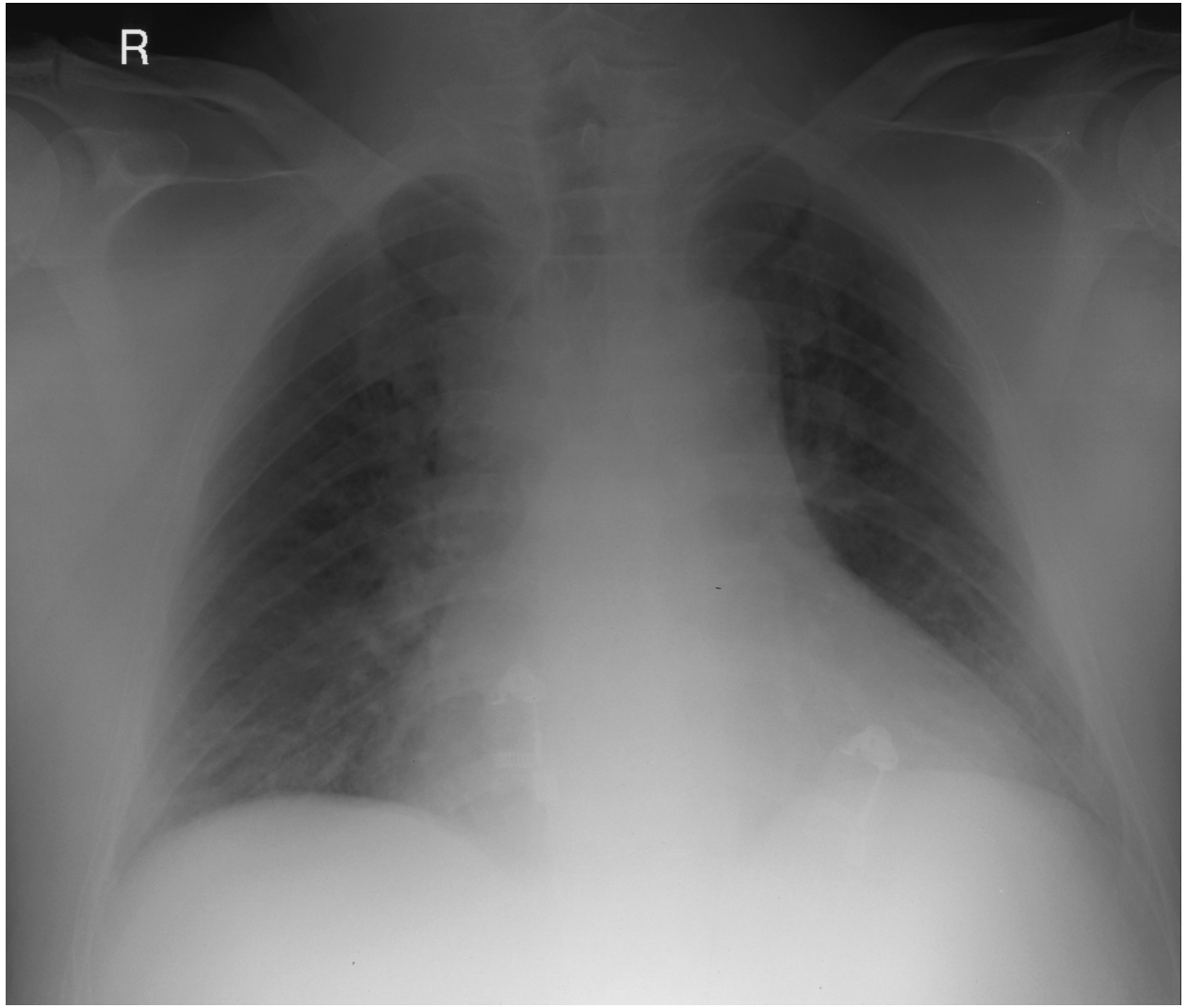
Not all turtles are slow

Chrysemys picta marginata; the diving turtle

47-year-old, shortness of breath and leg swelling for 2 weeks

- Unemployed Berliner, garden colony (*Laubenpieper*)
- No meds, “denies” alcohol intake
- BP 115/60, HR 96/Min, RR 36/Min
- Rales bilateral
- Distant heart sounds, no murmurs, ?S3
- Bowel sounds diminished
- Edema to sacrum
- Suspect CHF

Portable films are next to worthless



Acute labs

- Hb 13 g/dl, Hematocrit 38 vol%
- pH 7.30, $PaCO_2$ 20, PaO_2 105 (mm Hg), HCO_3 10,
- Na 123, K 6.9, Cl 87 (mmol/l)
- Glucose 5.6 mmol/l
- Lactate 14 mmol/l
- Anything life threatening here?

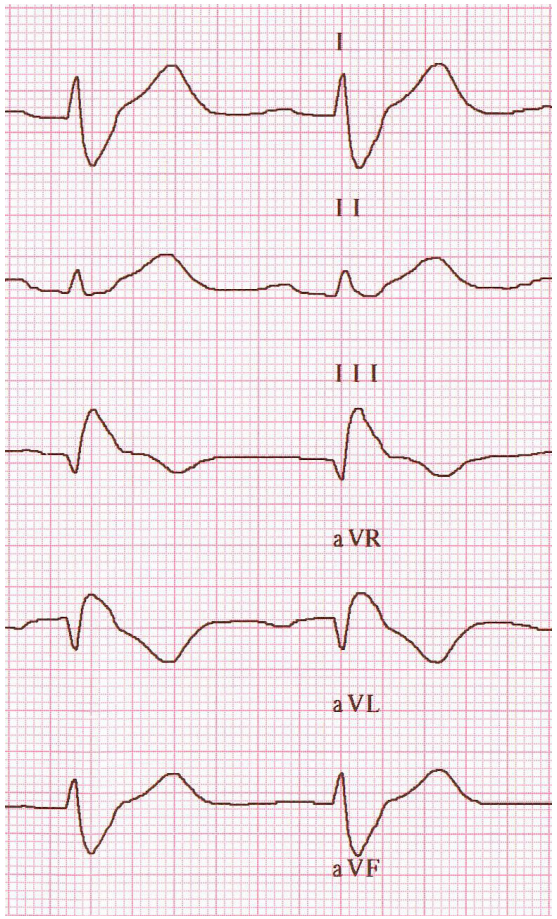
Anything lethal here?

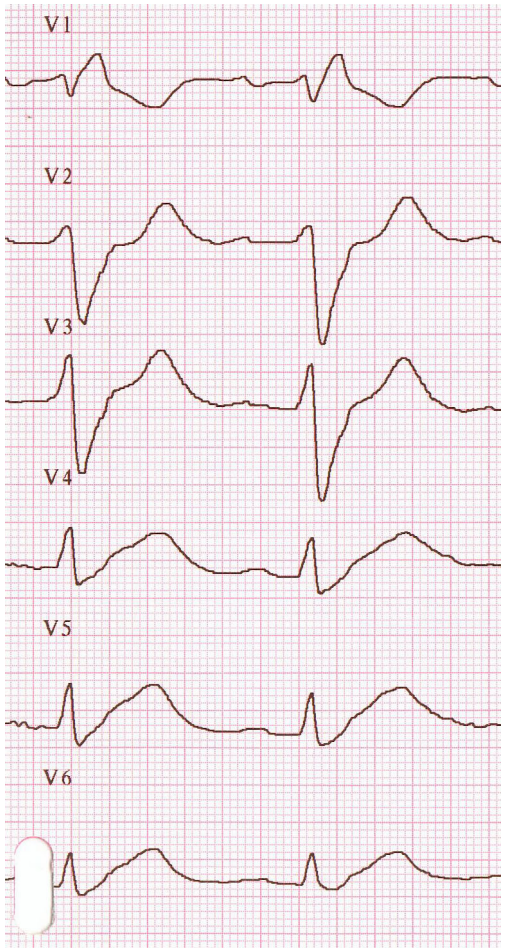
- Acid-base problem?
- Hyperkalemia?
- Hyponatremia?
- Poor oxygen delivery?
- Heart failure?
- Just being in our ICU?

The answer is „jawohl“!

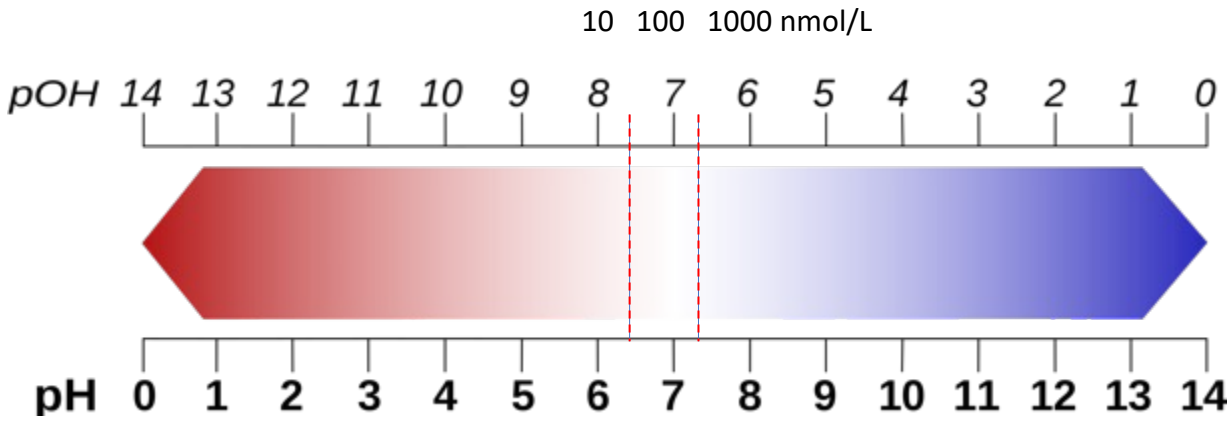
- Alveolar Gas Formula (Sea level)
- $PAO_2 = 150 - (PaCO_2)/0.8$ [RQ]
- = 150 - 105 + 25 = 20 mm Hg
- A-a gradient modestly elevated (not a problem).
- What is the hydrogen ion concentration at pH 7.30?
- How many people die because of hydrogen ions?
- None!

How about Hyperkalemia?

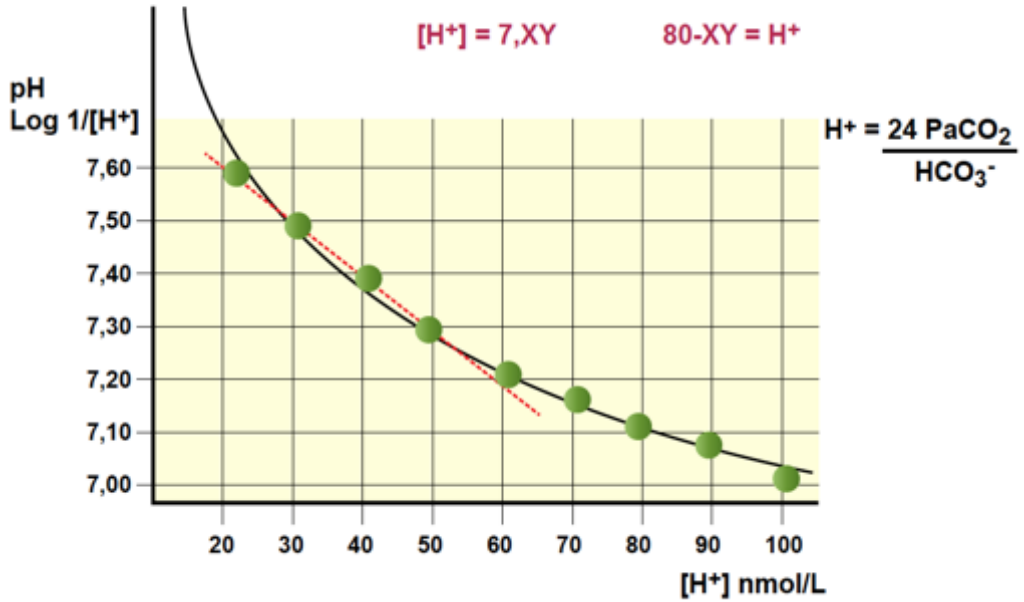




The pH was 7.30. What is the [H^+] in nanomols per liter



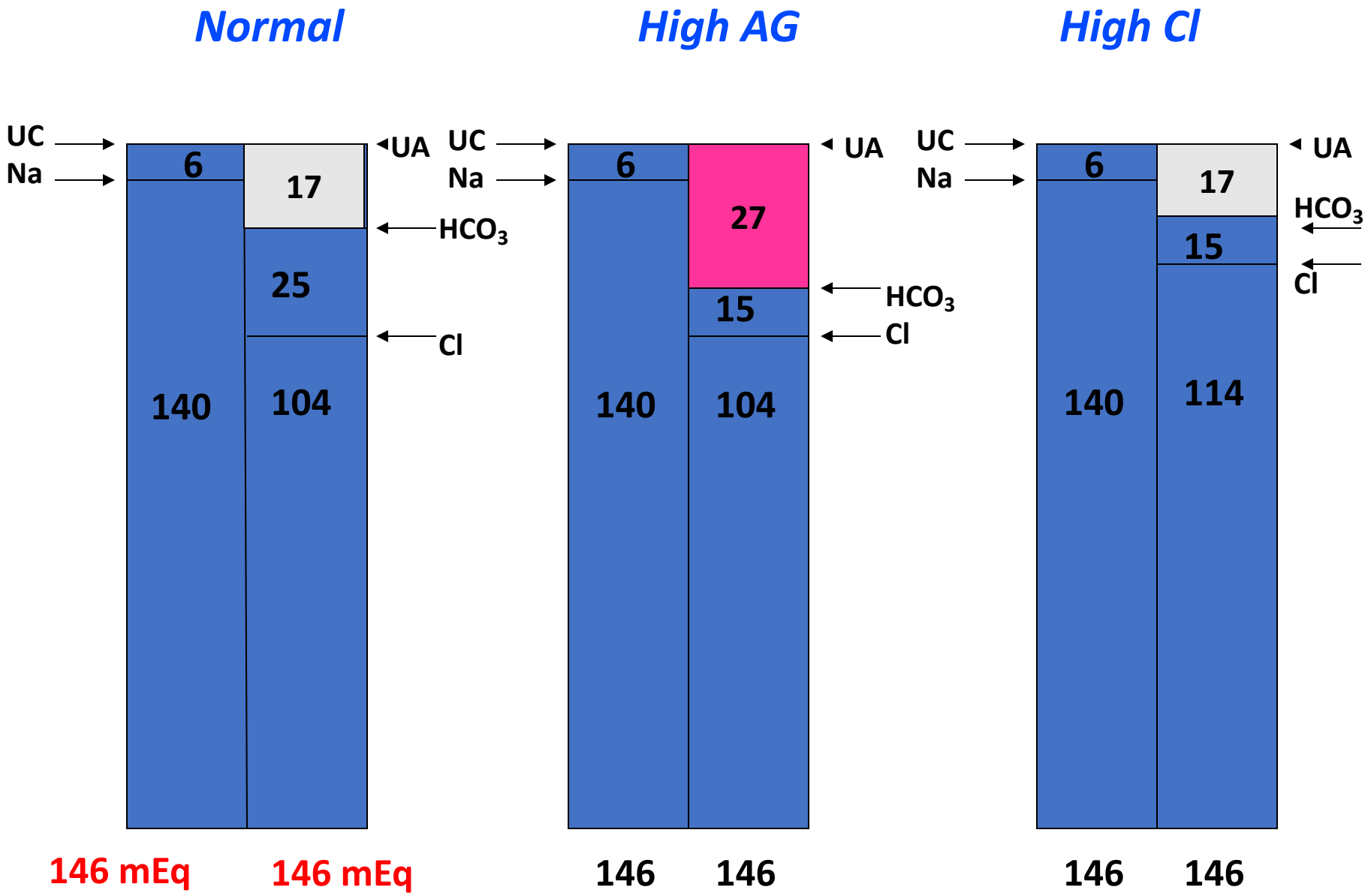
"PUISSANCE" HYDROGEN
Sorensen & Hasselbalch



Now the "nitty-gritty"!

- Is there an acid-base problem?
- Acidemia with a low HCO_3 and low $PaCO_2$
- Metabolic Acidosis
- HCO_3 fell by 15 mmol (25 to 10)
- Decrease in $PaCO_2$ was 20 mm Hg
- Metabolic Acidosis, slightly overcompensated ie. respiratory Alkalosis

Metabolic acidosis is caused by gain of [H^+] or loss of [HCO_3^-]



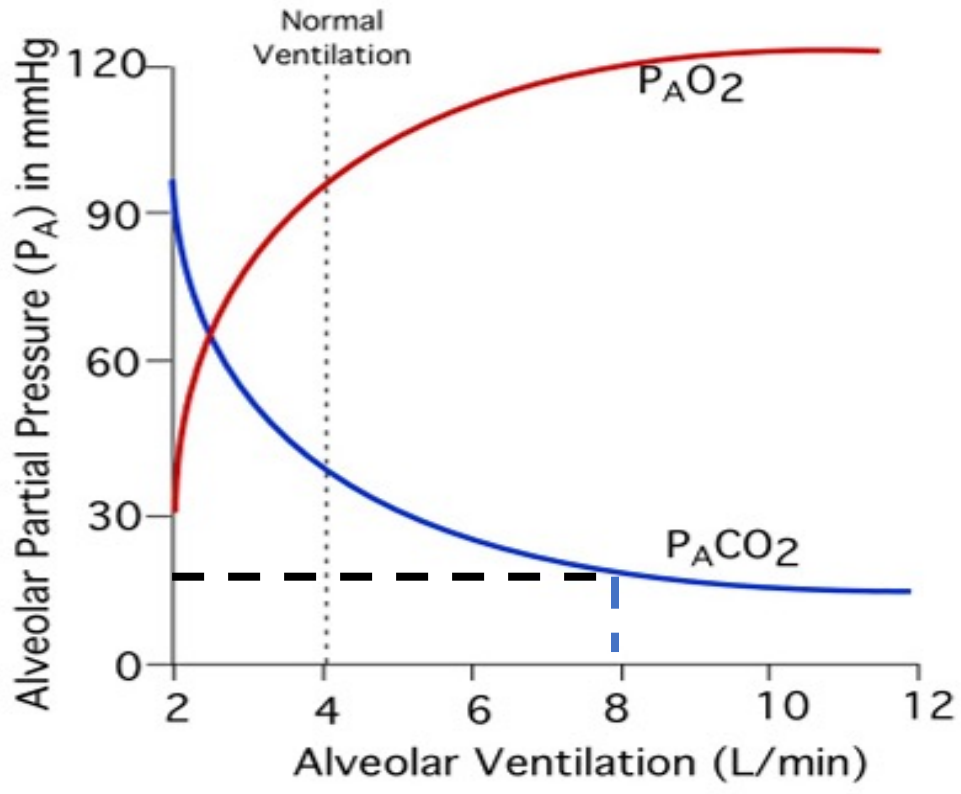
Laubenpieper has an elevated AG

- AG = Na - Cl - HCO_3 = 26 (12±2)
- AG is 14 mmol/l too high
- Lactate is elevated by 14 mmol/l
- Ahah! For every mmol/l increase in lactate we observe one mmol/l increase in AG
- „Delta“ for „Delta“
- So we have a pure anion-gap metabolic acidosis!

Is the respiratory compensation appropriate?

$H = (24 \times PCO_2)/HCO_3$

$PAO_2 = 150\text{-}Pa0_2 + PaCO_2/0.8$



Laubenpieper is shipped up to our ICU

- Leukocytes 16 000/μ^3
- D Dimer 0.48 mg/dl, Trop T 0.05 µg/l
- aPTT 18 sec, ALAT, ASAT, Bilirubin slightly elevated
- Crea 243 µmol/l, Urea 18 mmol/l
- Osmo 287 mosm/l
- Ethanol not detectable

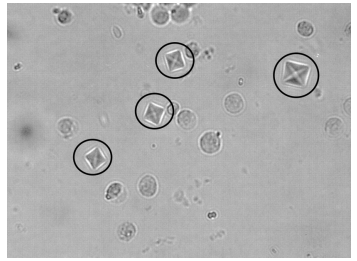
Can we dismiss methanol and ethylene glycol poisoning?

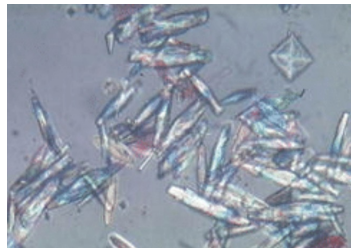
- Calculated Osmo = 2(Na+K) + Glu + Urea
- = 2(129) + 5.6 + 19 = 283
- Difference is only 4 mosm
- Most common cause of increased AG today?

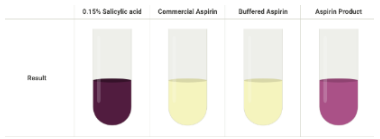
Mnemonics: Kussmaul or Goldmark?)

- Methanol; uremia; diabetic ketoacidosis (DKA); paraldehyde, phenformin; iron, isoniazid; lactic; ethylene glycol; salicylates (English)
- Kussmaul: Ketoazidose, Urämie, Salizyl-Säure, Metanol, Äthylenglykol, (mehr) Urämie, Laktat (German)
- Goldmark: Glycol, Oxoproline, L-Lactate, D-Lactate, Methanol, Aspirin, Renal Failure, Ketones

Can his urine tell us anything?





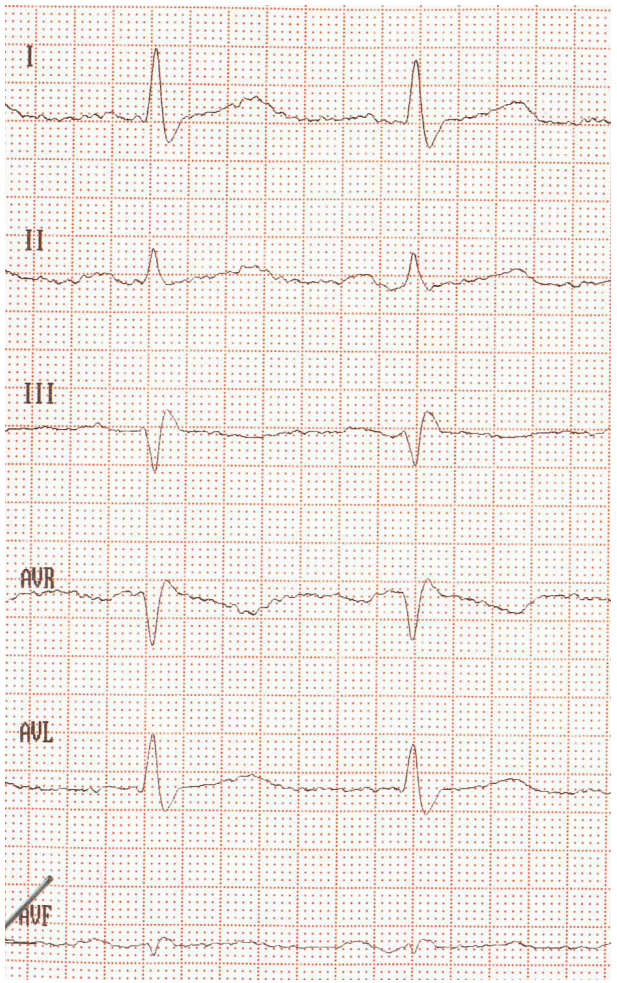


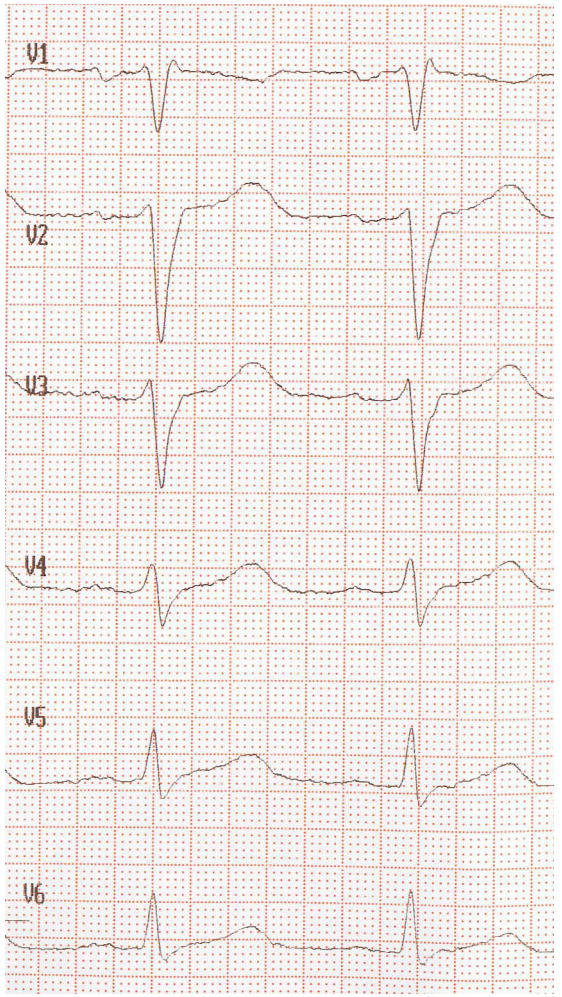
- Sediment for ethylene glycol
- Ferric chloride for acetyl salicylic acid, ketonuria, urea
- Lactate is 100% absorbed and does not appear in urine
- UK, UNa and UCreatinine

We check out his urine!

- UNa 10 mmol/l
- UCl 15 mmol/l
- UK 35 mmol/l
- Sp.Grav. 1.030 (What is Uosm??)
- Prot 2+
- WBCs und granulated cylinders
- Ketone not present
- Mnemonics lead us to lactate
- Prerenal acute renal failure?

Patient stayed oliguric despite a truck load of furosemide. Hemodialysis was done and fixed his ECG.





$Glukose+2ATP+2H_2PO_4 \rightarrow 2Lactate+2ADP+2H_2O$

- Lactate is the end product of anaerobic glycolysis
- Production is 1 mmol/kg/h, circa 2000 mmol/day for our 80 kg Laubenpieper
- Production in skeletal muscle, GI tract, brain and erythrocytes
- The liver uses it (for gluconeogenesis) or for fuel

Glycolysis

Glycogen

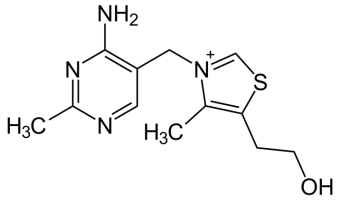
↓ ← Epinephrine

Glucose

↓ ← Alkalosis

2 Pyruvate —LDH→ 2 Lactate + 47 kcal

Tissue hypoxia
Endotoxin
Thiamine deficiency ⊣ PDH complex

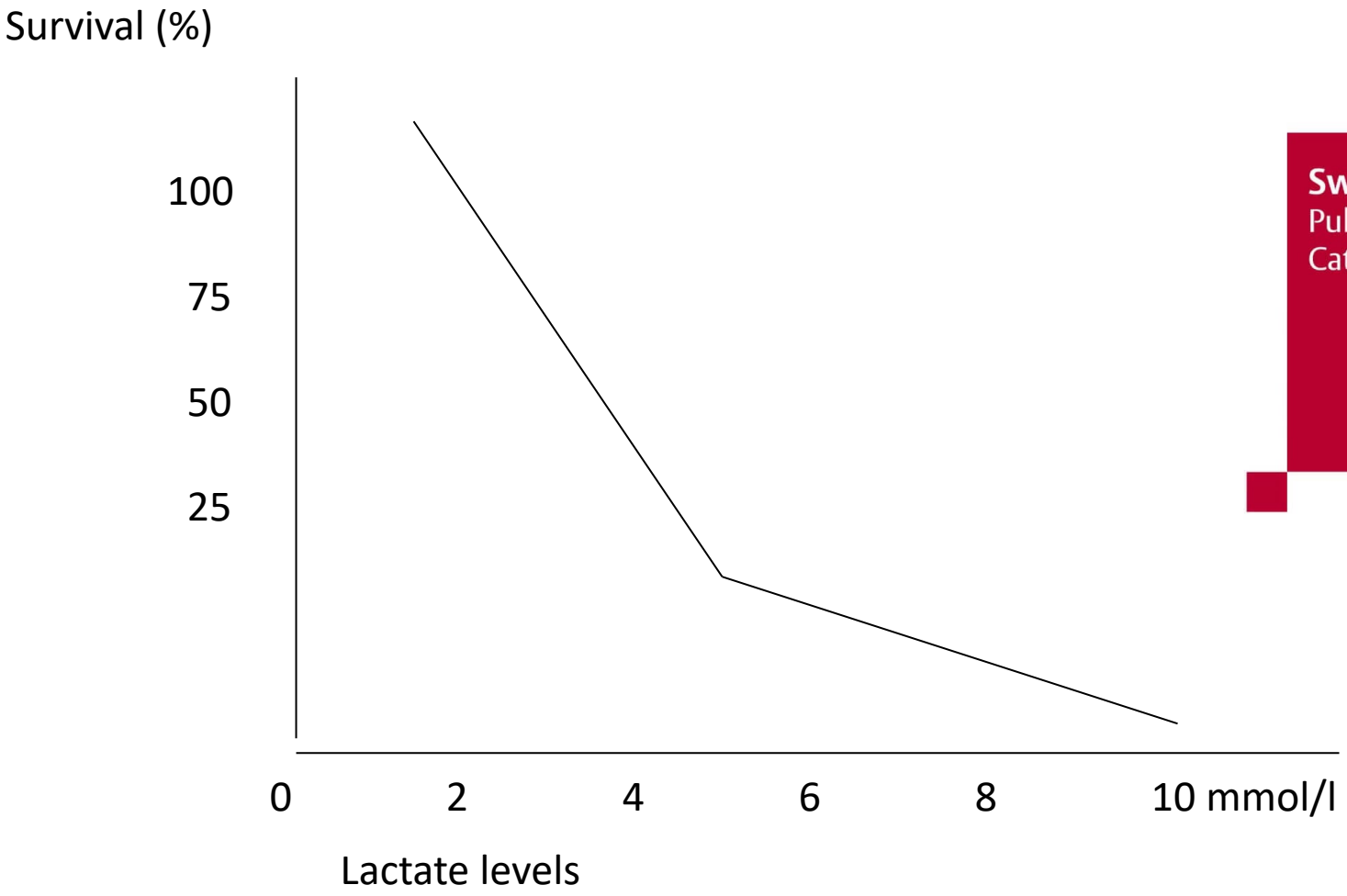


(Oxidation) → 673 kcal

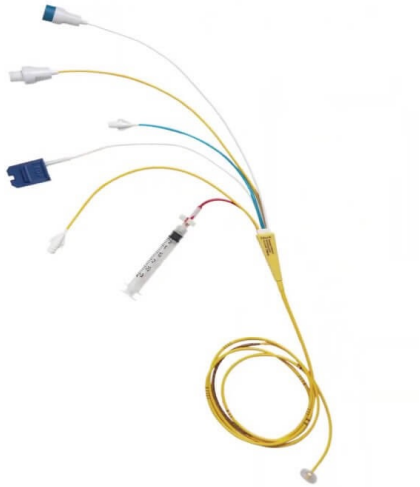
(Oxidation) → 652 kcal

(Gluconeogenisis) → Glucose

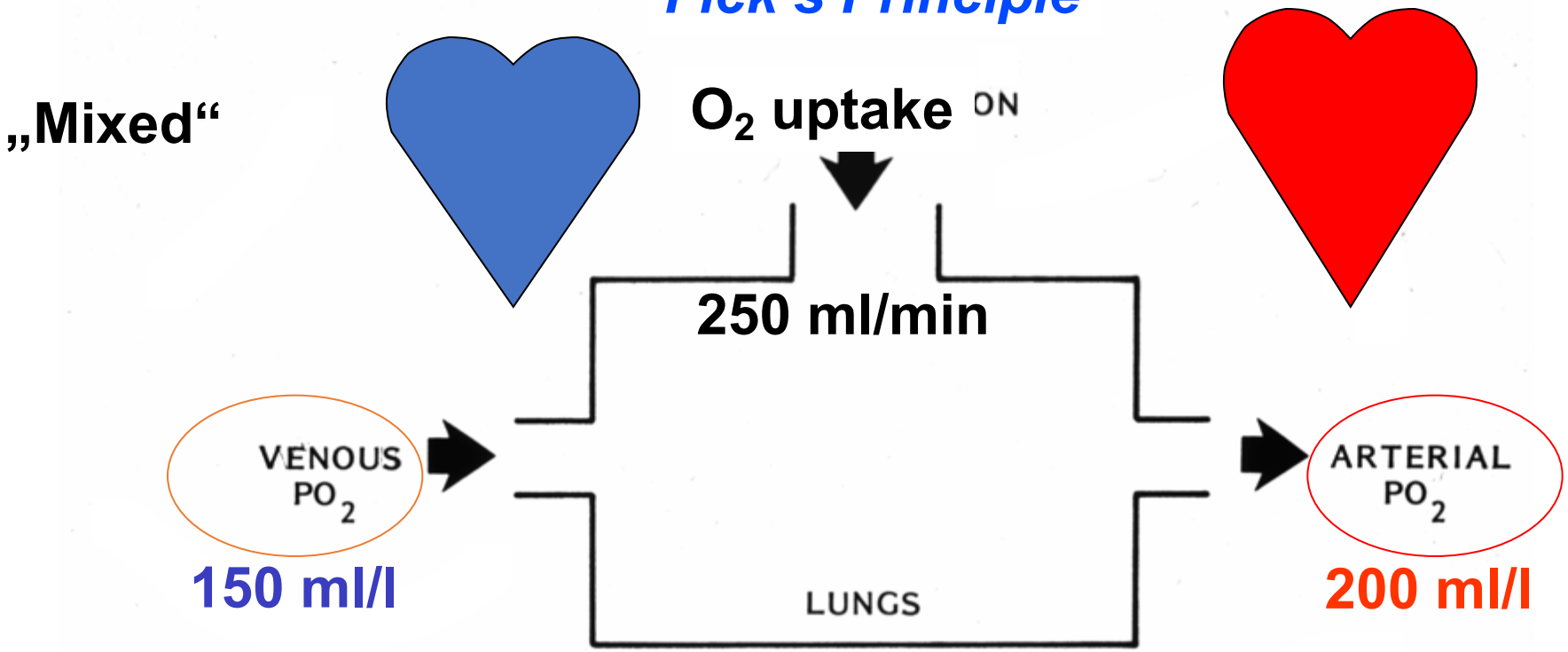
Tissue hypoxia - lactate associated with shock (Circulation 1975)



Swan-Ganz
Pulmonary Artery
Catheter



Fick's Principle



$$\text{C.O. (5 L/min)} = \frac{250 \text{ ml/min}}{CaO_2 \text{ (200 ml/l)} - CvO_2 \text{ (150 ml/l)}}$$

C is "content" i.e. Oxygen content

But Laubenpieper was not in Shock!

- CVP 25 mm Hg
- PCWP 20 mm Hg
- CO 9 l/min
- Peripheral resistance 336 dyne/cm^{-5}
- What was DO_2, consumption VO_2 and O_2 extraction?
- No Swan-Ganz catheters, unless you can do this!

$$R = \frac{\Delta p}{\dot{V}}$$

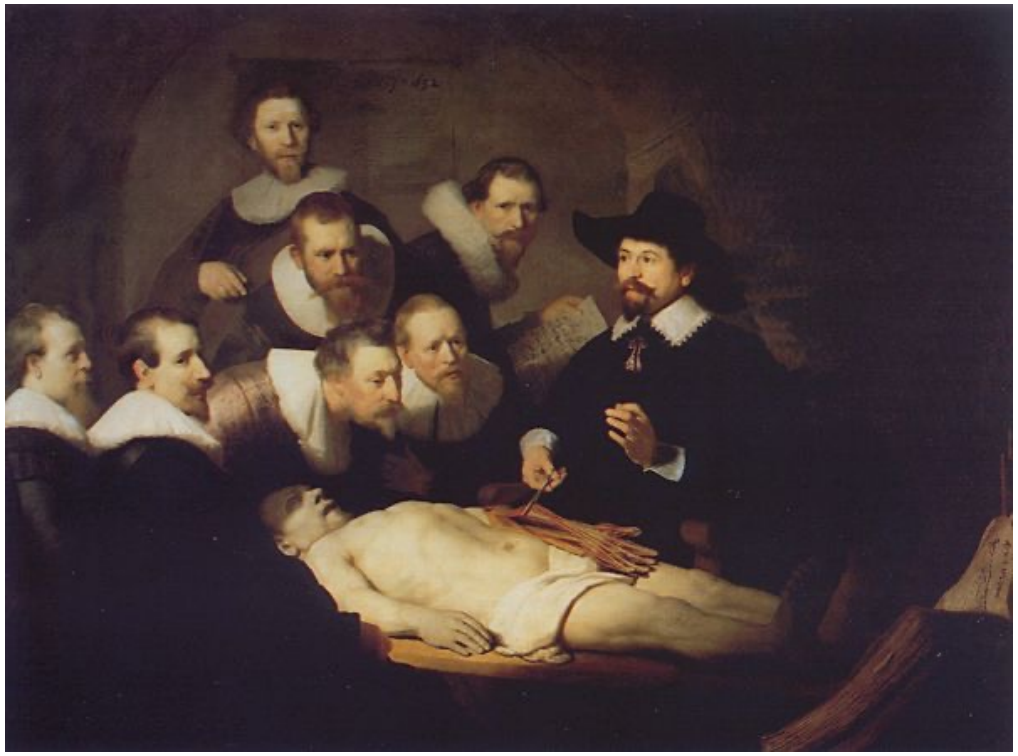
High output heart failure

- Hb(13 g/dl) x 1.34 = 17.4 ml O_2/dl or 174 ml/l
- CO = 9 l/min
- DO_2 = 174x9=1566 ml/min (O_2 offered per min.)
- $VO_2 = DO_2 \times (SaO_2 - SvO_2)$
- SaO_2 = 100%
- PvO_2 was 60 mmHg; SvO_2 = 90% (40 mm Hg; 75%)
- VO_2 = 156.6 ml/min
- O_2ER = 10% (normal O_2ER is 25%)
- Why does the Laubenpieper not utilize O_2?

What leads to O_2 uncoupling?

- Poisoning cytochrome C oxidase
  - Cyanide, CO
- Dinitrophenol
  - Atractyloside (a plant glycoside)
  - Bongkrekic
- Metformin
- Disturbances of PDH
- Endotoxin
- Thiamine deficiency

Who first described Beriberi?



Nicholas Tulp aus Leyden, 1739
Rembrandt in the
“Anatomy demonstration”

Christiaan Eijkmann, polished rice, Nobel Prize 1929

Laubenpieper received Thiamine

- Within 12 h Lactate fell to 1 mmol/l
- pH rose to 7.4
- HCO_3 increased to 24 mmol/l
- O_2 extraction was 20%
- Cardiac function improved within 1 week
- Liver and renal function normalized
- Signed out against medical advice

Plasma values (mmol/l) of Chrysemys picta marginata

Prior to hibernation

- Na 117
- Cl 73
- HCO_3 39
- AG 5

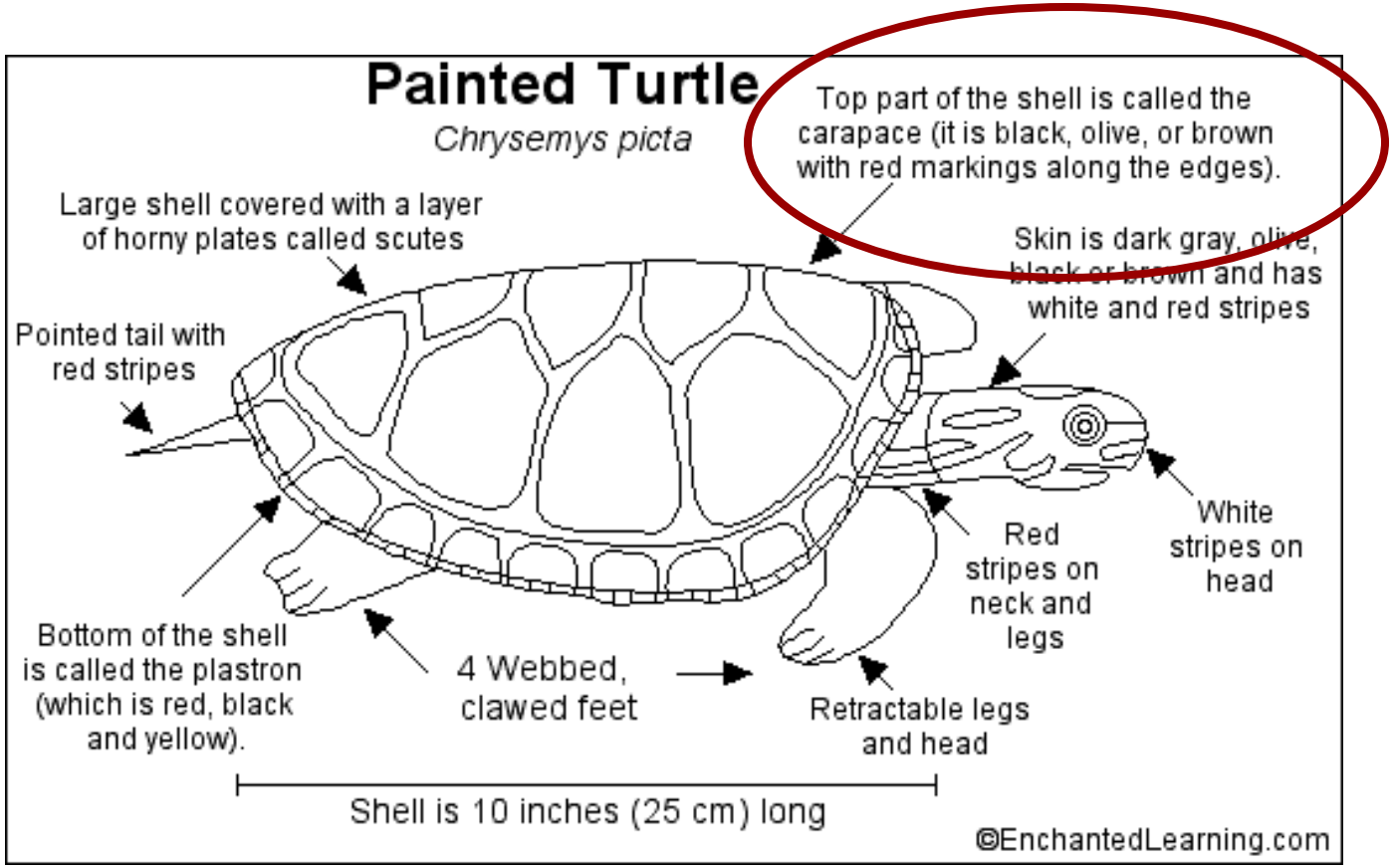
- Lactate 4
- K 2
- Mg 2.6
- Ca 3.7

Stuck under water for 5 months

- Na^+ 99
- Cl^- 44
- HCO_3^- 5 Δ34
- AG^- 50 Δ45

- $Lactate^-$ 185 Δ181
- K^+ 10
- Mg^{2+} 12
- Ca^{2+} 59

A physiological lactic acidosis



HCO_3 decease is much lower than would be expected than the lactate increase. Because H^+ Ions were buffered with $CaCO_3$ in the turtle's shell.

Teaching points

- Acid-base problems are not acutely lethal.
- Hyperkalemia (when treated) needs insulin (and glucose)
- Swan-Ganz allows metabolic assessments: DO_2 and VO_2.
- AG (like mosm/L) is a clinical tool, not a law of nature
- Lactic acidosis is today the most common cause of AG acidosis – there are two forms