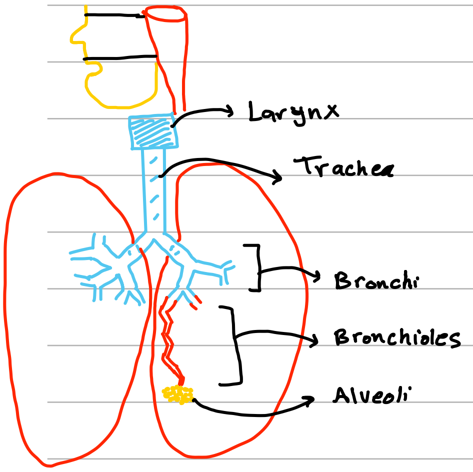
Respiratory Physiology 1

- Respiratory system → gas exchange +++
  → "Homeostasis" for → O_2, CO_2, pH

Arterial Blood gases (ABGs)
- P_aO_2 = 100 mmHg
- P_aCO_2 = 40 mmHg
- P_aH = 7.4

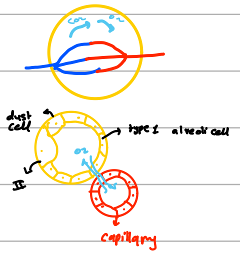
- Respiratory system depend on CVS → RS failure ⇄ heart failure

functional anatomy :-

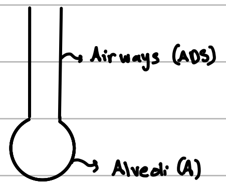


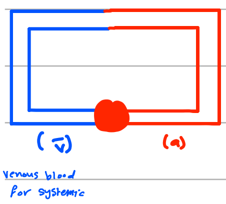
Conductive Zone (Airways)	Respiratory Zone
[no gas exchang]	[gas exchange]
(Anatomical Dead space)	

function
- → Conduction
- → humidification
- → warming & filtering



O_2 can cross Respiratory membrane :-
1. surfactant
2. Alveolar epithelium
3. Basement membran of alveoli
4. interstitium
5. Basement membran of capi.
6. endothelium.





* Respiration
  - → Ventilation
  - → External Respiration (gas exchange)
  - → transport
  - → Internal Respiration
  - → Cellular Respiration

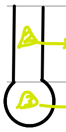
* in the Conducting Zone → flow = $\frac{\Delta P}{R}$

Resistance $\propto \frac{1}{r^4}$

- Bronchodilation → ↑ radius → $\downarrow^4$ R → $\uparrow^4$ flow.
- Broncho Constriction → ↓ r → $\uparrow^4$ R → $\downarrow^4$ flow.

* COPD → ↑ Resistance (disease)

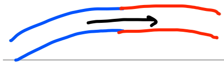
⊛ Composotion of ventilation :-



① → P(atm) = 760 mmHg
- 21% O_2 → 160 mmHg
- 79% N_2 → 600 mmHg
- 0% CO_2
- 0% H_2O

② → P = 760 mmHg
- 47 mm H_2O vapor
- 21% O_2 → 150
- 79% N_2 → 563

③ → P_{AO_2} = 100 · P_{ACO_2} = 40



$P\bar{v}\ O_2 = 40$ $Pa\ O_2 = 100$

$P\bar{v}\ CO_2 = 45$ $Pa\ CO_2 = 40$

Alveoli Volume >>> Capillary Volume

* one third of the Respiratory membrane is being used, the other two thirds are kept for reserve

* O_2 difusion is very high (تعبر اي حاجز كأنه مش موجود)

* CO_2 " " even x20 higher

⊛ type 1 Lung failure → ↓ O_2 - CO_2

⊛ type 2 Lung failure → ↓ O_2 ↑ CO_2

⊛ Hypoxia :

↓ O_2 utilization by cells

↳ Inadequate oxygenation
- ↑ altitude
- Chocking
- muscle Palarysi

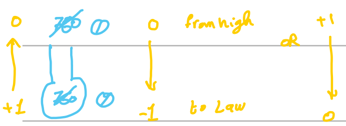
, or the cell itself suffers from toxins like ① Cyanide poisoning ② Gram-negative bacteria.

↳ Pulmonary disease
- obstructive (most common) ↑R
- Restrictive ↓ Compliance, ex: Pulmonary fibrosis
- Vascular, ex: pulmonary hepertension.

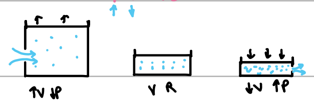
Respiratory physiology 2

* Mechanics of breathing

$$flow = \frac{\Delta P}{R}$$

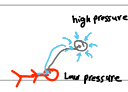


PV = K

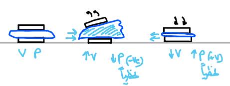


⇒

Positive Pressure breathing [Artificial]



Negative pressure breathing [normal]



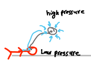
note

* في الوضع الطبيعي الرئة تزيد في الحجم

ما يسبب في دخول الهواء.

* اما في هذه الحالة، دخول

الهواء هو الذي يسبب في زيادة حجم الرئة

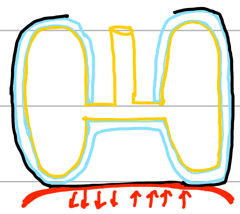


-ve pressure → during inspiration → p = 0 (equal) at the end

+ve pressure → during expiration → p = 0 (equal) at the end

- Inspiration → 2.1 ATP

Contraction of diaphragm
↓
expansion of thorax
↓
more (-ve) pleura
↓
↑ V Lung ⇒ (-ve) pressure Alveoli ⇒ flow inside

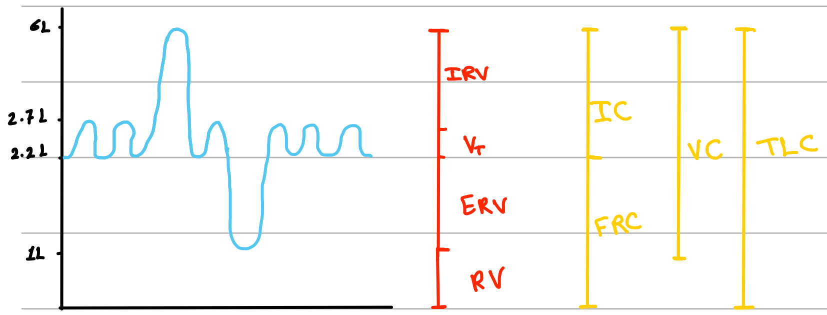


- Expiration → zero ATP

relax of diaphragm
↓
↓ thorax
↓
Less (-ve) pleura

↓ V (Lung) ⟶ +ve pressure (Alveoli) → flow outside

* Volumes of Capacities (part of Pulmonary Function Tests PFTs)



$IC = V_T + IRV$

$FRC = ERV + RV$

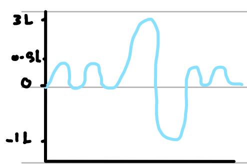
$VC = IRV + V_T + ERV = IC + ERV$

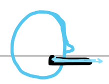
$TLC = \underbrace{IRV + V_T}_{IC} + \underbrace{ERV + RV}_{FRC}$

$TLC = IC + FRC$

$TLC = VC + RV$

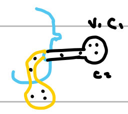
* spirometer





all number can be calculate except RV, FRC, TLC

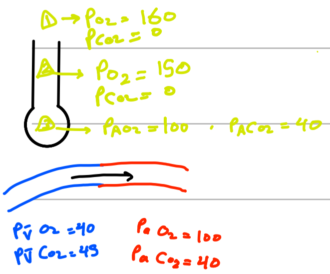
* He dilution method



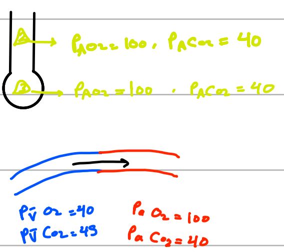
$V_1C_1 = V_2C_2$

$V_2 = V_1 + FRC$

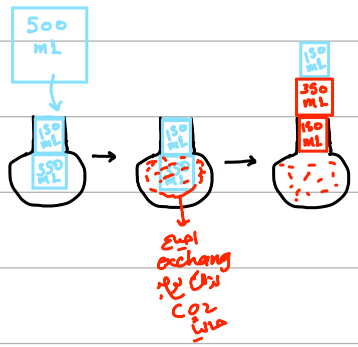
* Ventilation



(inspiration)



(expiration)



* RMV (Respiratory minute Ventilation) = T_v * RR (Respiratory Rate)

= 0.5L * 12 = 6L/m   [اذا لم يضعوا رقم في السؤال عن الـ 12 RR نفترض هذا الرقم].

Q = Perfusion ≈ V = Ventilation ⟿ V/Q ratio ≈ 1

if Q > V ⟿ wasted Perfusion

if V > Q ⟿ wasted Ventilation

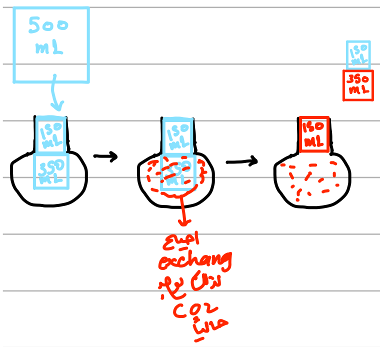
→ Av.MV = (T_v - ADS) * RR = 0.35 * 12 = 4.2 L   هذا تتم الاستفادة منه .

→ ADS.MV = ADS * RR = 0.15 * 12 = 1.8 L   هذا لايتم الاستفادة منه .

* PDS = ADS + wasted ventilation   , PDS ≥ ADS

(total or physiological dead space)

Respiratory Physiology 3



→ mixed Expiratory Air $\bar{E}$

$P_{\bar{E}}O_2 = \frac{350*100 + 150*150}{500} = 116$ mmHg

$P_{\bar{E}}CO_2 = \frac{350*40 + 150*0}{500} = 28$ mmHg

* P_{O_2} is highest in:-

A. art. blood ≈ 100

B. Alv. air = 100

C. Interstitial = 40

D. Mixed Exp. air = 116

E. ADS after Ins = 150

F. ADS after Exp = 100

Respiratory Diseases

%70 → Obstructive → ↑R (hard to exhale).

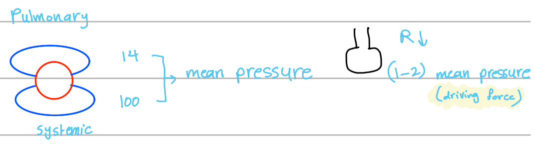
%20 → Restrictive → (hard to inhale)

%10 → Vascular

OHM Law

flow = $\frac{\Delta P}{R}$, $R \propto \frac{1}{r^4} \propto \frac{1}{A^2}$ * net cross sectional area

☺ Small resistance in Air way → Little driving force.

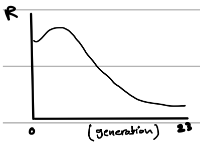


* if R increase

→ we need more ΔP

→ more work.

* more R in Larg airways (less net area).



* Variation of R (mainly from bronchioles)

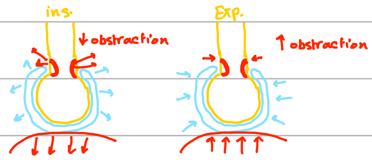
no Cartilage

dilation or constriction ↑SM
↓R ↑R

goblet cells → can be blocked by mucus

* when R is increase :-

- R is more during expiration



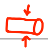
- variation of R → patho
→ physio → sym / para

sym: (Epi, NE,...) → B_2 → dilation (↓R)

para: Ach → receptors → constriction (↑R)

* Obstructive Disease

. Asthma



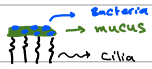
↓A ↑R

Hypersensitivity + chronic inflammation
(spasm)

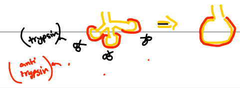
treat → SABA + ICS
عند حدوث التضيق / بشكل يومي

. COPD

→ Chronic Bronchitis

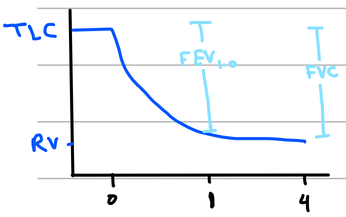


→ Emphysema



↑R ↓SA destraction of capillary

*Tests (Pulmonary function test (PFT))



① FEV1.0 / FVC

* diagnosis

> 70% normal oR Restritive

< 70% obstructive

↳ Variability (≥ 12% FEV1.0) → asthma

بعطي المريض SABA ، اذا كان التحسن ≥12% من الـ (FEV1.0) يكون (Asthma)

↳ non Variability → COPD

② FEV1.0

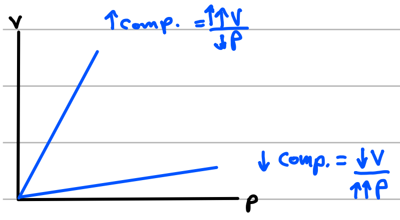
	Pred	obs	obs/ pred	
	4	4	100%	normal
	4	3	75%	

Staging
(60 – 80)% mild .
(40 – 60)% modarate .
< 40% severe .

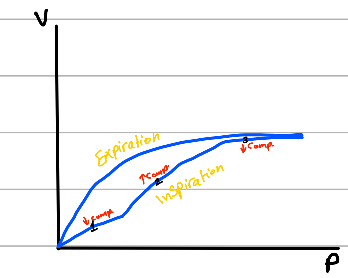
Respiratory Physiology 4

* Compliance

- how easy to expand
- compliance = $\frac{\Delta V}{\Delta P}$



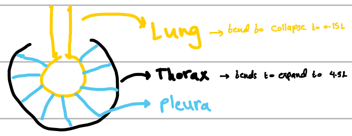
* inflation – deflation curve

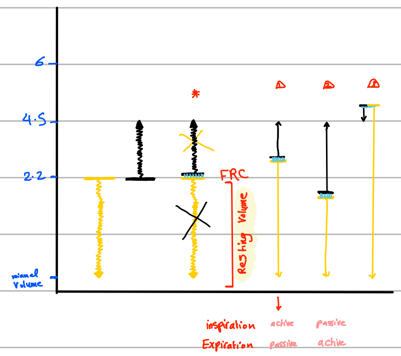


* Hysteresis :-
* Expiration differ from inspiration in the comp.
* Expiration more compliance than inspiration

*بالوضع الطبيعي نحن نتنفس حسب المرحلة الثانية .

* Lung – thorax system :-

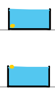




* ⇝ in the system the two forces are equal .
(1) ⇝ the system tends to collapse .
(2) ⇝ the system tends to expand .
(3) ⇝ the system tends to collapse .

* clinical application .

- Stilbirth ⇝ no volume
- born took breath ⇝ volume

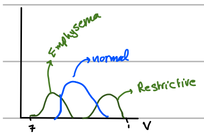


هذا التطبيق يستخدم في حالة وفاة الطفل محروقة اذا توفي في الرحم قبل ولادته او بعد الولادة مباشرة .

● ⇝ piece of Lung

* Compliance of Lung – Thorax < Compliance for Lung OR for thorax

* Emphysema ⇝ ↑compliance , FRC :- higher.
* Fibrosis , RDS ⇝ ↓compliance , FRC :- Lower.



(الارقام هون بالعكس)

⊛ Work of breathing

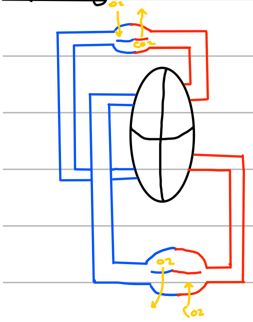
- 70% ↳ Elastic (static)
  - ⅔ ↳ Elastic fibers
  - ⅓ ↳ Surface tension
- 30% ↳ Non-Elastic (dynamic)
  - 20% ↳ Viscosity
  - 80% ↳ Resistance

Respiratory Physiology 5

*** Circulation** [* Starling forces]

Pulmonary — cardiac output (Co) = 5L

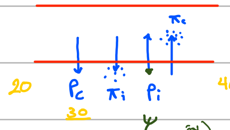
↓MAP
↓R



Systemic — cardiac output (Co) = 5L

↑MAP
↑R

*** systemic**



(يحق يمكن يكون اتجاه الـ P_i اما للداخل او للخارج)

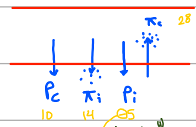
filtration 30L/d — reabsorption 27L/d

↓ Lymphatics 3L/d

Right lymph duct — Thoracic duct

480 mL/d — 2400 mL/d

*** Pulmonary**



يعني للخارج

↓↓↓ P_c → we don't need much filtration.

↑ π_i

P_i → more negative

Net filtration pressure (NFP)

10 + 14 + 5 − 28 = +1 (Low)

هون الكمية قليلة مقارنة مع الـ(systemic) لأنه هون لا احتاج اني (filtration) كثير فقط احتاج هنا للـ(exchange) ولذلك تحصل الـ(edema).

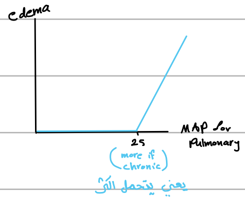
Safety factor ↑↑ Lymphatics

* Pulmonary edema

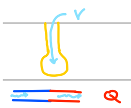
Cases :-

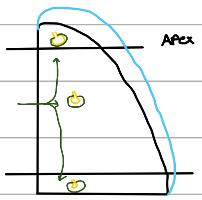
① left heart failure.

② damage to membrane.

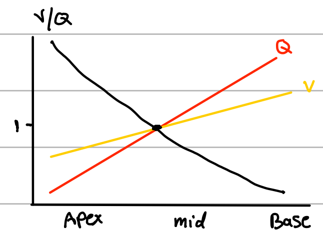


*** V/Q** ≈ 1





Apex	↓V	↓↓Q	$\frac{V}{Q}$ $\frac{\downarrow}{\downarrow\downarrow}$	>1	over ventilated, wasted vent.
	V	Q	$\frac{V}{Q}$	≈ 1	✓
Base	↑V	↑↑Q	$\frac{V}{Q}$ $\frac{\uparrow}{\uparrow\uparrow}$	<1	overperfused, wasted perf.



$VQ = \frac{V}{Q} = \frac{4.2}{5} \approx 0.84$ (normal)

* PDS = ADS + wasted ventilation

* Pathology :-

① Pulmonary Empolism (PE)

$\uparrow \frac{V}{Q} = \infty$ (Q → zero)

② obstruction

$\downarrow \frac{V}{Q} = $ zero (V → zero)

Zones of blood flow :

Ⅰ $P_A > P_a > P_v$ — [No flow] in cases of diseases

Ⅱ $P_a > P_A > P_v$ — [Intermittent] منقطع — Apex

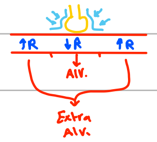
Ⅲ $P_a > P_v > P_A$ — [Continuous] most of the lung; exercise → all the lung

* bleeding → ↓Co → (تصير تقلبات في الـ P_a, P_v) — Zon I ↑, Zon II ↑

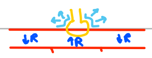
* Ventilator → ↑ P_A — Zone I ↑, Zone II ↑

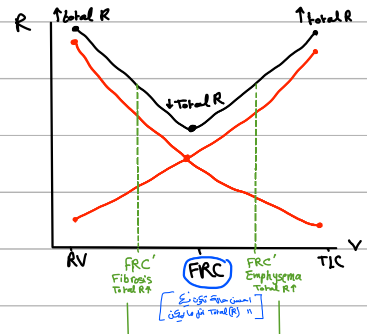
* Pulmonary Vascular Resistance.

↓Volume of air (RV)



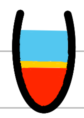
↑Volume of air (TLC)





↑after load → heart failure

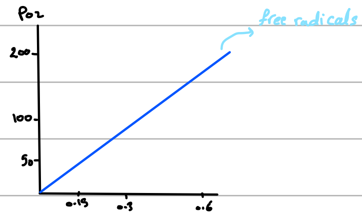
Respiratory Physiology 6



Blood
- cell (%45)
  - RBC
  - WBC → Immunity
  - Palelelets → clotting
- plasma (%55) → wat

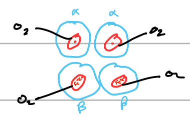
* O_2 Transport

① Dissolved in plasma → 0.3 mL/dL



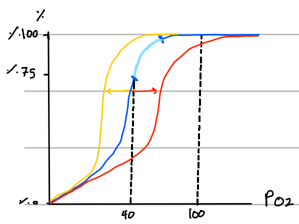
Henry's Law

② Hemoglobin → 20 mL/dL



1 g Hb $\xrightarrow{100\%}$ 1.34 mL

15 g Hb $\xrightarrow{100\%}$ 20 mL/dL



cooperativity (sigmoid)

Left (↓affinity)
- ↑ Temp
- ↑ CO_2, ↑H^+ (Bohr)
- 2,3 BPG

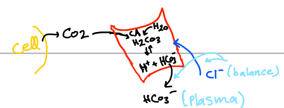
Right (↑affinity)
- ↓Tem.
- ↓ CO_2, ↓H^+
- co poisoning
- fetal Hb

* CO_2 transport

① dissolved %10

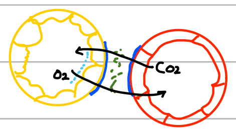
② Carbaminohemoglobin %20

③ HCO_3^- %70



Respiratory Physiology 7

* Diffusion (→ Passive) "External Respiration"

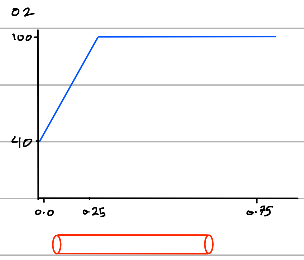


$$D = \Delta P \times \frac{A}{T} \times \frac{Sol}{\sqrt{MW}}$$

A → surface area
T → thickness
$\frac{Sol}{\sqrt{MW}}$ → أقل العوامل تأثيراً

A/T → Lung; Sol/√MW → gas OR diff. coeff.

diff. coeff. → $O_2 = 1$, $CO_2 = 20$, $CO = 0.8$



If I want to increase the amount of (O_2), there is no limited diffusion, but I increase the perfusion.

⊛ O_2 Content

$P_aO_2 = 100$ mmHg → $P_{O_2} = 40$ → $P_vO_2 = 40$ mmHg

[Hb] = 15 g/dL, 100%, 20 mL/dL

Extraction: 5 mL/dL, % 25 (variable)

[Hb] → 75%

* Anemia

[Hb] = 7.5 g/dL $\xrightarrow[1.34]{100\%}$ 10 mL/dL

Extraction

5 mL/dL ⇒ ratio = 50%

Hb in veins 50% saturated ⇒ $P_vO_2 = 26$

in the anemia ......

- (O_2) content ↓
- P_aO_2 = constant (100 mmHg)
- Extraction amount = constant.
- Extraction ratio ↑
- saturated of hemoglobin in the veins ↓
- → P_vO_2 ↓

⊛ muscle at rest

100 → 40

⊛ at exercise ??? ⇝ no change

⊛ Co Poisoning

- → Competitive ⇒ ↓ O_2 content
- → Sift to (left) Right

⊛ P_aO_2 = ~~100~~ > 95 normal

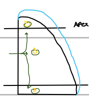
Cases ......

↳ shunt (physio.)

* Bronchial circulation → veins drain into the pulmonary circulation
* Cardiac veins → veins drain into the left atrium.

↳ V/Q mismatch

↓



	V	Q	V/Q				
Apex	↓V	↓↓Q	$\frac{V}{Q}$	$\frac{\downarrow}{\downarrow\downarrow}$	>1	over ventilated wasted vent.	Ex. P_{O_2} = 130 mmHg
	V	Q	$\frac{V}{Q}$		≈ 1	✓	P_{O_2} = 100 mmHg
Base	↑V	↑↑Q	$\frac{V}{Q}$	$\frac{\uparrow}{\uparrow\uparrow}$	<1	over perfused wasted perf.	P_{O_2} = 90 mmHg (more volume)

* higher than 100mmHg (Apex) cannot compensate ???.
- because, already 100% saturation.

⊛ O_2 consumption, CO_2 production

(V_{O_2}) (V_{CO_2})

* V_{O_2} = CO * extraction

$$= 50\ \frac{dL\ (blood)}{min} * 5\ \frac{mL\ (O_2)}{dL\ (blood)}$$

$$= 250\ mL\ (O_2)/min$$

diet	(RQ)
- carbs	1.0
- protein	0.8
- fat	0.7
- mix	0.8

$$* RQ = \frac{CO_2}{O_2}$$

$$0.8 = \frac{V_{CO_2}}{250} = 200\ \frac{mL\ (CO_2)}{min}$$

V.V. important note

The amount of (O_2) consumed doesn't necessarily equal the amount of (CO_2) produced

Respiratory Physiology 8

* transport & Extraction

O_2

- Dissolved in plasma

$0.003 * 100 = 0.3$ mL/dL

- Hb

$15 * 1.34 = 20$ mL/dL

O_2 extraction (5mL/dL)

$P_{O_2} = 100$ mmHg
↳ 0.3 mL/dL
↳ 20 mL/dL

5mL
↳ 0.18 from diss.
↳ 4.82 from Hb

$P_{O_2} = 40$ mmHg
↳ 0.12 mL/dL
↳ 15.18 mL/dL

VO_2 = O_2 Consumption.

$50 * 5 = 250$ mL/dL

- Can increase by :- Attention, there is a VO_2 max
  - ↳ ↑ extraction
  - ↳ ↑ blood flow

CO_2

① dissolved %10

② Carbaminohemoglobin %30

③ HCO_3^- %60

CO_2 Production (4mL/dL)

$(RQ) = \frac{CO_2}{O_2}$

$0.8 = \frac{CO_2}{250}$

$VCO_2 = 200$ mL/min

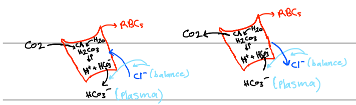
$0.8 = \frac{CO_2}{5}$

$VCO_2 = 4$ mL/dL

* why Hb is in RBCs ???

Protection for Hb
- Protease
- filtration in kidney

Tissue | Lung



(venous blood) | (arterial blood)

Ven $[Cl^-]$ plasma < Art $[Cl^-]$ plasma

Ven $[Cl^-]$ RBC > Art $[Cl^-]$ RBC

Ven $[HCO_3^-]$ plasma > Art $[HCO_3^-]$ plasma

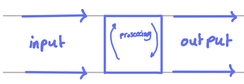
* Bohr's effect vs Haldane effect

$CO_2 \rightarrow H^+$ → release of O_2 (Tissue)

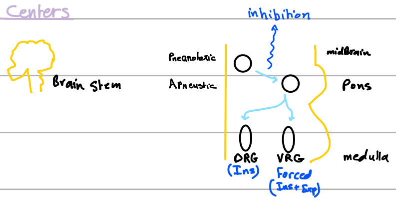
O_2 → relase of CO_2 (Lung)

Respiratory Physiology 9

* Control



* Centers



DRG → dorsal Respiratory group.

VRG → ventral Respiratory group.

* Inputs

[chemoreceptors]
- → CCR — BBB (Blood-Brain Barrier) — CO_2, H^+ — Medulla
- → PCR → aortic, carotid
  - ↓ $PiO_2 = PaO_2$

↓ +

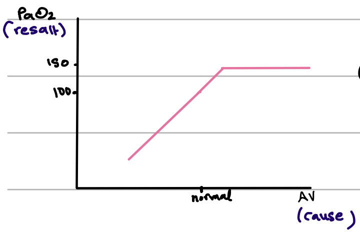
Proporeceptor (movement↑, breathing↑)

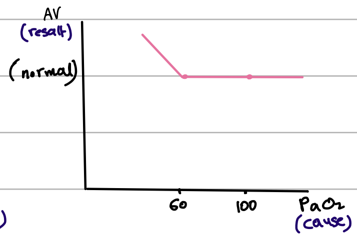
- → CO_2
- → H^+ → CO_2, Metabolism
- → O_2 < 60 mmHg

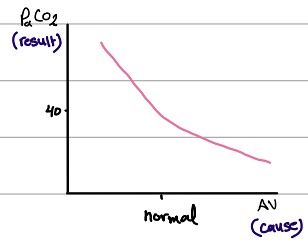
* output

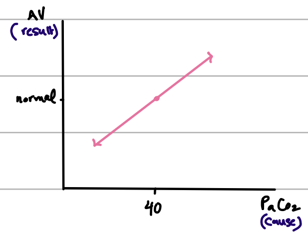
- by phrenic nerve ++

* P_aO_2 & P_aCO_2 & AV









* ↓↑ $P_aO_2 \propto \frac{\uparrow AV}{\uparrow \dot{V}O_2}$ (metabolism)	* ↓↑ $P_aCO_2 \propto \frac{\uparrow \dot{V}CO_2 \text{ (metabolism)}}{\uparrow AV}$

Q :-

1. exercise < metabolism ↑, AV ↑
   - PaO_2 = ?? no change
   - $PaCO_2$ = ?? no change

2. Met ↑, AV no change
   - $PaCO_2$ = ?? ↑
   - PaO_2 = ?? ↓

3. P_AO_2 ↑ & P_ACO_2 ↓ in :-
   1. FiO_2 ↓ 19% sea level P_AO_2 ↓
   2. ↑ AV, met no change P_AO_2 ↑, P_ACO_2 ↓
   3. ↑ met, AV no change

4. Anemia ⟶ AV = ??
   - PaO_2 ⟶ no change (100 mm Hg).
   - O_2 content ↓.
   - AV (no change).

5. breathing CO
   - PaO_2 ⟶ no change.
   - AV ⟶ no change.