Lecture 20, Apr 6, 2023

Changes During Normal Breathing

- Changes during normal breathing:
  1. Lung volume
     - Volume increases until the completion of inspiration, where P_A equalizes with the outside atmosphere
     - Then during exhale P_A becomes higher than atmospheric
  2. Pleural pressure
     - Before inspiration begins, $P_{pl} = -5$
     - Halfway through inspiration, the pleural pressure gets more negative, $P_{pl} = -6.75$ because you're expanding the size of the cavity
     - Pleural pressure reaches a minimum at the completion of respiration, $P_{pl} = -7.5$; at this point the lung recoil (transmural pressure) reaches a maximum, $P_{LR} = 7.5$
     - As the diaphragm relaxes during expiration, both pressures return to normal; halfway through respiration $P_{LR} = 6.65$
     - At the end of expiration everything returns to normal
     - The two ends of the path for pleural and lung recoil pressures are the same but the paths are slightly different
       * Negative pleural pressure drives inspiration, lung recoil pressure drives expiration
       * During inspiration the lung recoil pressure lags the pleural pressure and catches up at the end of inspiration
       * During expiration the pleural pressure lags the lung recoil pressure
     - The flow rate is directly proportional to the alveolar pressure, which is the difference between the pleural and lung recoil pressures

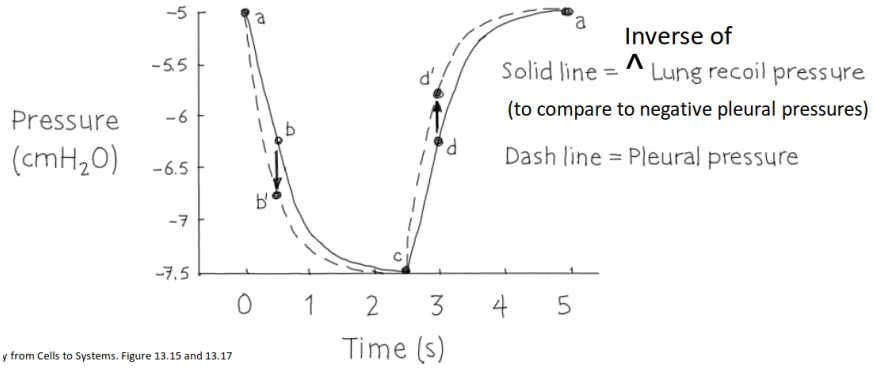

Figure 1: Changes in pleural and lung recoil pressure during breathing

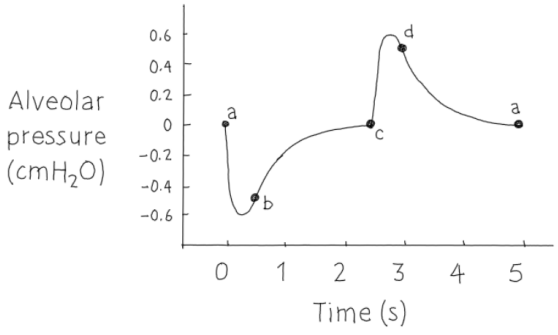

Figure 2: Changes in air flow during breathing

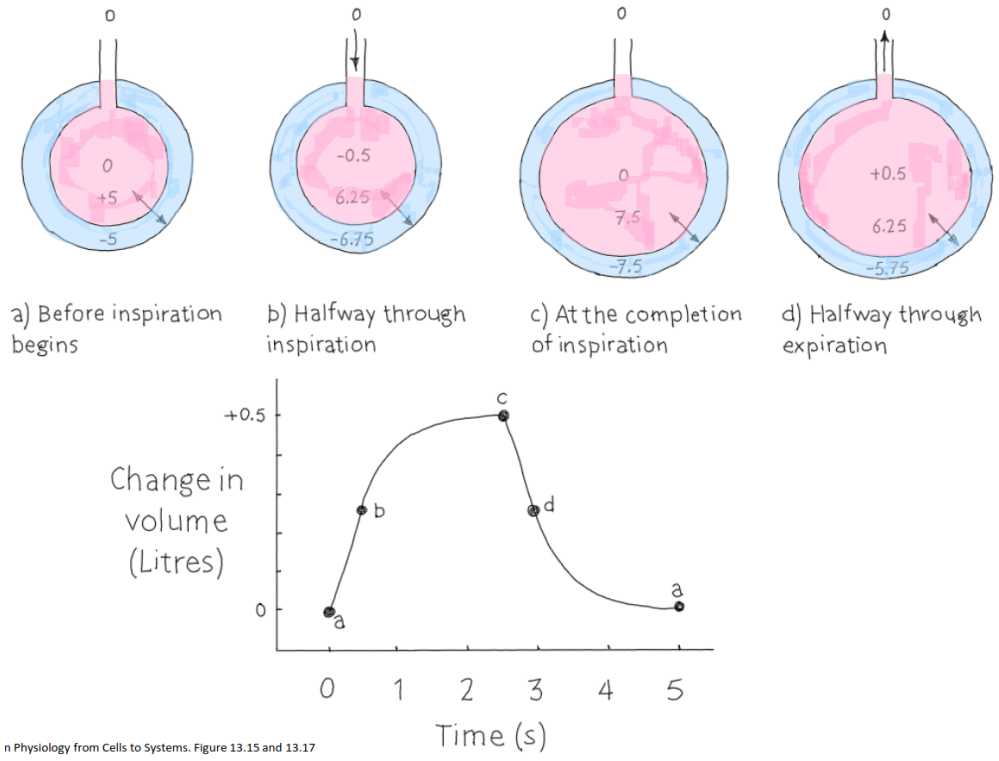

Figure 3: Changes in lung volume and pressure during breathing (relative change)

- Minute ventilation $\dot{V}_E = V_T \times f$ is the volume of gas breathed per minute; V_T is the tidal volume and f is the respiratory rate
  - Air exchange only happens at the ends of the lungs, so the upper airways are functional dead spaces that do not transfer oxygen
  - Expired gas is a combination of alveolar and dead space air, $\dot{V}_E = \dot{V}_A + \dot{V}_D$
  - If you breathe too fast, the breaths will be very shallow and only dead space air will be exchanged, which is why you feel lightheaded since you're not getting fresh air
  - Dead space volume is a constant offset subtracted from the total ventilation, about 0.15L
- In alveolar gas, the composition of water vapour and carbon dioxide get much higher and oxygen lowers

Spirometry and Lung Volume

- Residual volume is the amount of air left in the lungs no matter how hard you breathe
- Expiratory reserve volume is the amount of air you have left after expiration during normal breathing; this gives a functional residual capacity (ERV + RV)
- The tidal volume is the normal volume change during breathing
  - This is the sum of dead space and alveolar volumes
- The difference between the total lung capacity and the normal lung capacity after inspiration is the inspiratory reserve volume
- During typical breathing, only the tidal volume is exchanged; in forceful breathing, the IRV and ERV can be exchanged
- The total lung capacity cannot be changed, but IRV/ERV can be increased with training (with a stronger diaphragm muscle)
- The vital capacity is the sum of IRV, ERV and VT, and is the maximum volume you can exchange during breathing
- Inspiratory capacity is the sum of tidal volume and IRV, from the end of normal expiration to total

capacity

- Total lung capacity is the sum of vital capacity and residual volume
- RV cannot be measured directly with spirometry since it can only measure air coming out of or going into the lungs

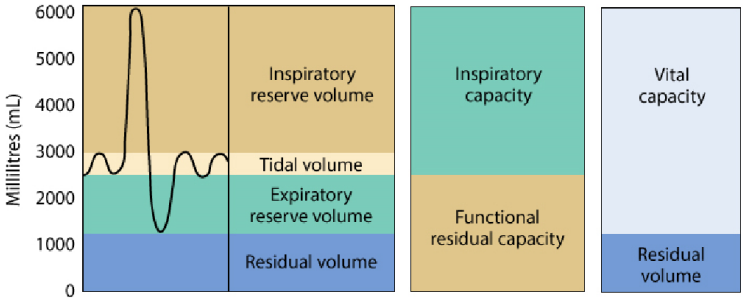

Figure 4: Lung volume and capacity breakdown