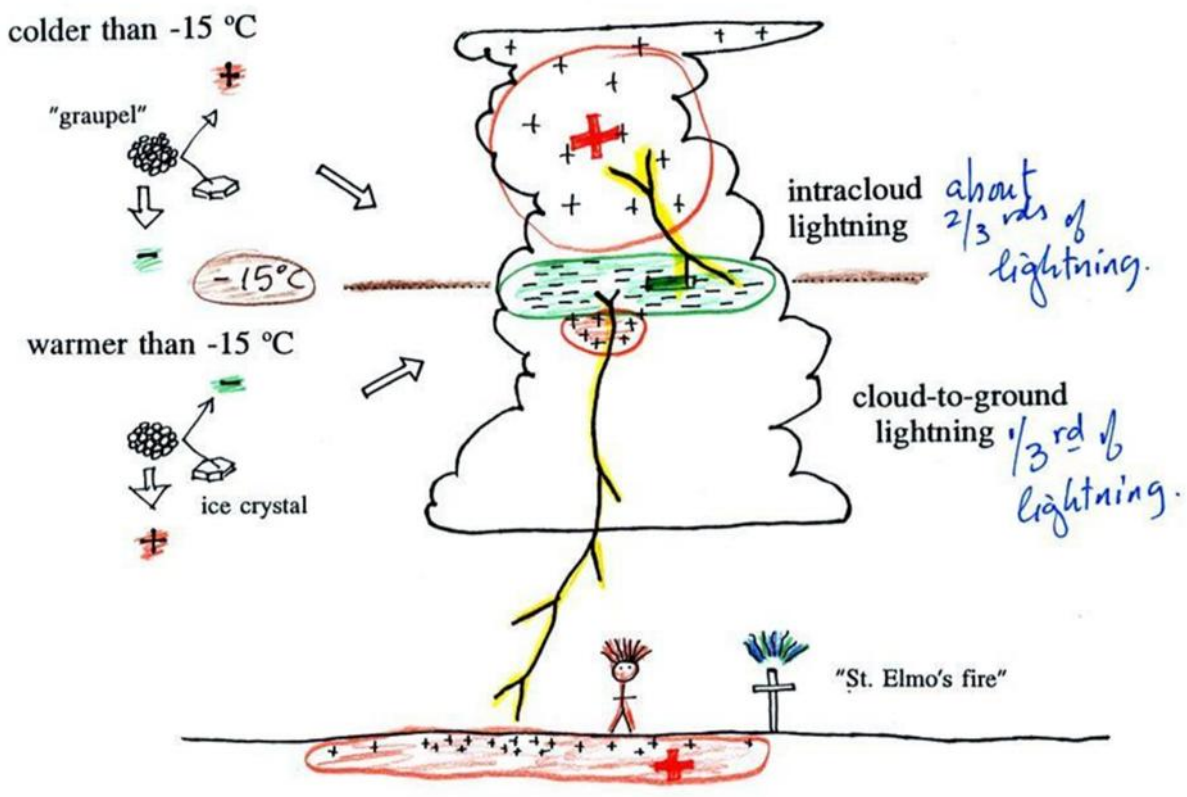
Chapter Ten
Lightning

Mechanisms of Charge Separation

- The top of a thunderstorm (cumulonimbus) cloud becomes positively charged, while the middle-to-lower portions of the cloud becomes negatively charged.

- Often there is also a smaller pocket of positive charge near the bottom of the cloud.

- The reason for this charge separation is not completely understood, but some of the more prominent theories are described below.



- When temperatures are colder than -15 C, graupel becomes negatively charged after colliding with an ice crystal. The ice crystal is positively charged and is carried up toward the top of the cloud by the updraft winds.

- At temperatures warmer than -15 (but still below freezing), the polarities are reversed. Large positive and negative charge centers begin to build up inside the cloud.

- When the electrical attractive forces between these charge centers gets high enough lightning occurs.

- Most lightning (2/3 rds) stays inside the cloud and travels between the main positive charge center near the top of the cloud and a large layer of negative charge in the middle of the cloud; this is intracloud lightning.

- About 1/3 rd of all lightning flashes strike the ground. These are called cloud-to-ground discharges (actually negative cloud-to-ground lightning).

- Attraction between positive charge in the ground and the layer of negative charge in the cloud can become strong enough that a person's hair will literally stand on end

- Saint Elmo's fire is a faint electrical discharge that sometimes develops at the tops of elevated objects during thunderstorms. It was first observed coming from the tall masts of sailing ships at sea (Saint Elmo is the patron saint of sailors).

Evolution of the Lightning Stroke

- Most cloud to ground discharges begin with a negatively-charged downward-moving stepped leader. A developing channel makes its way down toward the cloud in 50 m jumps that occur every 50 millionths of a second or so. Every jump produces a short flash of light

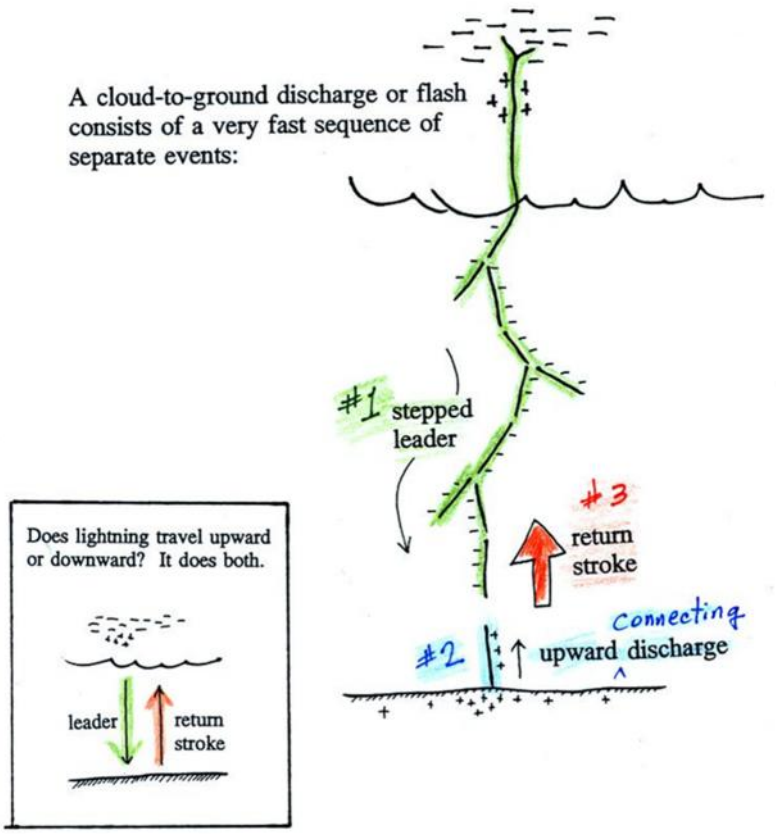
- The bottom segment, highlighted in yellow, produces a bright flash of light (the remainder of the channel is often weakly illuminated).

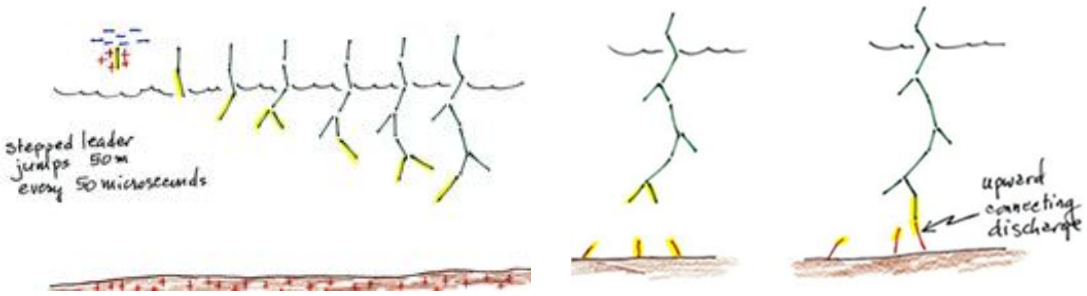
- As the leader channel approaches the ground strong electrical attraction develops between negative charge in the leader channel and positive charge on the surface of the ground.

- Several positively charged sparks develop and move upward toward the stepped leader. One of these will intercept the stepped leader and close the connection between negative charge in the cloud and positive charge on the ground.

- Once the stepped leader and the return stroke have connected, then electrons from the cloud can flow to the ground, and positive charges can flow from the ground to the cloud.

- This flow of current from the cloud to the ground is visible at the return stroke.

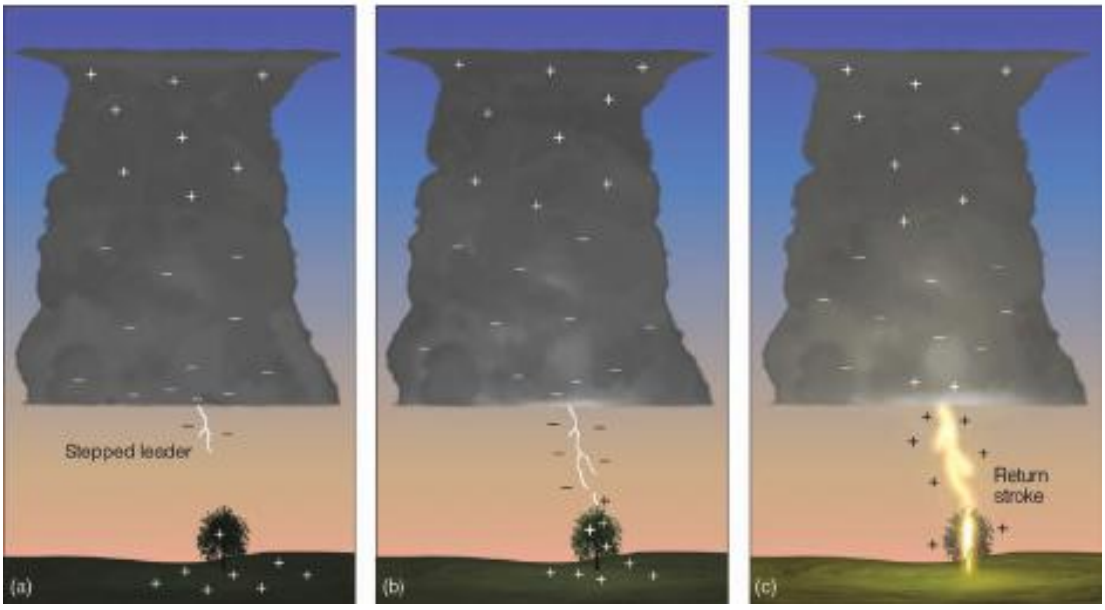




- The return stroke is several cm in diameter

- After the first discharge, it is possible for another leader to propagate down the channel created by the first stepped leader.

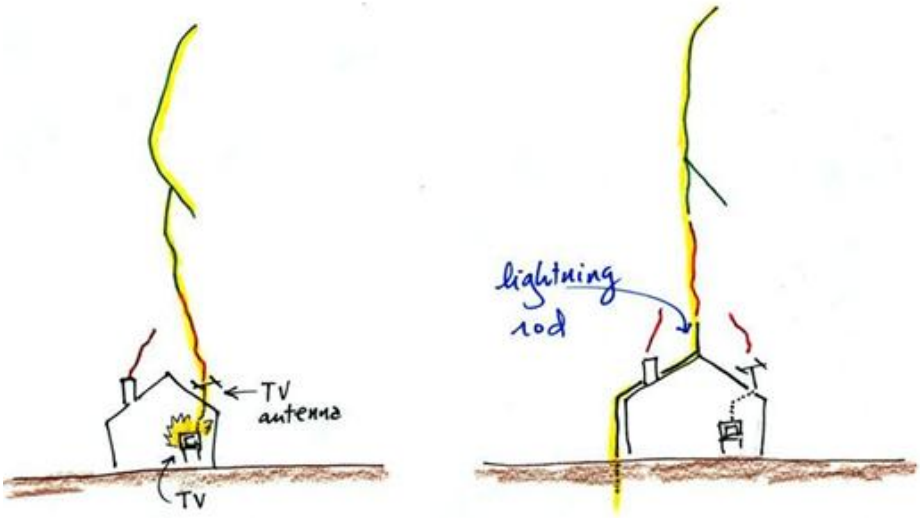
- This new leader is called a dart leader.
  - And can have a more significant impact on ozone chemistry.



Lightning Rod

- Houses with and without lightning rods are shown below.

- When lightning strikes the house without a lightning rod the powerful return stroke travels into the house destroying the TV and possibly starting the house on fire.



Other types of lightning

- Forked lightning
- Ribbon lightning
- Bead lightning
- Ball lightning
- Sheet lightning
- Heat lightning
- Saint Elmo's fire