Inhalation is typically 1/2 liter. 

- **Inspiratory Reserve Volume.** How much you can inhale beyond the normal inspiration. About 2.5 liters in adults.
- **Expiratory Reserve Volume.** How much you can exhale beyond the normal exhalation. About 1 liter.
- **Residual Volume.** There is a quantity of air that remains in lungs after you have exhaled all that you can. This is residual volume. We cannot speak on residual air, because we cannot expel it. Residual air is important,

1. For maintaining the blood oxygen exchange. If there was no residual air, in the lungs, then blood oxygen would rise & fall with each breath.
2. Keeps lungs from collapsing

- **Dead Air.** Volume of air within the passageways to the lungs. Cannot be involved in blood/oxygen exchange. This is a component of residual volume and not a discrete volume by itself.

- **note about lung volumes. these are all discrete—that is separate—measures. tidal volume is never made of a combination of any of the others, etc. there is no overlap. they each represent discrete measurements.**

### Capacities

- **Vital Capacity.** The most you can exhale after a deep inhalation. The most useful measure of total lung capabilities. Includes all volumes except residual. About 4 liters in average adult.
- Vital capacity is affected by ...
  - size /shape/gender of person
  - strength of musculature
  - health vs. disease
  - also changes with age -- reduces in older individuals
- **Functional Residual Capacity.** The volume of air in the body at the end of passive exhalation. Includes expiratory reserve and residual volumes. About 2.5 liters.
- **Total Lung Capacity** is the sum of all lung volumes. How much air can you hold in the lungs when you hold as much as you can? Is the sum of all you normally inhale, plus all the extra you can inhale plus all that is residually there. About 5.1 liters.
- **Inspiratory Capacity.** The maximum inspiratory Volume possible after Tidal Expiration. Equals the Tidal Volume plus the inspiratory reserve volume. About 3 liters.
- Note that capacities are cumulative and represent a combination of volumes.

### Other Comments about the Amount of air.

- Quiet breathing is easily represented by tidal volume
  - Amount of air required is affected by age and activity. More air for strenuous work. Less for passive activities.
  - Laryngeal habits influence air & improper laryngeal habits waste a good deal of breath. Try talking in a breathy voice.
  - Interesting to note that not all speakers require more breath for loud speech than for normal speech
- Amount of air required for speech
  - With normal posture, speech requires a volume of air that is between 30 and 60 percent of the vital capacity. Recall that resting breathing, produces a volume that is roughly 1/2 of the vital capacity.

### Air pressure
spends 10% inhaling and 90% exhaling.

- Eventing out the air pressure over the whole expiratory cycle is known as the **checking action**.
  - During the beginning of a phrase this air pressure, exceeds the capacity of the speech mechanism to talk on, or use this air.
  - To compensate for this, the inspiratory thoracic muscles become operational and slow down the rate or pressure at which the air is expelled.
  - When the speaker gets about to the middle of the phrase/expiratory cycle, relaxation pressure is adequate for speech.
  - By the end of the phrase/expiratory cycle, passive relaxation pressure isn't enough. We need to increase the air pressure from the lungs.
  - Now we use **expiratory reserve**. Do this by using expiratory muscles. Abdominal muscles now "kick in" and give you additional time in the expiratory cycle.

**Speech Specific Posturing**

- **Speech Specific posturing**
  o Research has show there is a "speech specific" posturing of the rib cage & abdomen. The rib cage is relatively more expanded than during resting breathing and the abdomen is relatively more compressed or tensed.
  o We use the thoracic muscles to influence pressure in 2 ways we mentioned earlier speech.
    1. Long steady pressure to provide general loudness
    2. Short bursts of additional pressure to provide emphasis for stress and syllables
  o This speech specific posturing puts the chest walls in a optimum configuration for generating rapid pressure changes,
  o These rapid, little changes are what other texts called pulse like changes. They are the changes we use to add stress and emphasis to certain syllables.

- **Adding pressure to the air stream**
  o Another way to add pressure to the air stream is to add resistance by closing off or partially closing off the escape route that is the airway. Much like the air coming out of a balloon.
  o In speech this is accomplished at the level of the glottis or larynx and again in the mouth. We can increase subglottal pressure by constricting the glottis. We can increase intraoral pressure by constricting the articulators—such as in /s/.

- **During speech the air pressure is affected by both** ...
  1. Increasing air pressure by action of the thoracic musculature.
  2. Constricting the air passage
    - The vocal folds serve to systematically block the air passage and hence build up sub glottal pressure.
    - The articulators tongue, lips and mouth also block the escape of air and intermittently affect the air pressure. This gives us the different sounds associated with the consonants—each requiring a specific combination of subglottal and intraoral pressure.

Examples

| Initiate @ 80% | \[ P = P_{\text{subglottic}} + P_{\text{respiratory}} \]
| Initiate @ 60% | \[ P = P_{\text{subglottic}} + P_{\text{respiratory}} \]
| Initiate @ 40% | \[ P = P_{\text{subglottic}} + P_{\text{respiratory}} \]

Then need pressures to add to create 10 cm H2O
When subject exhales into tube, gas entering the air chamber causes the chamber to rise. These changes are charted on a recording drum as lung volumes.
Relationships of pressures, flows, and volumes to diaphragm activity. Contraction of the diaphragm causes a drop in intrapleural and alveolar pressure which results in an increase in airflow and lung volume.
Lung volumes and capacities as displayed on a spirogram.
Atmospheric

Intraoral

Subglottal

Intrpleural

Relaxation Pressure Curve

Percent Vital Capacity

Resting Lung volume

Alveolar pressure (cm H2O)

RELAXATION PRESSURE CURVE
Subglottal pressure

Excessive relaxation pressure

Relaxation pressure becomes inadequate about here, and continued phonation requires abdominal muscle activity.

Region of equilibrium

Excessive relaxation pressure becomes inadequate about here, and continued phonation requires abdominal muscle activity.

Degree of inspiratory muscle activity required to overcome excess relaxation pressure shown on right.

6 cm H₂O Subglottal pressure

Expiratory muscle activity begins about here.

Continued phonation requires heightened expiratory muscle activity.

Percent of vital capacity

Relaxation pressure

Percent of vital capacity

Relaxation pressure
Muscle actions required to maintain a constant subglottal pressure of 20 cm H2O during loud speech (sustained vowel). Note: checking action of inspiratory muscles to resist recoil forces, and then change to expiratory muscles to meet pressure requirements.
SPEECH BREATHING AS AN EFFICIENT PROCESS

HIGH-EFFICIENCY SYSTEM PRODUCES A LARGE OUTPUT WITH A MINIMUM EXPENDITURE OF ENERGY

RESEARCH HAS DEMONSTRATED:
(1) SPEECH IS PRODUCED WITHIN A RANGE OF LUNG VOLUMES THAT ALLOWS A SUBSTANTIAL OUTPUT (SUBGLOTTAL PRESSURE) WITH MINIMAL EXPENDITURE OF ENERGY.

(2) THE ABDOMINAL MUSCLES ARE CONTRACTED CONSTANTLY THROUGHOUT SPEECH PRODUCTION—THEREFORE, EXPIRATORY AND INSPIRATORY PHASES OF SPEECH BREATHING ARE HIGHLY EFFICIENT.

(3) THE RESPIRATORY SYSTEM IS ALWAYS UNDER SOME TYPE OF MUSCULAR CONTROL DURING SPEECH PRODUCTION.

FACT ONE:
- SPEAKER’S INITIATE CONVERSATIONAL SPEECH AT APPROX. 60% OF VITAL CAPACITY,
- CONTINUE SPEAKING TO 35-40% OF VC (R.E.L).
  R.E.L. = RESTING EXPIRATORY LEVEL-ELASTIC REST POSITION OF THE RESPIRATORY STRUCTURES
- THEN REFILL LUNGS TO 60% TO BEGIN NEXT UTTERANCE.

QUESTION: WHY NOT DEEPER BREATHES FOR SPEECH?

Ps = Pr + Pmus

Ps= Subglottal Pressure demands= cm H20, (often in the region of 10 cm H20).
varies with loud, comfortable or soft speech. Louder speech requires greater subglottal pressure, quiet speech requires less subglottal pressure.

Pr = Relaxation Pressure,
  passive pressure,
  strictly due to elastic/structural characteristics of the respiratory system,
  not under speaker’s control,
  varies according to lung volume for example at 80% VC — relaxation pressure is much higher than at 60% VC.

Pmus = Muscular Pressure
  Active pressure generated by muscular forces
  Under a speaker’s control
Requires energy expenditure.

So why initiate speech in a lung volume range of slightly above REL (i.e., 60% VC) if desire a pressure head of 10 cm H2O?

Look at the extremes i.e., 80% VC (well above REL) or well below REL (30% VC).

At 80% net muscular effort is inspiratory because the strong recoil forces of the lungs need to be offset by an expanding muscular force. Active (muscular) and passive (elastic) forces are pitted against one another - not very efficient.

At 30% lung volume, the passive characteristics of the respiratory system exert an inspiratory force (outward recoil - like a sponge squeezed tightly). This creates a negative alveolar pressure that results from the passive recoil in the inspiratory direction. However the Ps is positive. We have a problem. Push-pull problem.

The net muscular effort is expiratory because the expanding recoil forces of the lungs need to be offset by a compressing muscular force. Again the speaker is faced with a situation in which his passive and active respiratory forces must work against each other to produce the Ps required for conversational speech.

At 60% opposing respiratory forces are typically not required. Pr is near the desired Ps, therefore only small muscular forces need to be applied to achieve the desired Ps. As long as speaker doesn’t speak beyond REL, the respiratory system is not required to use opposing forces at any time to achieve the magnitude of Ps typical of conversational speech.

60%-REL RANGE IS VERY EFFICIENT FOR CONVERSATIONAL SPEECH

WHAT ABOUT LOUD SPEECH- WHERE SHOULD I INITIATE IF I WANT TO GENERATE Ps of 15-20 cm H2O.

Solution is to initiate speech at higher lung volumes and get the relaxation pressure (Pr) that is the best match to the Ps demand.

MUSCULAR FORCES: ABDOMINAL ACTIVITY DURING SPEECH PRODUCTION- OPPOSING VIEWS CLASSIC VS. CONTEMPORARY VIEWS

If abdominal muscles were not active during speech then all the muscular effort would be generated by muscles of rib cage alone. In the absence of abdominal muscle activity, the diaphragm would be driven downward and displace the abdominal contents outward.

This downward displacement is in the inspiratory direction, even though the muscles of the rib cage were attempting to develop expiratory force. Therefore downward displacement would compromise effort of rib cage and difficult to maintain a constant Ps.
If abdominal muscles active- could resist downward displacement of diaphragm. But isn’t this inefficient-just another muscle group?-abdominals vs. rib cage.

Distorting the diaphragm from its typical domed shape to a more flattened configuration is not efficient from a muscle contraction state. The dome shape of the diaphragm is the shape when in an uncontracted state- it’s “physiological rest length”.

Muscles are capable of generating maximal contractile force when a contraction is initiated from the physiological rest length, as compared to any other length. Thus, diaphragmatic contraction for the purpose of inspiratory refill between utterances should be most forceful (and probably most rapid) when the contraction is initiated from the domed configuration.

Thus flattening of the diaphragm would produce a configuration far from physiological rest length, and the inspiratory side of speech breathing would be inefficient. If abdominals maintain the diaphragm close to its physiological rest length, it can generate forceful contractions for utterance refills. Therefore, abdominals serve to “tune” the diaphragm.

Passive Control of Respiration:
Discussion of Pr=Ps, problems with passive control of speech respiration at a point when no muscular force required to generate Ps. Is it better to turn off all muscles or have balance between expiratory and inspiratory muscular forces.

Problem is muscular contraction delay= dead spot where no muscular control over linguistic stress. Need to rapid contractions to produce linguistic stress.

Volume solution= Continuous change in muscular effort through utterance, which is directed specifically at maintaining a constant Ps. Volume solution because it describes how the respiratory muscles compensated for the the change in Pr which occurs as a function of lung volume.

If you want to stress a syllable in an utterance- must produce a brief increase in an otherwise constant Ps- there must be a modification to “volume solution”. What is required is a positive muscular effort which is momentarily in excess of that required by the volume solution.

Brief, extra compression of the lungs = increased Ps. These brief expiratory muscular efforts are part of the “pulsatile solution”.

Pulsatile solution can be thought of as superimposed on volume solution.

Question: How can a speaker stress a syllable at a point in the lung volume where Pr = Ps, if all respiratory muscles are turned off? If turn off all muscles get this dead spot.
Solution to have both expiratory and inspiratory muscle activity and slight adjustments in the balance will produce the desired increment in Ps and thus linguistic stress. It would be impossible for the brain to plan to avoid stress at certain points in the lung volume.
Sentences used to elicit Lexical Stress stimuli.

A
Bob went to the town fair. He played the shooting game. Bob shot his gun at the target. **He hit the bullseye.**

Bob lived on a farm. He didn’t like the farm bull. He put a rock in his slingshot and aimed. **He hit the bull’s eye.**

B
Bob went to the town fair. He purchased a ticket to win a loaf of bread. His ticket was drawn. **Bob was the bread winner.**

Bob had a large family. He worked two jobs just to pay the bills. His wife stayed at home and looked after the children. **Bob was the breadwinner.**

C
Bob liked sitting in his comfortable Lazy-Boy chair. He sat there for days. His friends knew how much Bob loved his chair. **Bob was the chair man.**

Bob worked for a large multinational corporation. He liked giving orders to people. His employees feared Bob. **Bob was the chairman.**
Volume in liters (relative to mid-respiration)

Pressure (cm H2O)

Diaphragm
External intercostals
Internal intercostals
External obliques
Rectus abdominis
Latissimus dorsi

5 10 15 20 25 30 35 40
Time (seconds)