM HCN
PERCENT O_2
PPM CO
TEMPERATURE °F(°C)
PPM HCN
25
20
15
10
5
0
70000
60000
50000
40000
30000
20000
10000
0
2000 (1095)
1800 (982)
1600 (871)
1400 (760)
1200 (649)
1000 (538)
800 (427)
600 (315)
400 (204)
200 (93)
0
16
18
20
22
24
26
28
30
32
34
36
38
1 2 3
4
5
6

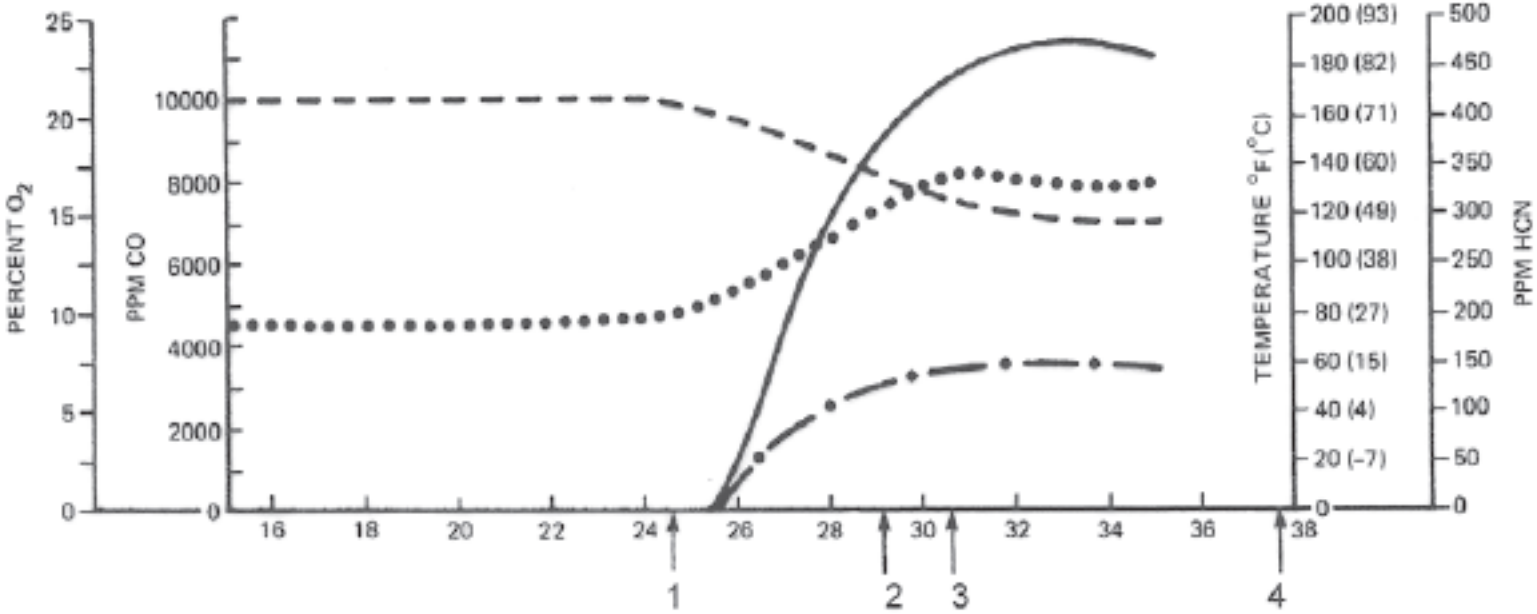


PPM CO

PERCENT O_2

TEMPERATURE °F(°C)

PPM HCN



Mechanisms of Injury

- Heat (Thermal)
- Hypoxia
- Direct toxins
- Systemic toxins

Thermal Injury

- Smoke is hot, but dry
- Low specific heat capacity
  - Rare to have subglottic burns from smoke alone
- Can burn if moist heat, or with general burn injury (ambient heat)

Hypoxia

- Fire consumes oxygen
- FiO2 of inhaled air decreases
  - Causes neural damage
  - Potentiates other toxins
  - Increases minute ventilation
    - More smoke inhaled

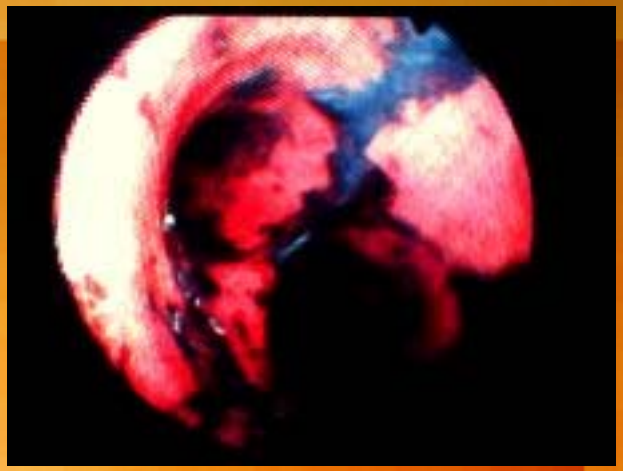
Direct Toxins

- Substances toxic to respiratory epithelium
  - SO_2, NO_2, N_2O, Chlorine, multiple organic compounds
  - HCl, HBr, HF, other inorganic compounds
- Effects usually appear 12-48h after exposure
  - Neutrophilic invasion
  - Mucociliary sloughing
  - Increased epithelial permeability

Airway evaluation

- Should be carefully performed in any potential inhalational injury victim
- Indications for early intubation
  - Hoarse voice
  - Stridor
  - Burns above clavicles
  - Soot in nares or mouth, carbonaceous sputum
  - Singeing of facial hair
  - Significant (>30% BSA) burns
  - Altered mental status

Bronchoscopy

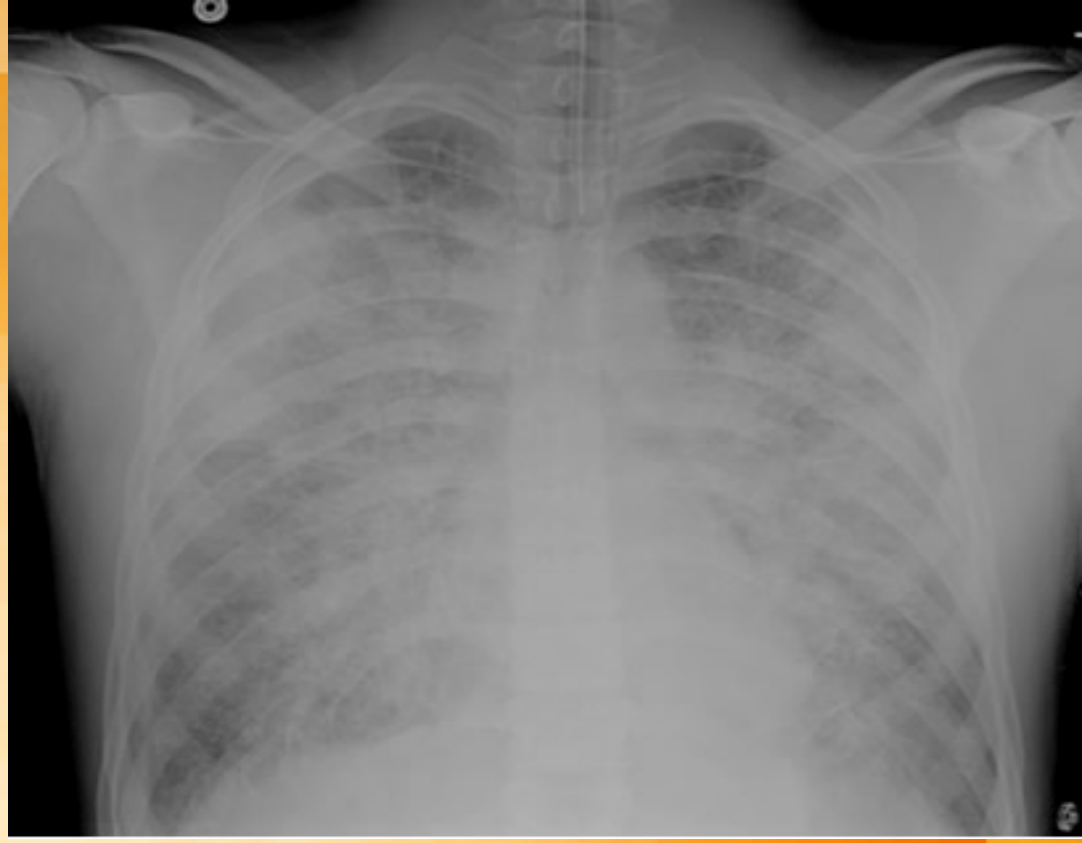


- Controversial
- Demonstrates
  - depth of burn
  - carbonaceous sputum
- May help with unclear airway status
- No clear correlation with long-term prognosis

ARDS

- Common after inhalational injury
- Due to toxin inhalation
  - Edema, inflammation, bronchospasm, mucociliary sloughing
  - Microatelectasis, loss of surfactant, capillary leak
  - Can form bronchial casts
- Secretions build up, can obstruct ETT
- Peaks at ~72h post injury

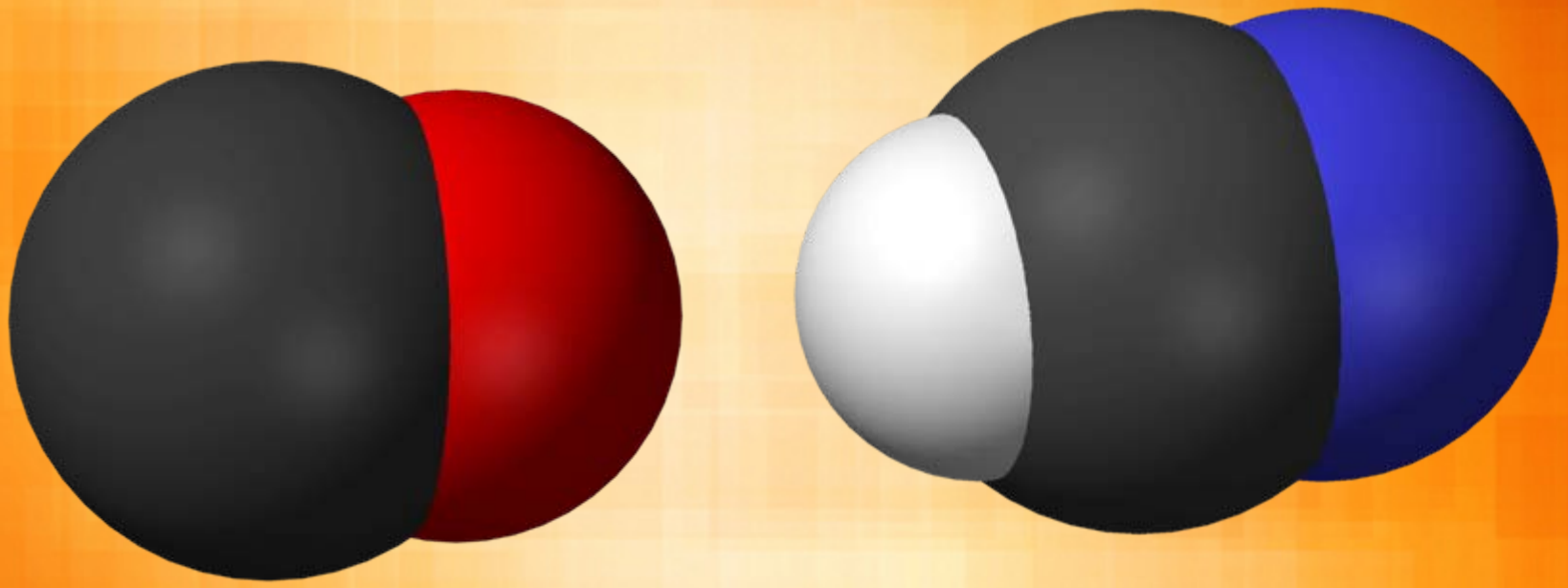
ARDS



- PEEP
- Permissive hypercapnia
- Frequently complicated by pneumonia (30-70%)

Systemic Toxins

- Carbon Monoxide and Cyanide



Carbon Monoxide Poisoning

- Has 240 times the affinity for Hb as O2
- Also binds to porphyrins elsewhere
  - Mitochondrial cytochromes, NADPH reductase
- Half-life:
  - Room air: 300 minutes
  - 100% FiO2: 90 minutes
  - 3 atmospheres 100% FiO2: 30 minutes

Carbon Monoxide Toxicity - Diagnosis

- Cannot use SpO2
- Only co-oximetry, or, where not available, high index of suspicion

Carbon Monoxide Poisoning - Treatment

- 100% O2 for all potential victims
- Hyperbaric therapy considered if:
  - Unconscious, altered MS, neurologic deficit
  - ECG changes, CO-Hb >40% (20% if pregnant)

Carbon Monoxide - Treatment

- Hyperbaric therapy after acute injury
  - Controversial
  - 2 RCT's - opposite conclusions about neurocognitive sequelae
  - Both flawed studies
    - Poor randomization in one
    - Poor follow-up in the other

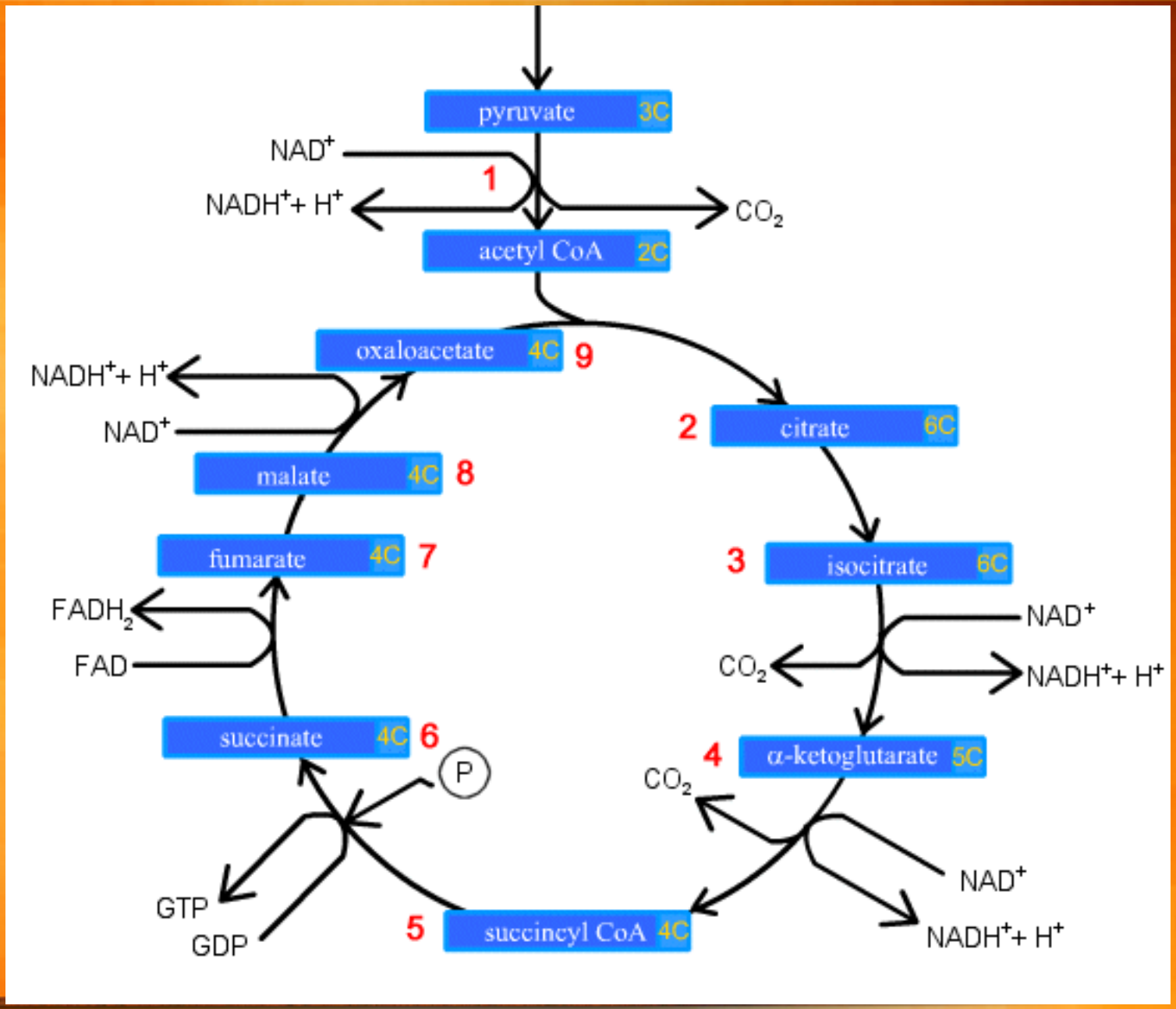
Carbon Monoxide - Treatment

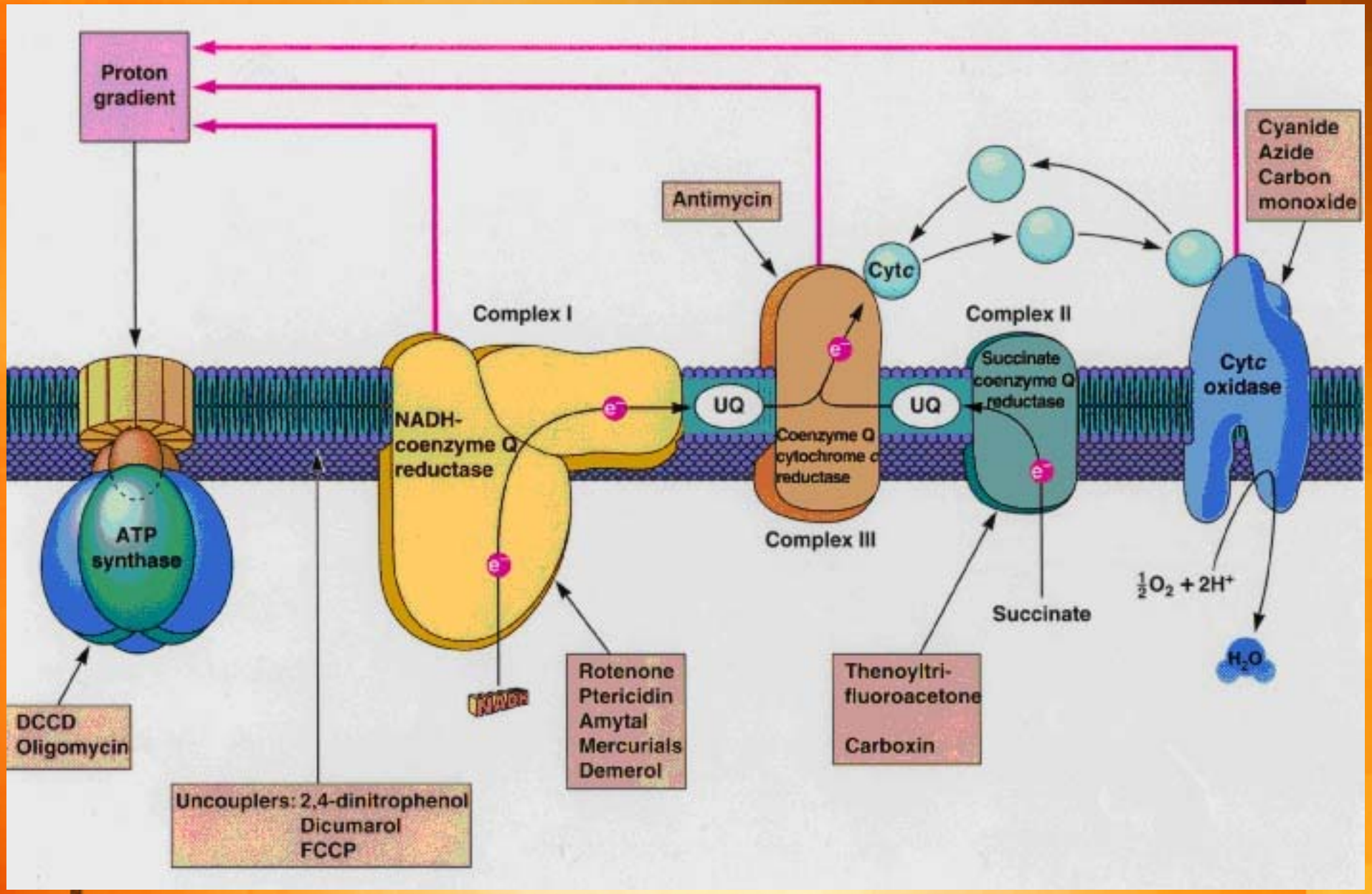
- Isocapnic hyperpnea
  - Hyperventilating with a small amount of CO_2 in the circuit to maintain $PaCO_2$ at 40
  - Doubles rate of CO-Hb elimination

Hydrogen Cyanide (HCN)

- Liberated from any burned substance that has carbon and nitrogen
  - Plastics, natural fibres, insulation, upholstery


STAND BACK
I'M GOING TO TRY
SCIENCE


pyruvate 3C
NAD+
1
NADH+ + H+
CO2
acetyl CoA 2C
oxaloacetate 4C 9
NADH+ + H+
NAD+
2 citrate 6C
malate 4C 8
fumarate 4C 7
3 isocitrate 6C
FADH2
FAD
NAD+
CO2
NADH+ + H+
succinate 4C 6
P
4 α-ketoglutarate 5C
CO2
GTP
GDP
5 succincyl CoA 4C
NAD+
NADH+ + H+


Proton gradient
Antimycin
Cyanide
Azide
Carbon monoxide
Cytc
Complex I
Complex II
Succinate coenzyme Q reductase
Cytc oxidase
NADH-coenzyme Q reductase
UQ
UQ
Coenzyme Q cytochrome c reductase
Complex III
ATP synthase
$\frac{1}{2}O_2 + 2H^+$
Succinate
H_2O
Rotenone
Ptericidin
Amytal
Mercurials
Demerol
Thenoyltri-fluoroacetone
Carboxin
DCCD
Oligomycin
Uncouplers: 2,4-dinitrophenol
Dicumarol
FCCP

Cyanide Toxicity

- Binds Fe3+ on Cytochrome Oxidase a3
- Stops oxidative phosphorylation
- Cells switch to anaerobic metabolism
  - Vomiting, abdominal pain
  - Confusion, headache, seizures
  - Hyper- and hypotension, tachycardia, CV collapse, AV block, Ventricular arrhythmias
  - Tachypnea
  - Flushing of skin, renal failure, hepatic necrosis

Cyanide Toxicity - Diagnosis

- Presumed present if significant burn or smoke inhalation
- Any base deficit, lactic acidosis, or anion gap in a burn/smoke inhalation victim
- VBG with abnormally high PO2

Cyanide toxicity - Treatment

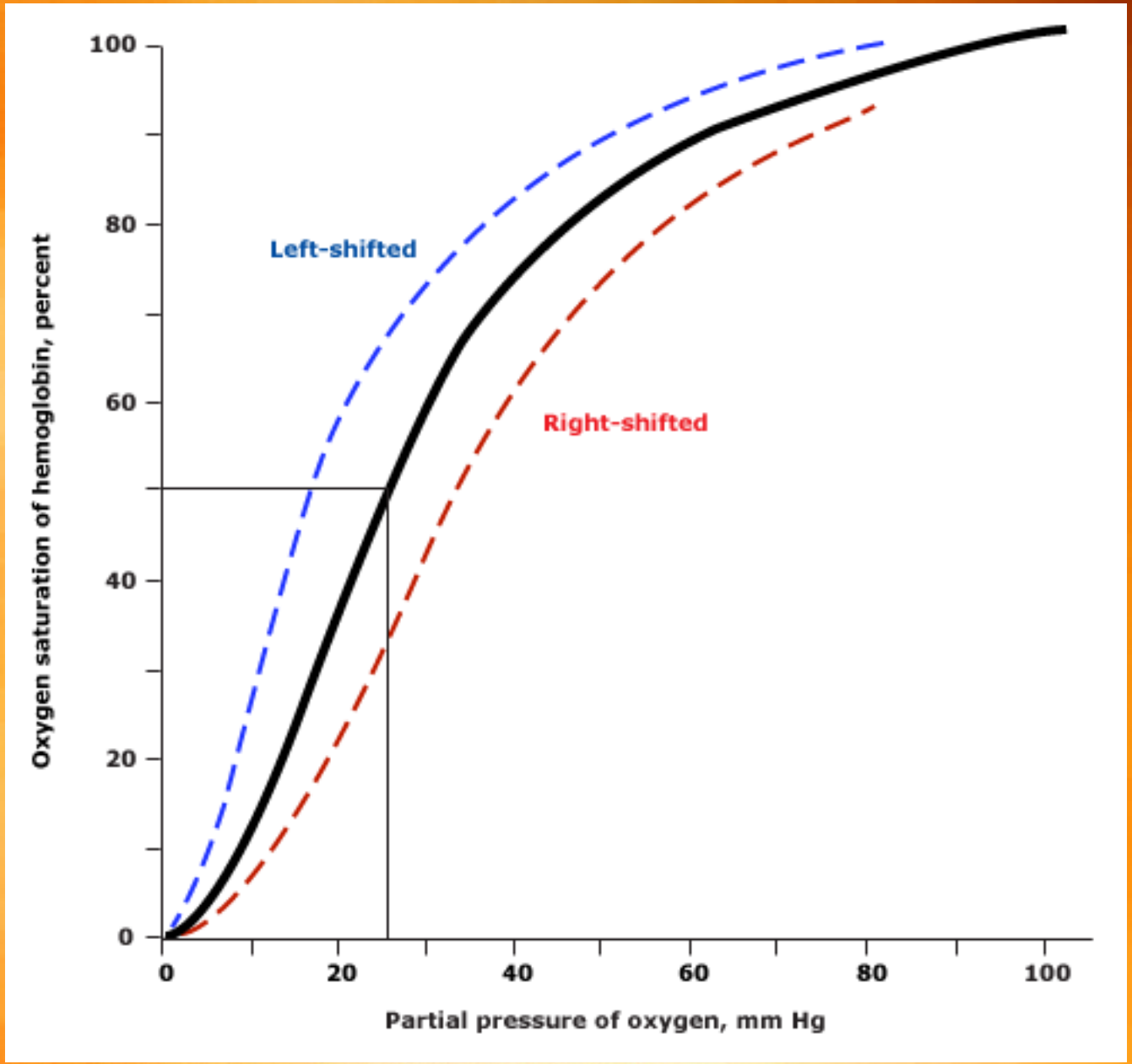
- Lilly Kit

→ Induction of methemoglobinemia

  - Cyanide binds Fe3+ >> Fe2+
  - Inducing methemoglobinemia creates a competitive site for the cytochrome binding site for CN- a cyanide “sink”
  - CN-Hb is relatively nontoxic

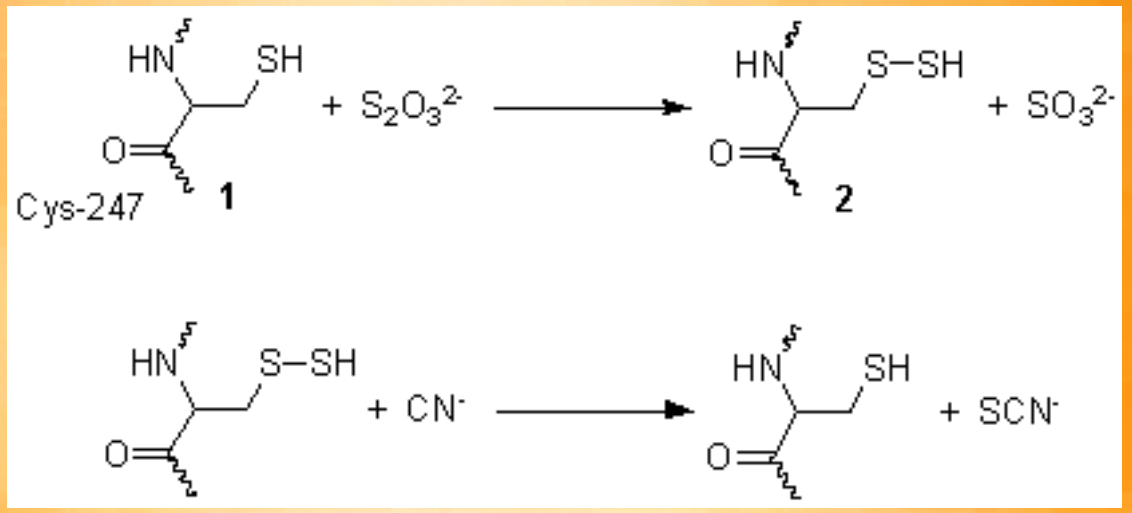
Cyanide Toxicity - MetHb

- Sodium nitrite
  - Given IV - dosed to achieve 10-30% MetHb
  - Causes left-shift of Oxygen-Hemoglobin dissociation curve
- Contraindicated in concomitant CO poisoning


100
80
60
40
20
0
Oxygen saturation of hemoglobin, percent
Left-shifted
Right-shifted
0
20
40
60
80
100
Partial pressure of oxygen, mm Hg

Cyanide Toxicity - Sulfur Donation

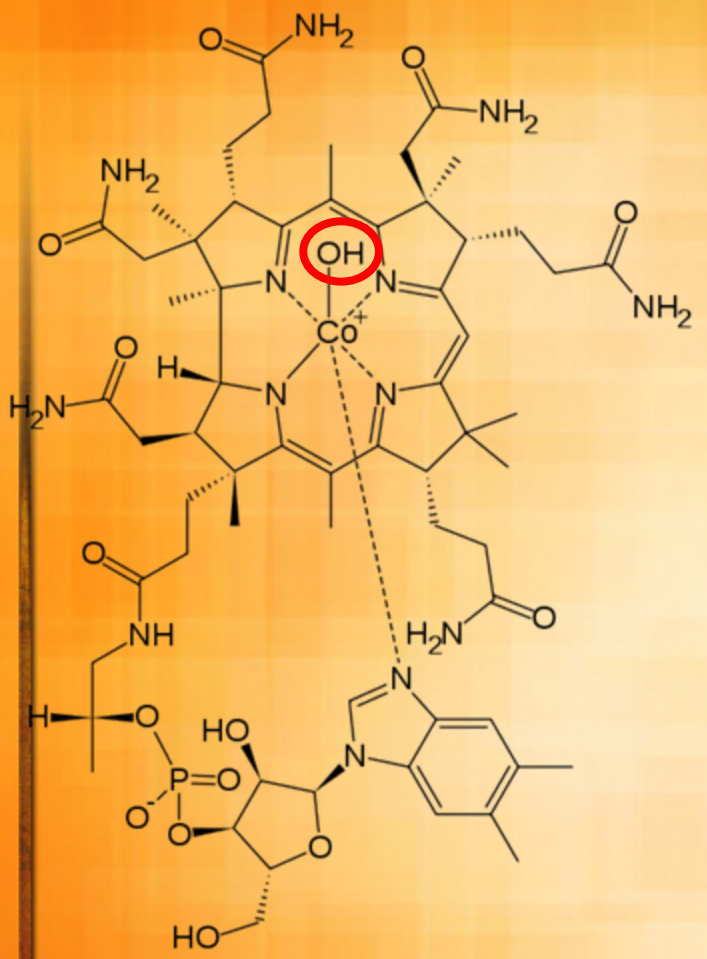
- Sulfur donor to allow natural elimination of cyanide by rhodanese



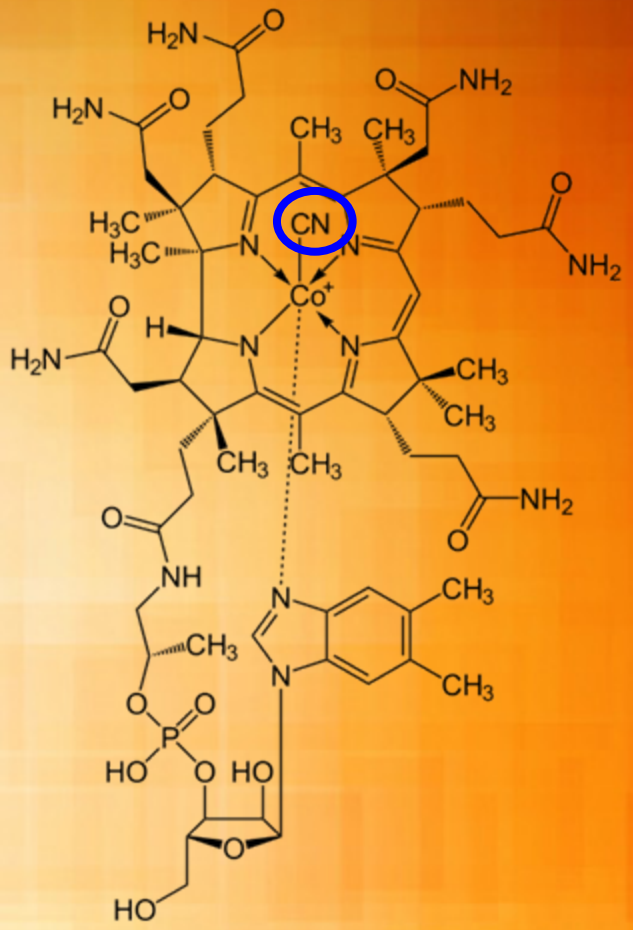
Cyanide Toxicity - Sulfur Donation

- Given via sodium thiosulfate
- Often in combination with inducing methemoglobinemia
  - Together increase lethal dose of cyanide 10-15x

Cyanide Toxicity - Treatment



Hydroxocobalamin



Cyanocobalamin

Cyanide Toxicity - Hydroxocobalamin

- Standard of care
- Rapid, safe, nontoxic
  - Side effects: Red skin, urine, mucous membranes
  - May interfere with co-oximetry
- May be used with thiosulfate

Conclusion

- Inhalational injury requires rapid diagnostics and interventions
- Must have high index of suspicion for toxic exposures
- Airway evaluation is critical
- Beware your sat probe!

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