

# **Impacts Of Lightning On Trees: Power, Force & Injury**

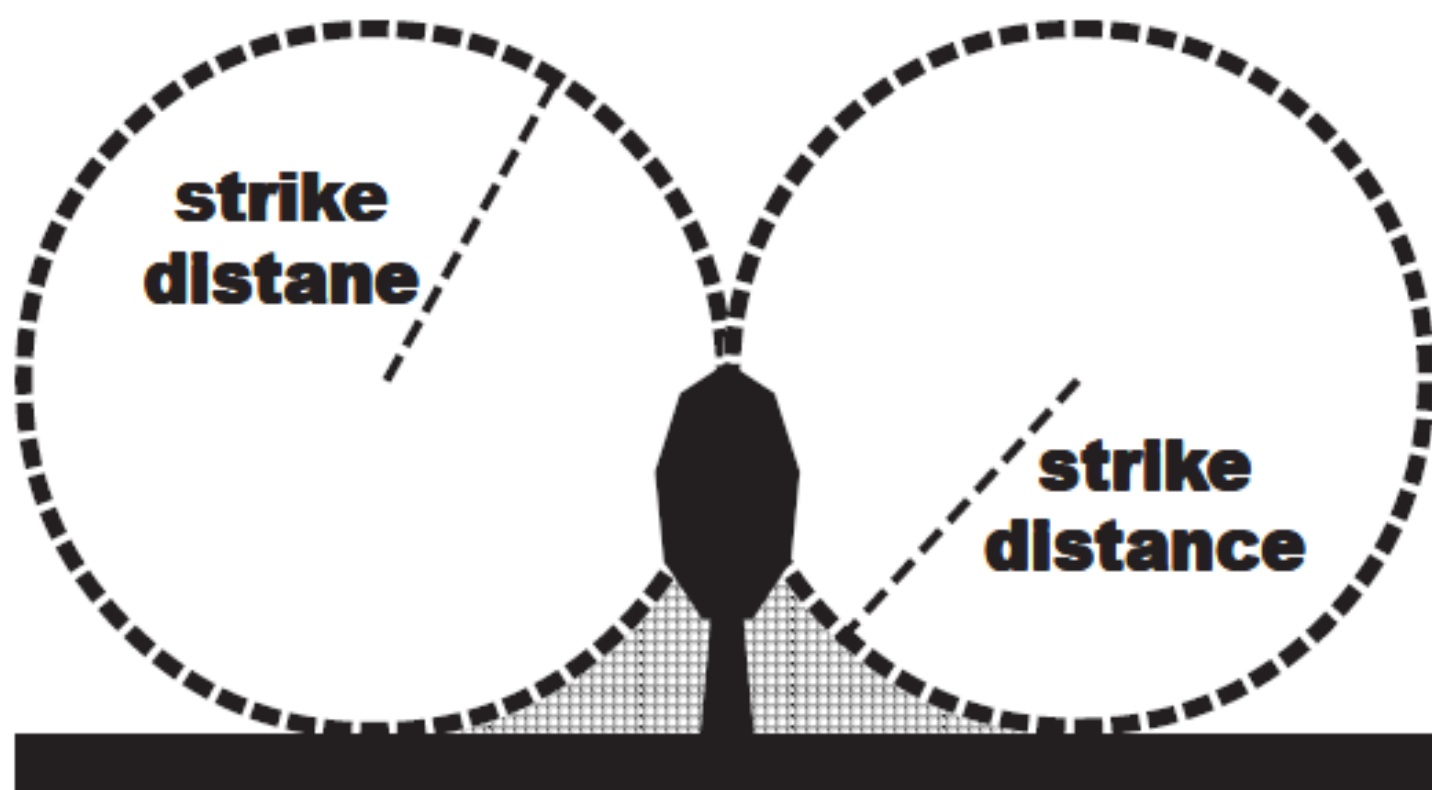
**Dr. Kim D. Coder**

**Professor of Tree Biology & Health Care  
Warnell School, University of Georgia**



# **Trees & Lightning: Principles For Controlling Damage**

**Dr. Kim D. Coder, Professor of Tree Biology & Health Care  
Warnell School of Forestry & Natural Resources  
University of Georgia (9/2013)**



## **ROLLING SPHERE PROTECTION ZONE**

**OUTREACH MONOGRAPH WSFNR13-8**

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# **Lightning Strikes**

**ground somewhere  
on Earth**

**9 million per day  
6,200 per min  
100 per sec**

# **United States**

**(annual)**

**~1,000 injuries**

**500 serious  
(75% permanent)**

**Deaths = 1/5 of  
serious injuries  
annually**

# **Injuries & Damage**

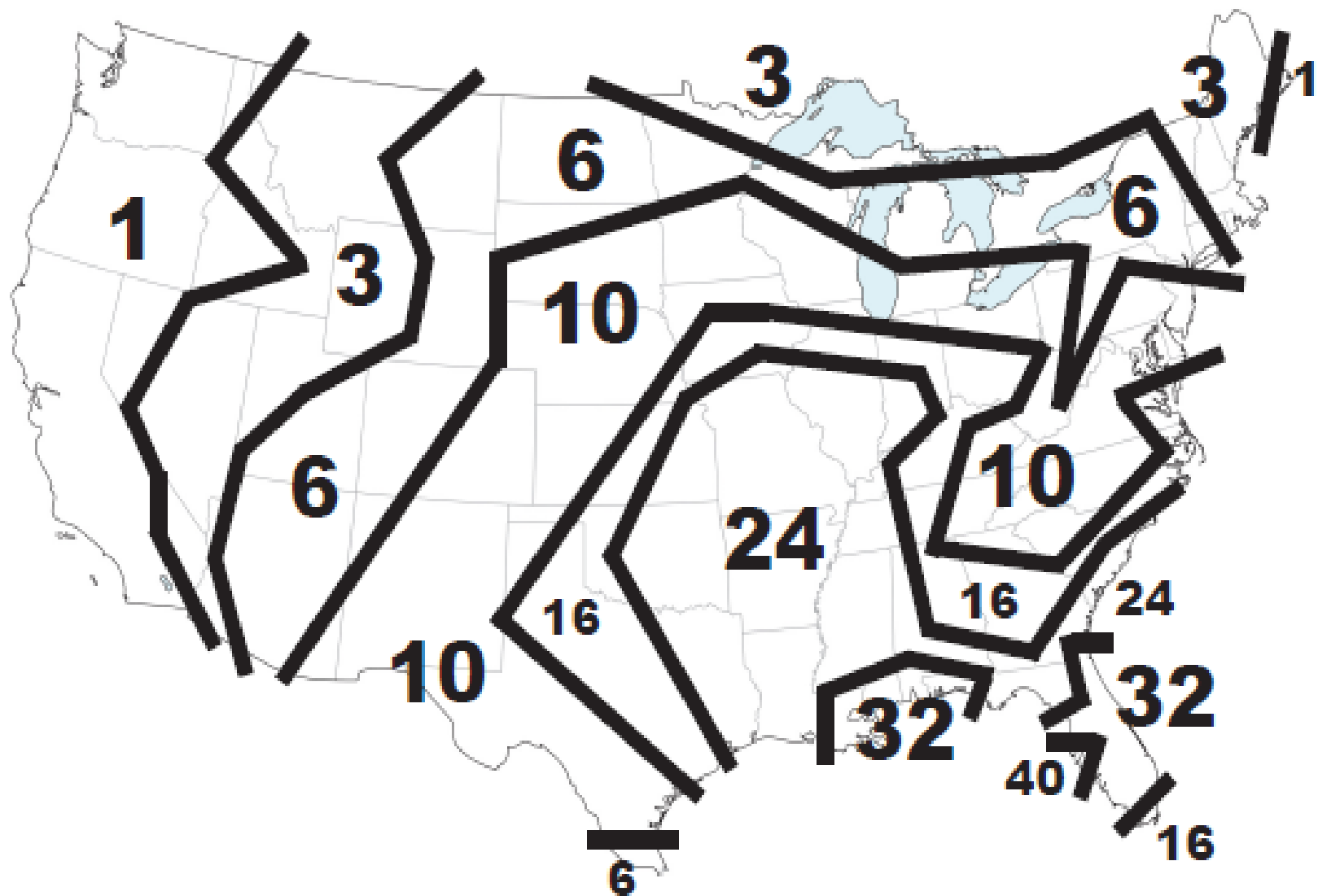
**feed lot &  
pastured animals**

**property ~\$175M**

**~\$1/2B utility losses**

**TREES in forest & yards  
severely damaged**

# Annual Strikes per square mile last 15 years

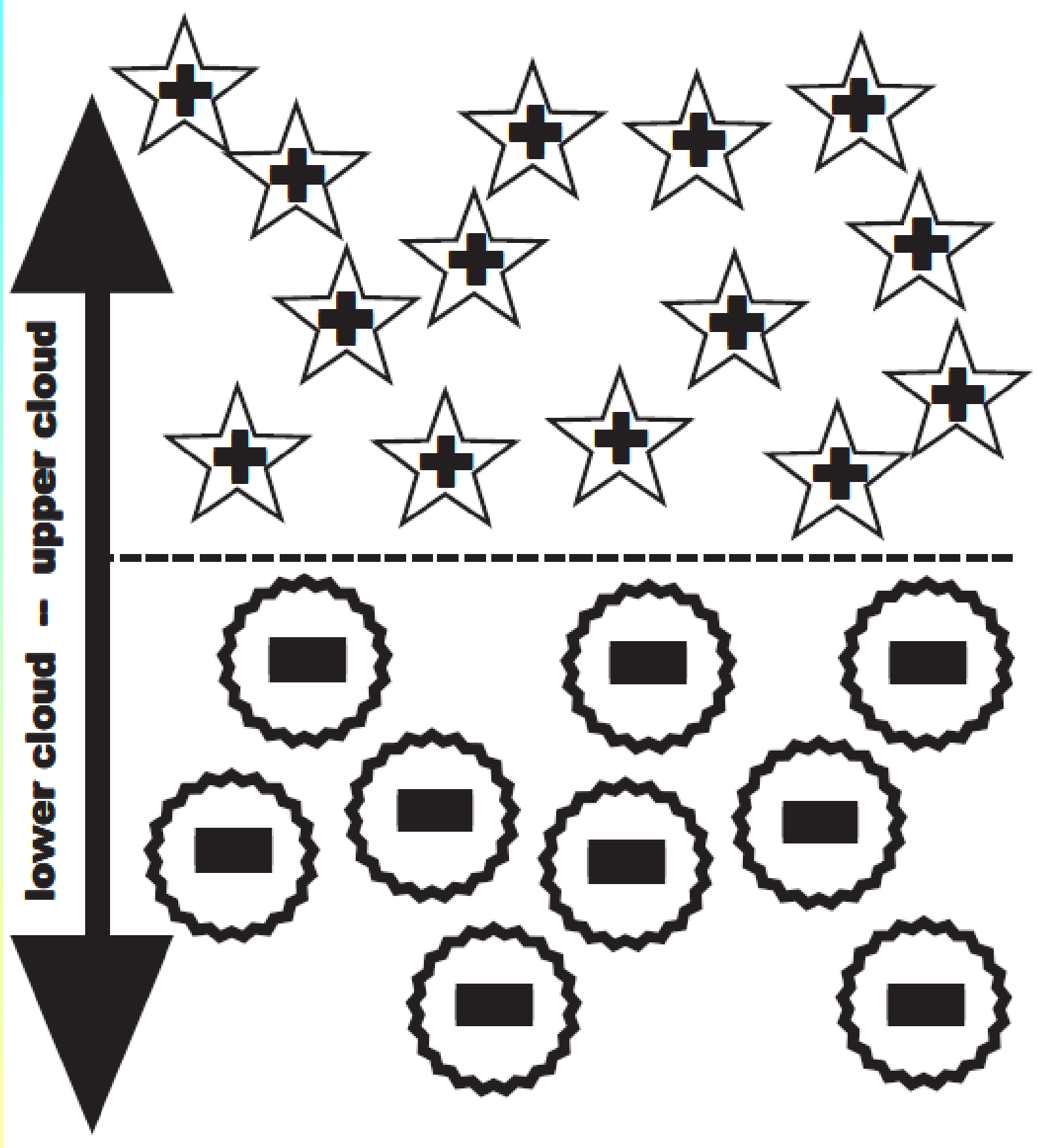




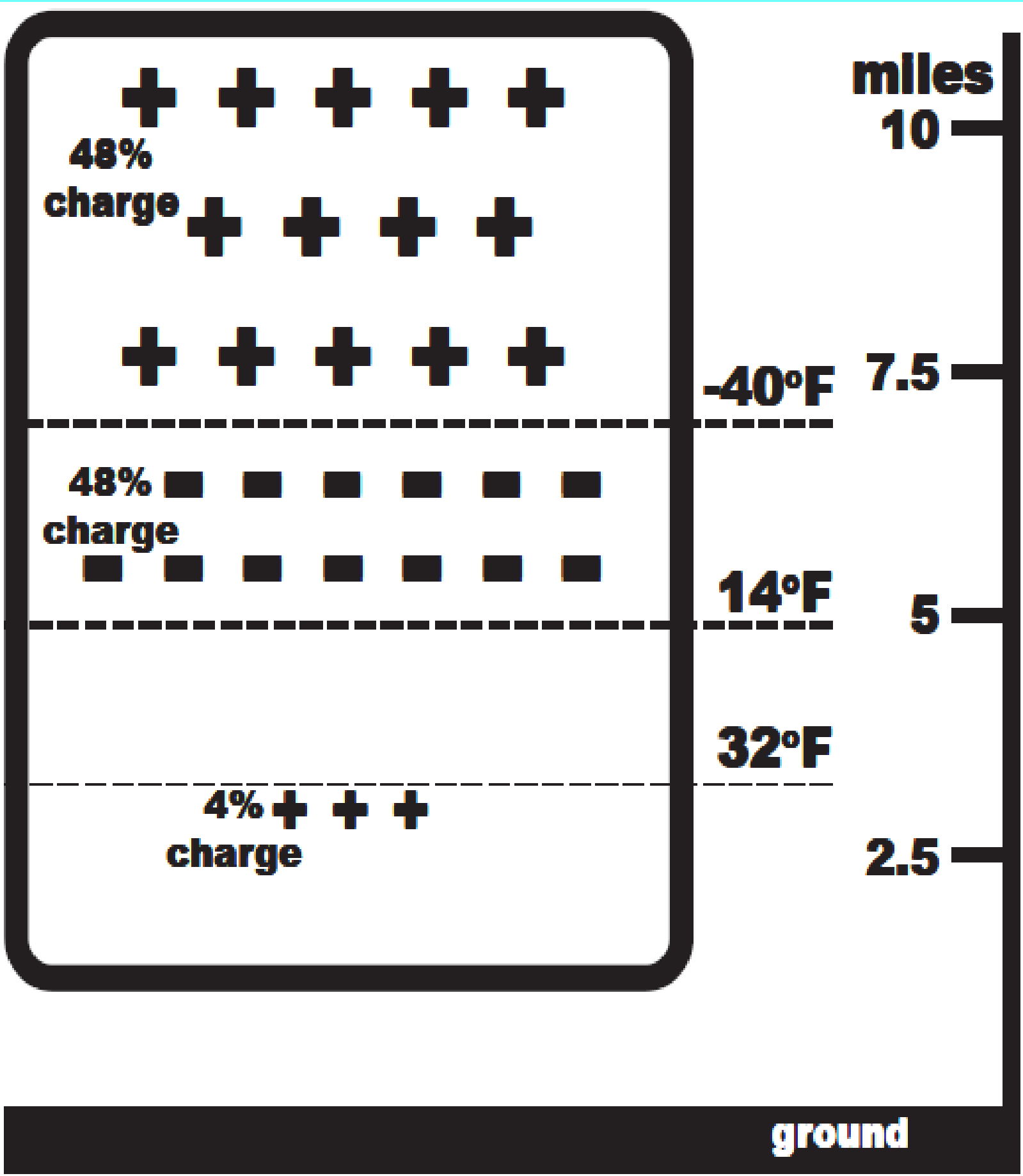
# **Storms**

**generate large  
updrafts**

**pull moisture  
to high,  
cold altitudes**



# Charge Size & Location



1

+ + + + + + + + +

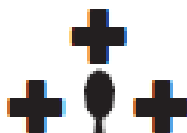
+ + + + + + + +

+ + + + + + + + +

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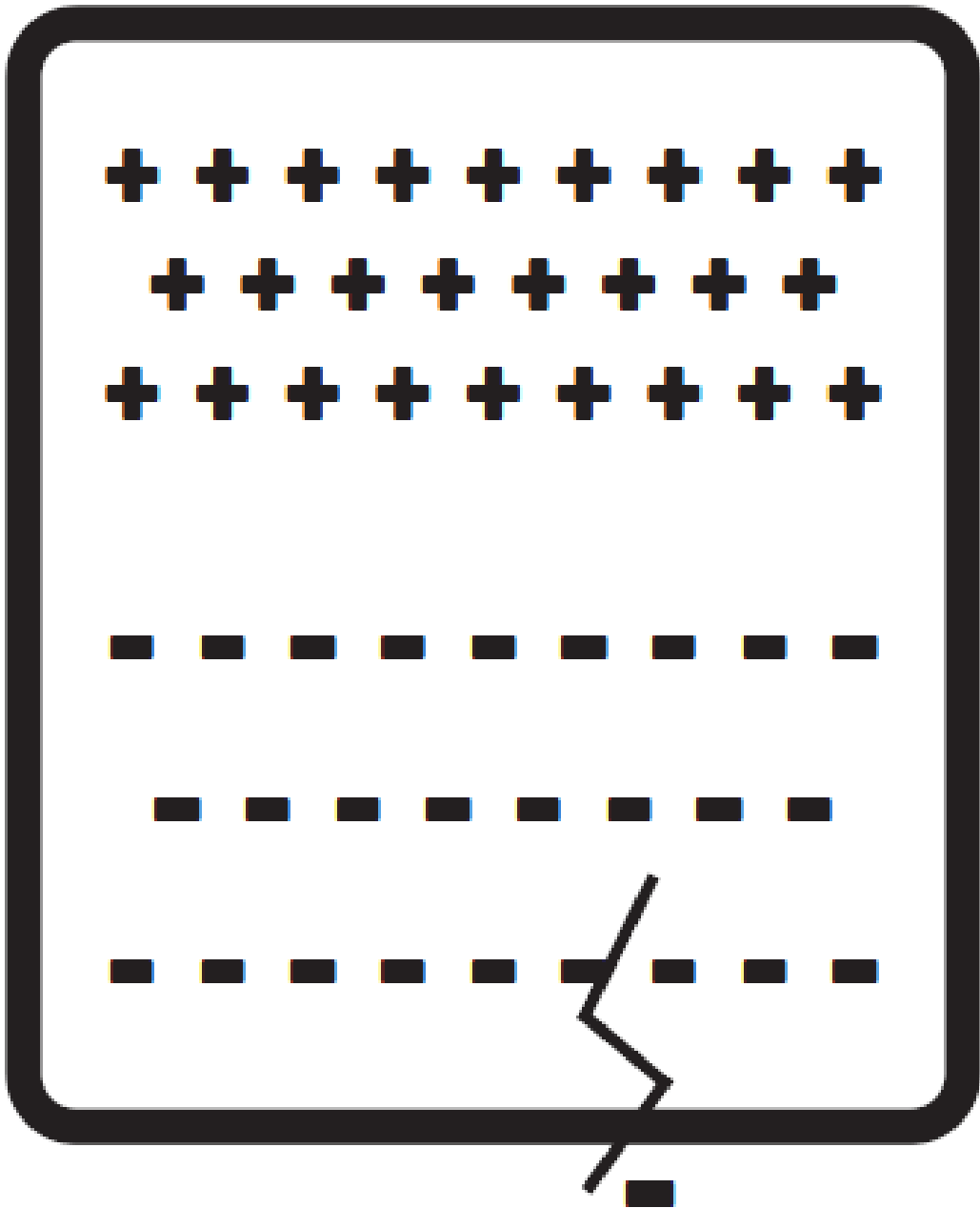


+ + + + + + + + + + + + + + + +

# **Cloud Leaders**

**near invisible  
fingers of  
negative charge  
pushing  
downward from  
bottom of cloud**

2



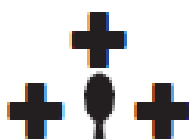
3

+ + + + + + + + +  
+ + + + + + + +  
+ + + + + + + + +

- - - - - - - - -

- - - - - - - -

- - - - - - - - -



+ + + + + + + + + + + + + + + + +

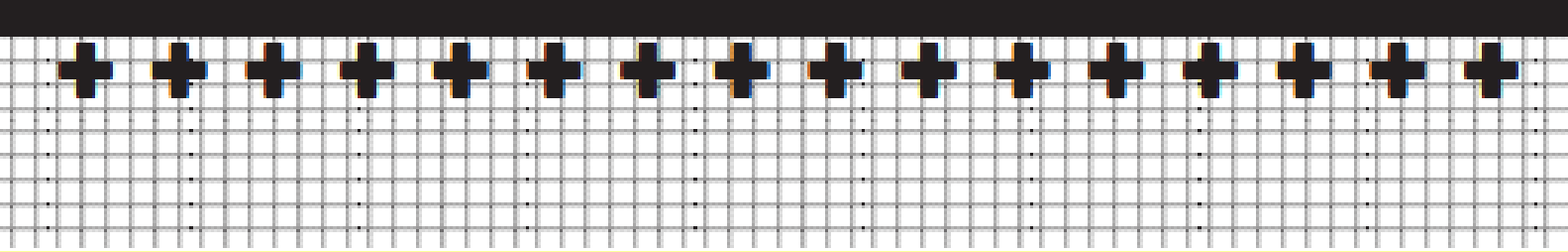
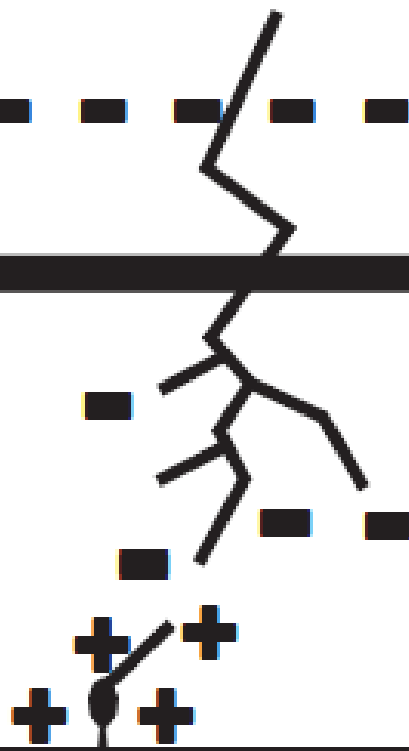
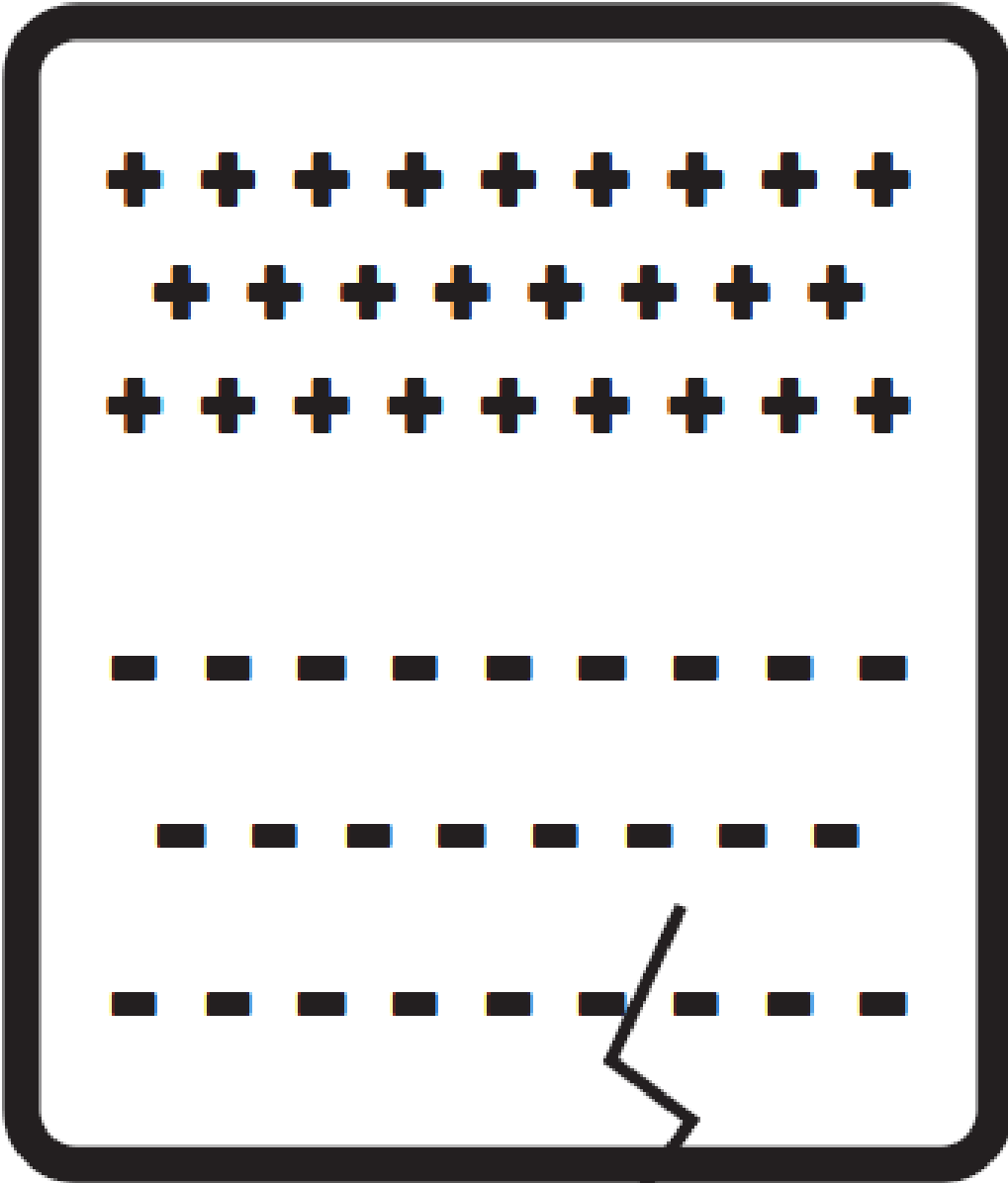
# **Ground Streamers**

**enhanced field  
along Earth's surface  
below storm**

**pulled (or stream)  
upward toward cloud base**

**flow up & off top of  
tall objects as standing  
charge wave passes**

4



5

+ + + + + + + + +

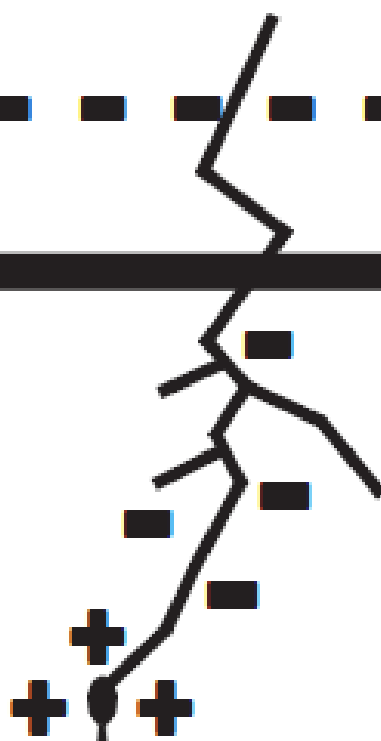
+ + + + + + + +

+ + + + + + + + +

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+ + + + + + + + + + + + + + + + +

# **Charge Exchange Path**

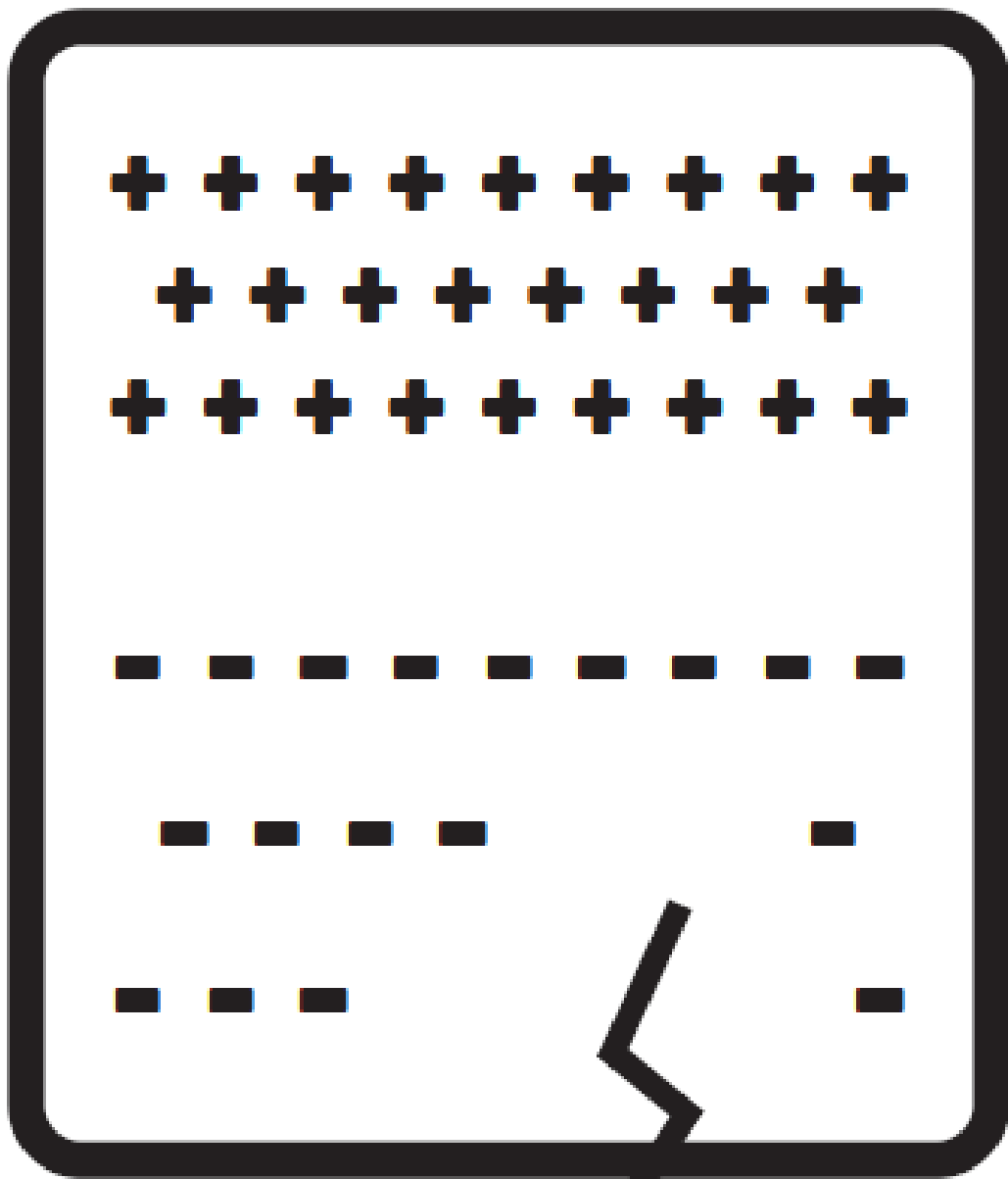
**opens & rapidly  
exchanges**

**temporarily neutral**

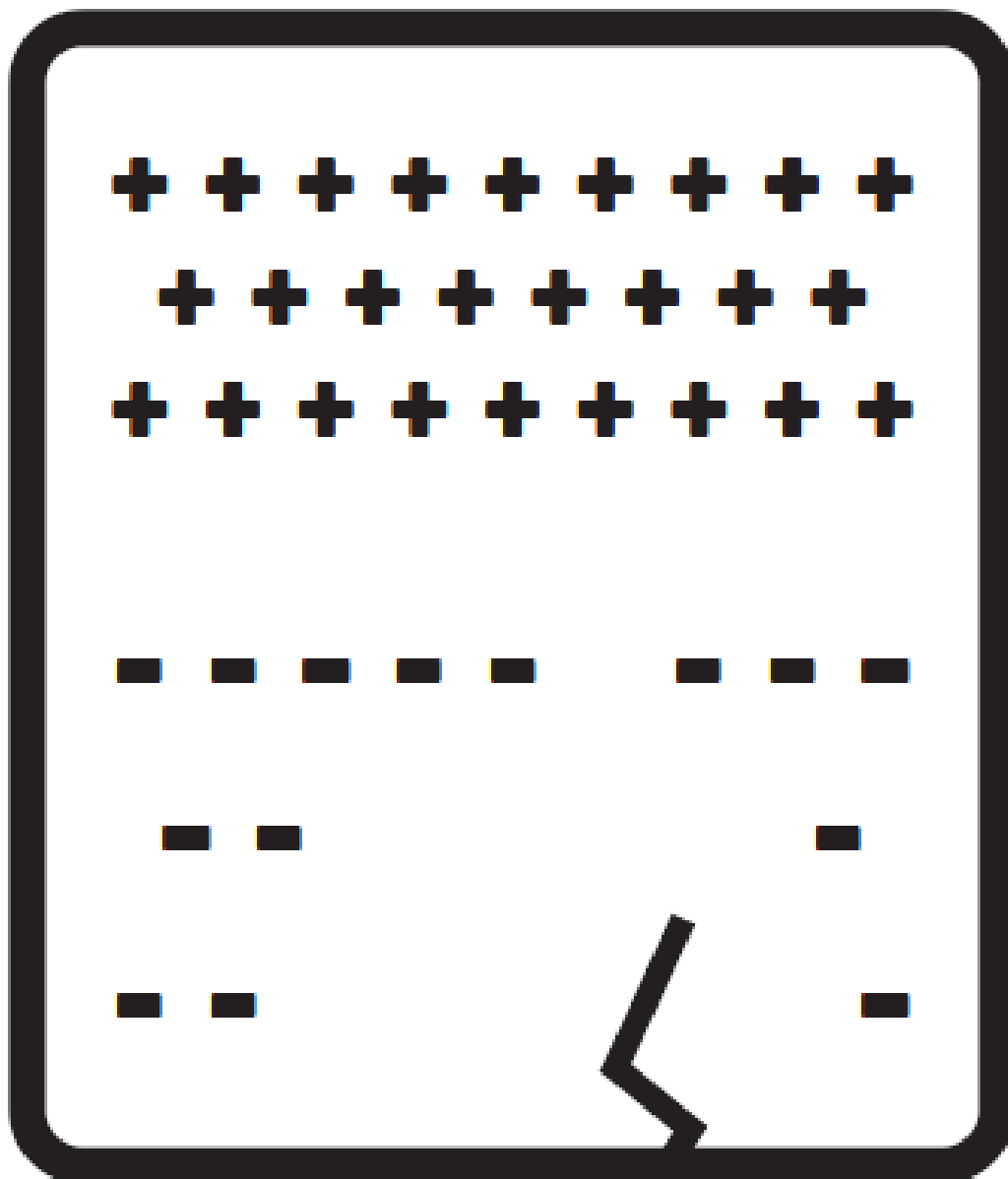
**massive charge  
exchange generates**

**light**

6



7



+ + + + +

+ + + + +

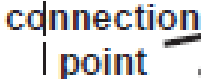
# ***Flash***

**lightning strike =  
number of strokes  
(average 3-4)**

**each stroke =  
10's of milliseconds**

**strike duration  
~1/2 second  
(human perceived flicker)**





**(ms = millisecond)**

**Average Strike**

**100 million volts**

**35,000 amps**

**strike core**

**1/5 to 1/2 in. diameter**

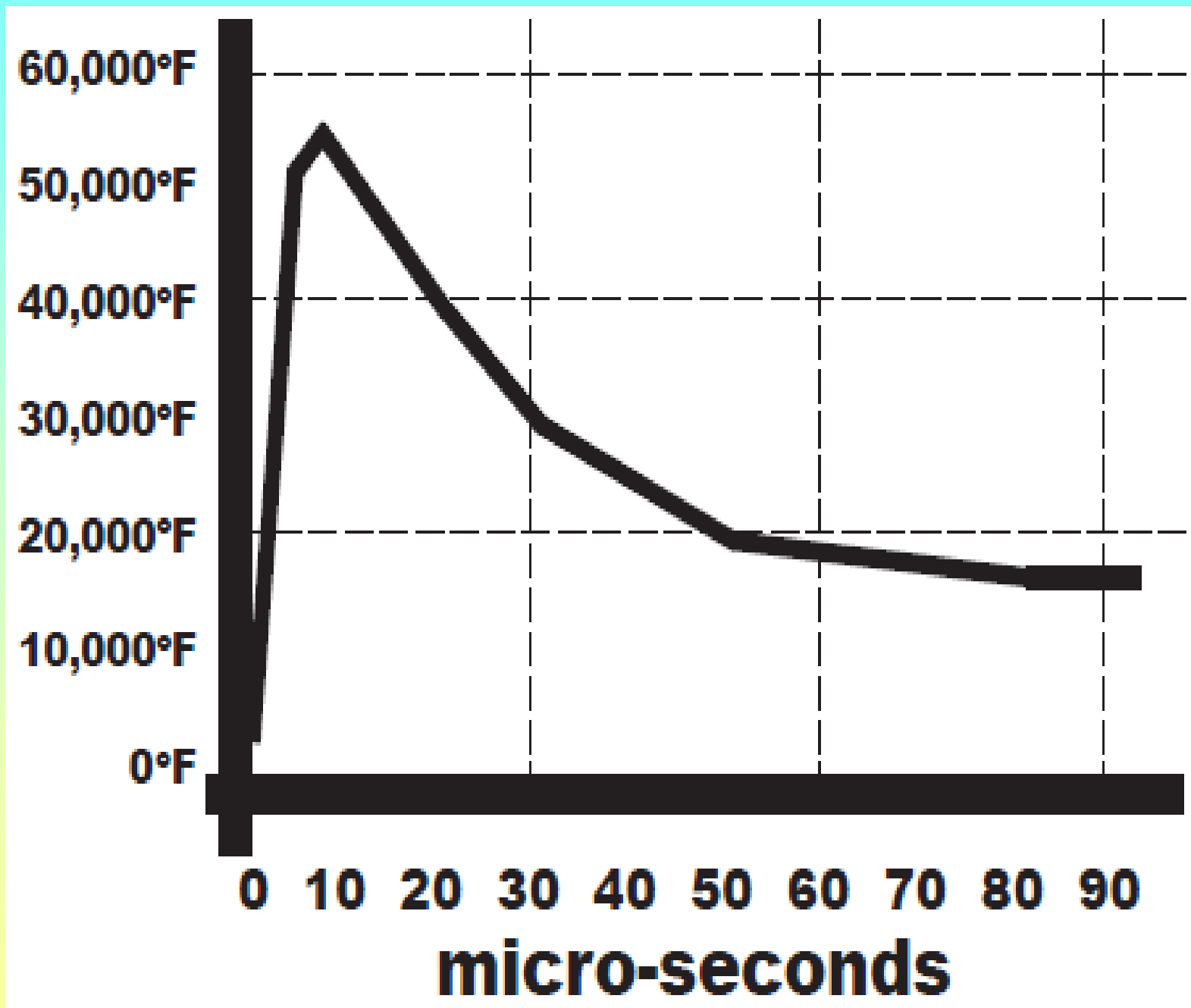
**ionized envelope**

**4-6 in. diameter**

**bright light corona**

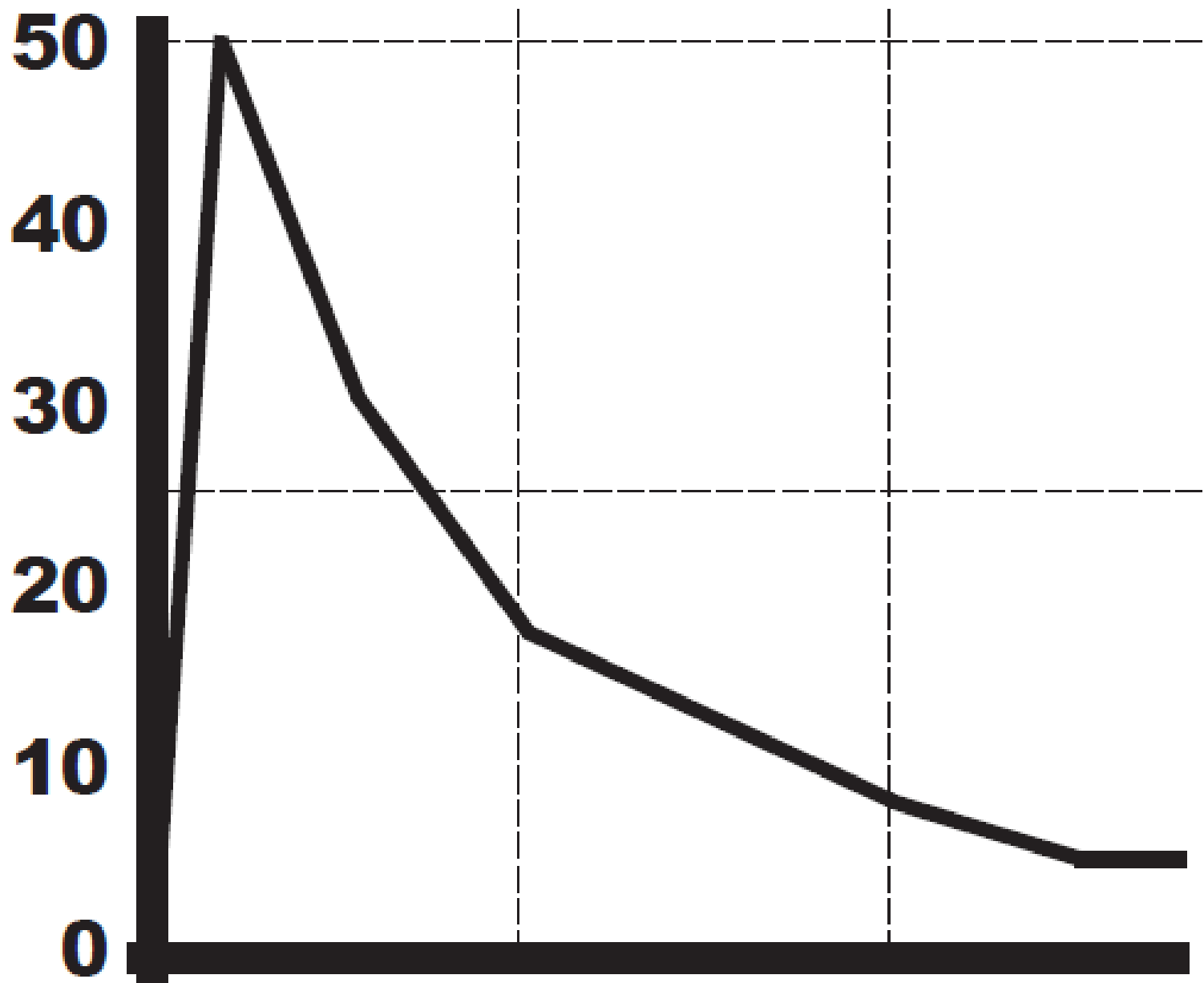
**1-5 ft. diameter**

# Average Strikes



**(1 micro-second = 0.000,001 second)**

**pressure  
(atms)**



**0      0.4      0.8      1.2      1.6      2.0**in  
**tree      (4)      (10)      (18)      (28)      (40)**  
**surface**

**distance travelled (inches)**  
**(time in micro-seconds)**

# **Core Shockwave**

**10X**

**Speed of  
Sound**



# **Grounding**

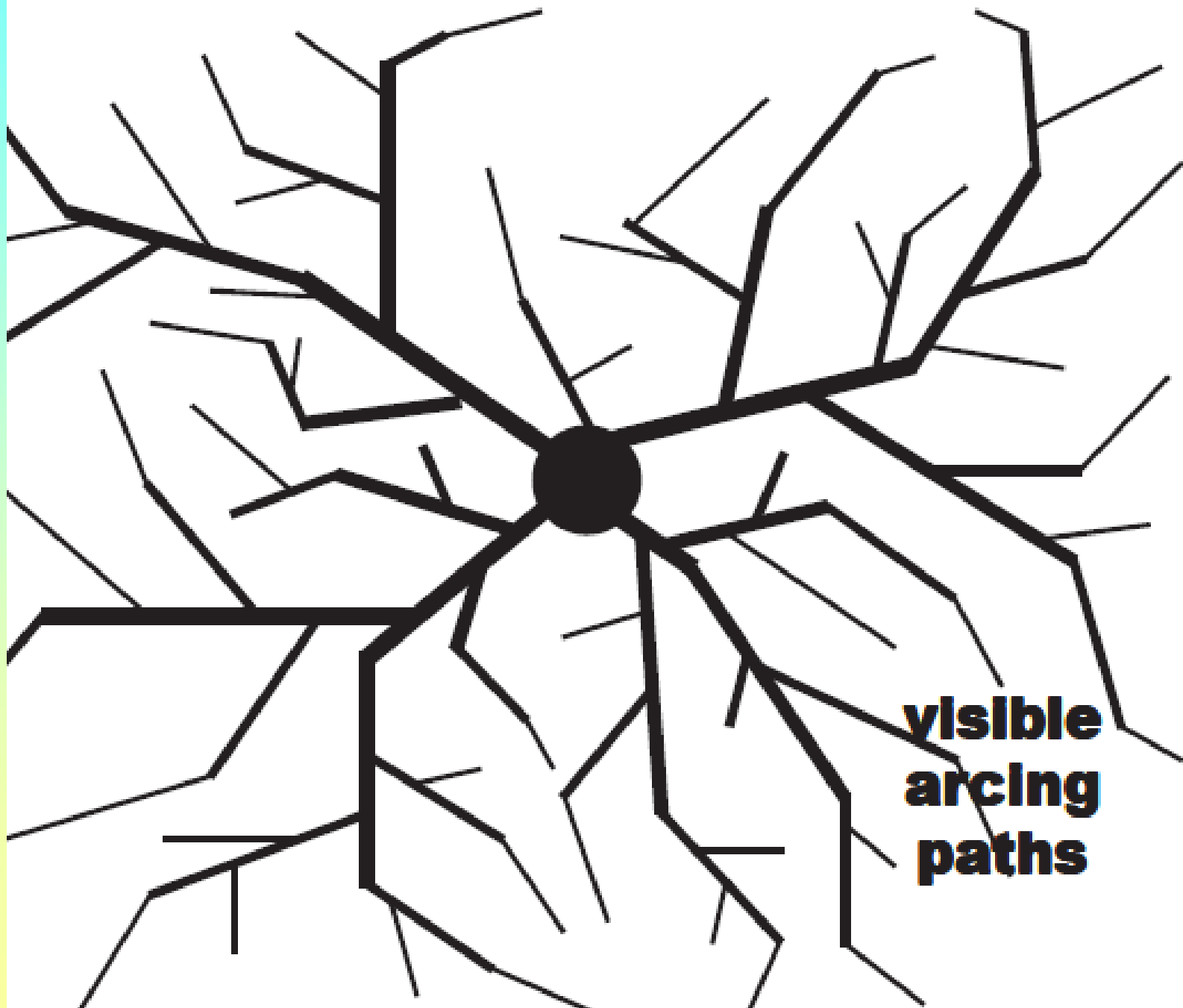
**charge exchange  
path opens**

**energy races along  
soil surface**

**dissipates across  
surface & into soil**

**soil channeling  
large voltages**

# **Surface Flash Over / Arcing (maximum distance = 65ft)**



**visible  
arcing  
paths**

# Step Voltage Soil Resistance

| closest<br>radial<br>distance<br>from<br>tree stem<br>(feet) | soil electrical resistance measures (ohms) |     |     |     |     |     |      |      |
|--------------------------------------------------------------|--------------------------------------------|-----|-----|-----|-----|-----|------|------|
|                                                              | 25                                         | 50  | 100 | 150 | 200 | 250 | 300  | 400  |
| 1 ft.                                                        | 89kV                                       | 179 | 358 | 537 | 716 | 895 | 1074 | 1432 |
| 2                                                            | 46                                         | 92  | 185 | 278 | 371 | 464 | 557  | 742  |
| 3                                                            | 32                                         | 64  | 129 | 193 | 258 | 323 | 387  | 517  |
| 4                                                            | 25                                         | 50  | 100 | 150 | 200 | 250 | 300  | 401  |
| 5                                                            | 20                                         | 41  | 82  | 123 | 164 | 205 | 246  | 328  |
| 6                                                            | 17                                         | 34  | 69  | 104 | 139 | 174 | 209  | 279  |
| 7                                                            | 15                                         | 30  | 60  | 91  | 121 | 151 | 182  | 242  |
| 8                                                            | 13                                         | 26  | 53  | 80  | 107 | 134 | 161  | 215  |
| 9                                                            | 12                                         | 24  | 48  | 72  | 96  | 120 | 144  | 193  |
| 10                                                           | 10                                         | 21  | 43  | 65  | 87  | 109 | 131  | 175  |
| 20                                                           | 5                                          | 11  | 22  | 34  | 45  | 56  | 68   | 91   |
| 30                                                           | 3                                          | 7   | 15  | 23  | 30  | 38  | 46   | 61   |
| 40                                                           | 2                                          | 5   | 11  | 17  | 23  | 29  | 34   | 46   |
| 50                                                           | 2                                          | 4   | 9   | 14  | 18  | 23  | 28   | 37   |



# ***Boom***

**flash & sound  
generated**

**thunder 770 mph  
at 70°F**

**count seconds  
times  $1/5$  mile**

**strong  
shock  
wave**

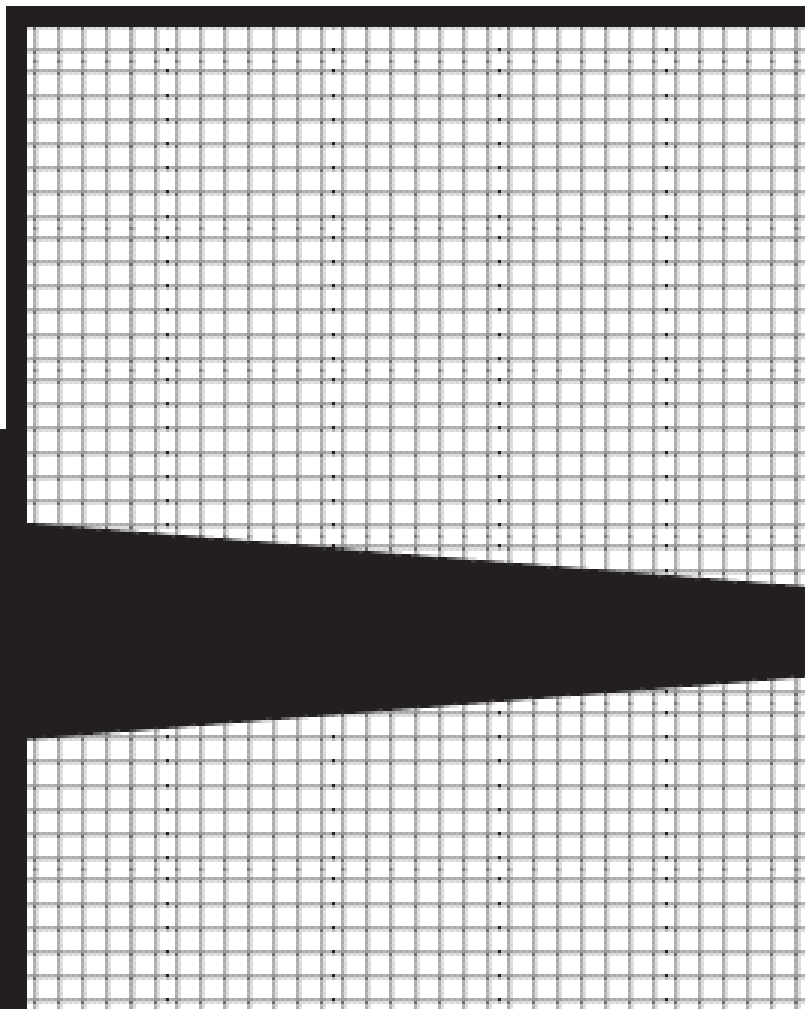
**weak  
shock  
wave**

**acoustic  
wave**

**THUNDER**

**tree surface**

**0 0.4 0.8 1.2 1.6 2.0 in.  
distance from tree surface**



# **Tree Impacts**

**heat generation  
& steam (S)**

**strong  
shockwave (10S)**

# **Tree Reactions**

---

**most trees  
not killed**

**damage mirrors  
strength of current &  
structural components  
of tree**

**Several trees in  
row damaged  
from different  
strokes in  
one strike**

**Some trees  
struck many  
times !**

# **Groups of Trees**

**orchards & forest  
stands in high  
resistance soils  
decimated by  
single strike**

**center tree strike  
- remaining trees  
grounding root injury**

# Observing

**--80% tree lightning  
scars shallow &  
continuous**

**--between 80%  
height to within  
several feet  
of base**

# **Observing**

**~20% no visible signs**

**~10% trees more than  
one scar**

**~ 9% various portions  
crown damaged**

**~ 1% large areas  
ripped apart**

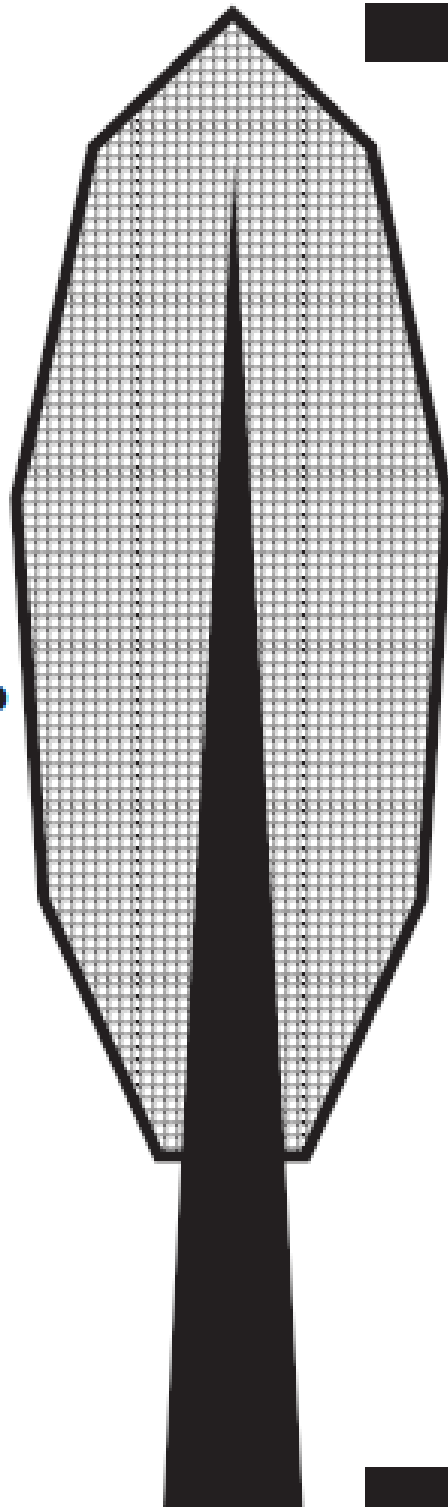
**79%**

**side strike  
connection  
45% - 90%  
of height**

**(peak side  
strikes ~75%  
height)**

**5%**

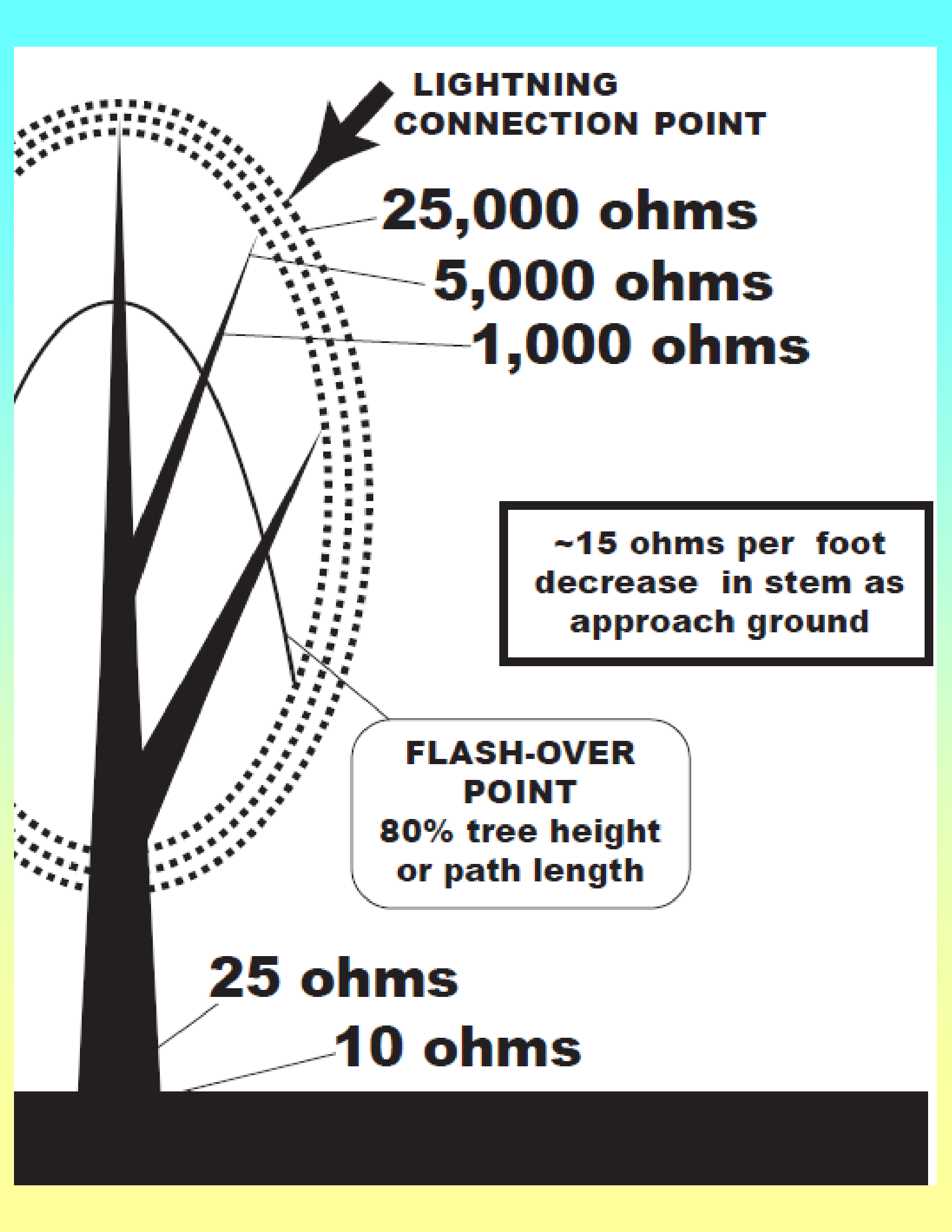
**16%**



# Years Between Strikes

| tree height<br>(feet) | lightning strikes per square mile per year |       |       |       |       |       |       |       |       |       |
|-----------------------|--------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                       | 2                                          | 5     | 10    | 15    | 20    | 25    | 30    | 35    | 40    | 45    |
| 5 ft                  | 9,999                                      | 8,000 | 4,000 | 2,500 | 2,000 | 1,500 | 1,300 | 1,100 | 1,000 | 900   |
| 10                    | 5,000                                      | 2,000 | 1,000 | 650   | 500   | 394   | 328   | 281   | 246   | 219   |
| 20                    | 1,200                                      | 500   | 246   | 164   | 123   | 98    | 82    | 70    | 61    | 54    |
| 30                    | 550                                        | 219   | 109   | 73    | 54    | 43    | 36    | 31    | 27    | 24    |
| 40                    | 308                                        | 123   | 61    | 41    | 30    | 24    | 20    | 17    | 15    | 13    |
| 50                    | 197                                        | 78    | 39    | 26    | 19    | 15    | 13    | 11    | 9     | 8     |
| 60                    | 136                                        | 54    | 27    | 18    | 13    | 10    | 9     | 7     | 6     | 6     |
| 70                    | 100                                        | 40    | 20    | 13    | 10    | 8     | 6     | 5     | 5     | 4     |
| 80                    | 77                                         | 30    | 15    | 10    | 7     | 6     | 5     | 4     | 3     | 3     |
| 90                    | 60                                         | 24    | 12    | 8     | 6     | 4     | 4     | 3     | 3     | 2     |
| 100                   | 49                                         | 19    | 9     | 6     | 4     | 3     | 3     | 2     | 2     | 2     |
| 120                   | 34                                         | 13    | 6     | 4     | 3     | 2     | 2     | 1     | 1     | 1 yrs |





The diagram illustrates the resistance of a tree to lightning at various heights. A solid black line represents the tree trunk, with a black arrow pointing to the top labeled 'LIGHTNING CONNECTION POINT'. Three dotted lines curve from the top of the tree down to the ground, representing the lightning path. Labels with leader lines indicate resistance values at specific heights: 25,000 ohms, 5,000 ohms, and 1,000 ohms along the upper path. A box on the right states a resistance decrease of ~15 ohms per foot as the path approaches the ground. A rounded box at the bottom indicates the 'FLASH-OVER POINT' at 80% of the tree height or path length. At the base of the tree, resistance values of 25 ohms and 10 ohms are shown.

**LIGHTNING  
CONNECTION POINT**

**25,000 ohms**

**5,000 ohms**

**1,000 ohms**

**~15 ohms per foot  
decrease in stem as  
approach ground**

**FLASH-OVER  
POINT**

**80% tree height  
or path length**

**25 ohms**

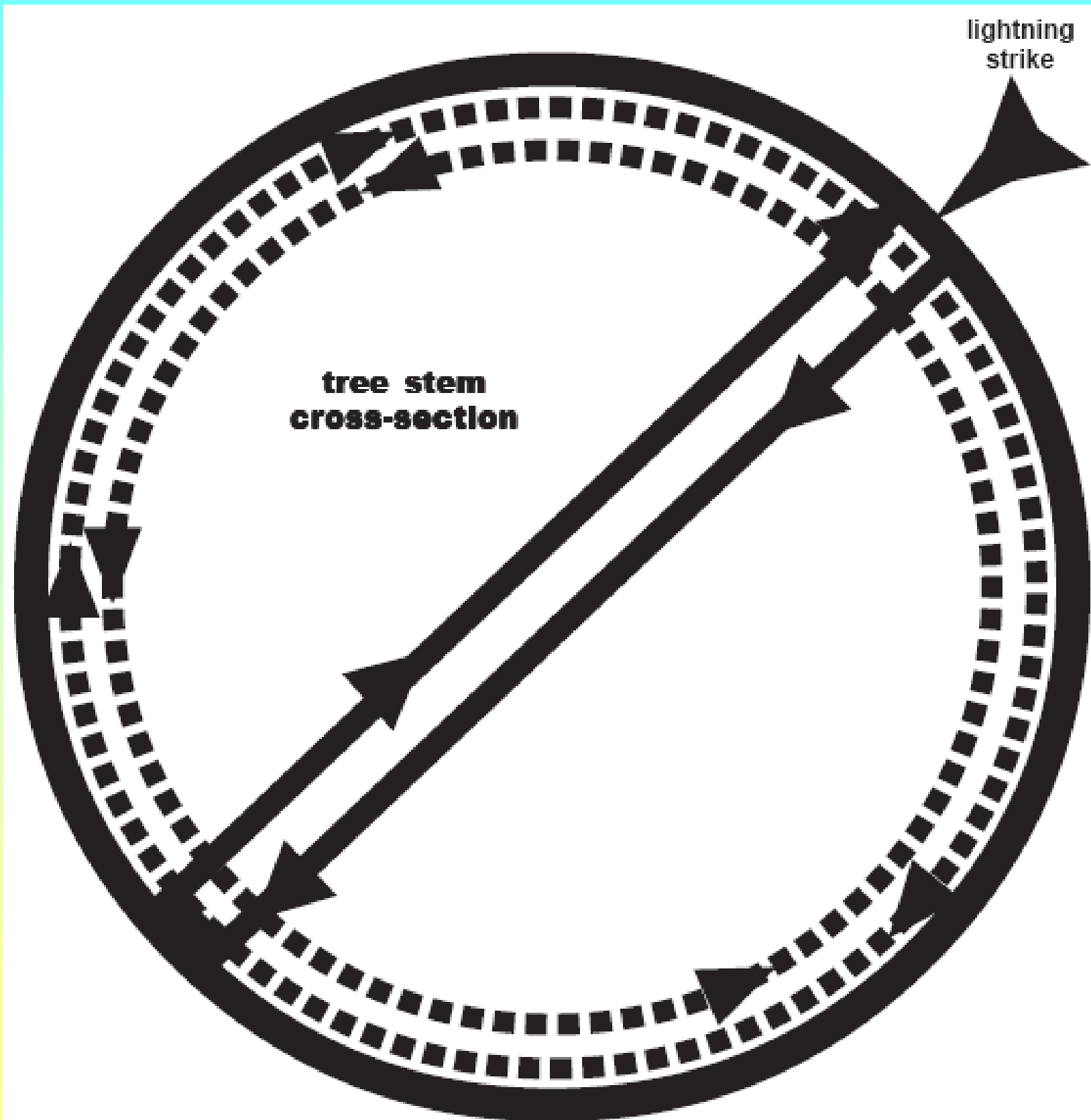
**10 ohms**

# **Pressure Wave**

**surface flash-over builds  
generates strong  
shock wave  
pounds against bark**

**first focused  
compression,  
then tension  
wave rebound**

# Compress Then Tension

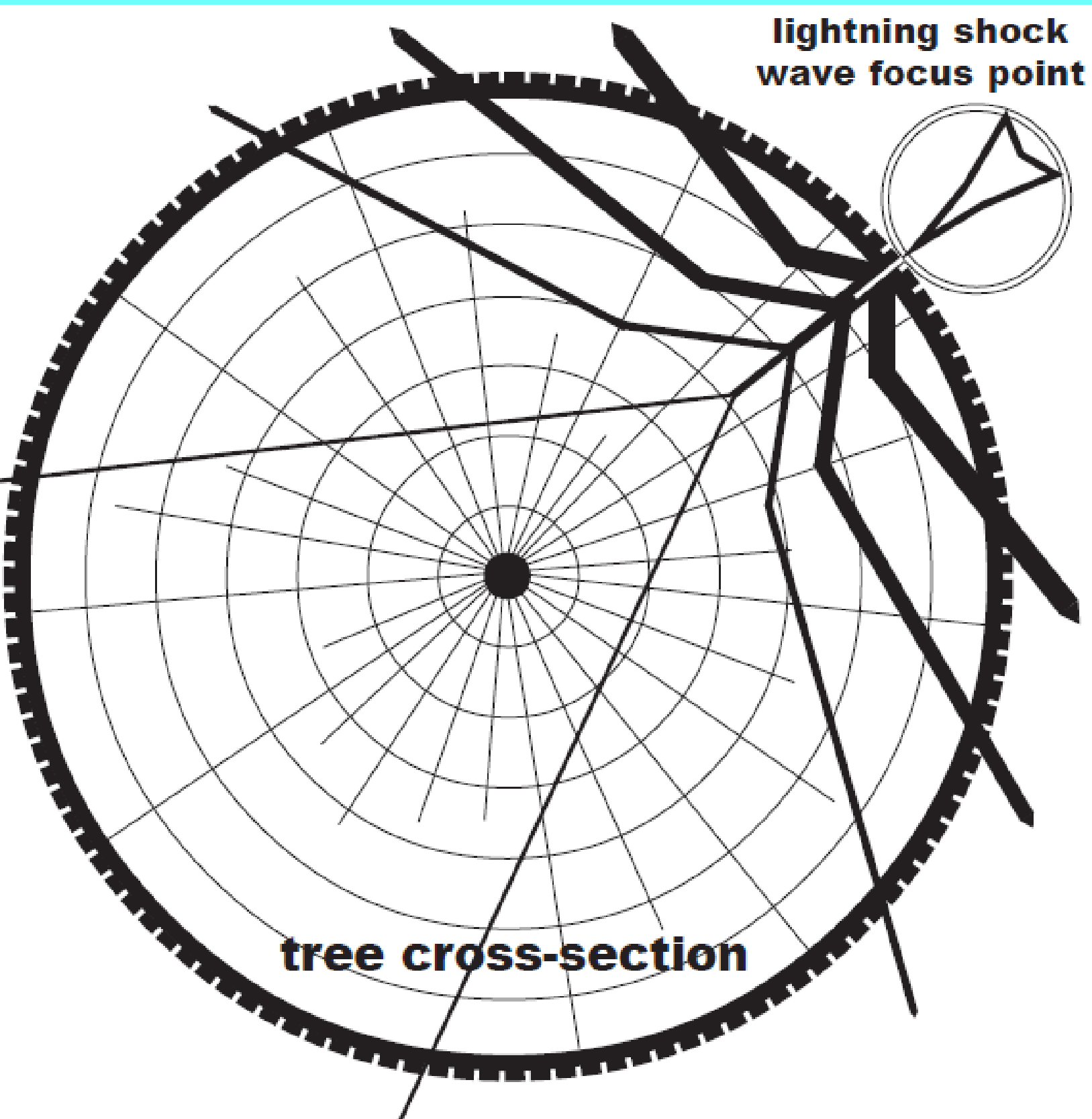


# **Blown Out**

**steam explosions  
(small energy)**

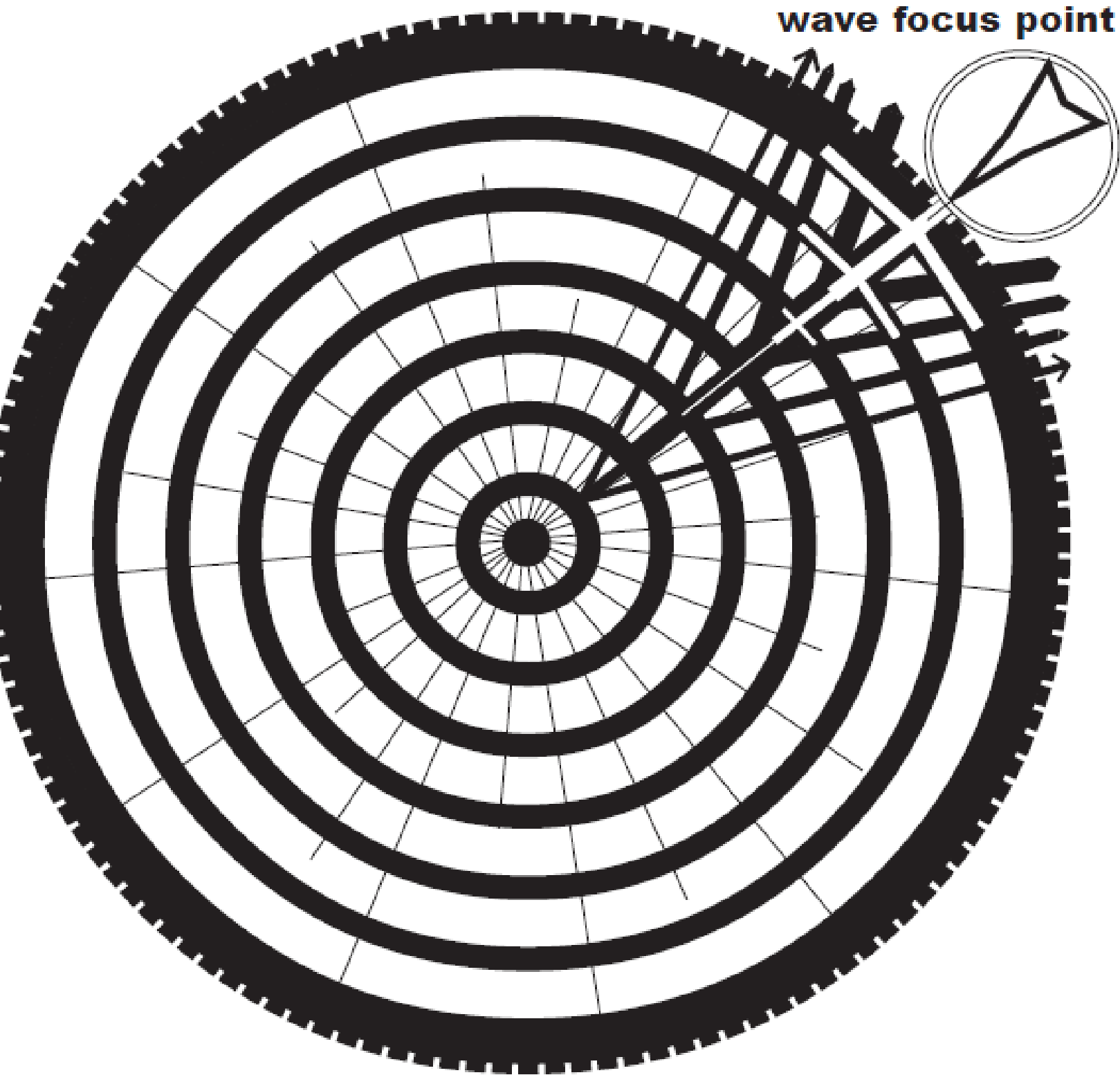
**explosive shock wave  
(big energy)**

**>600 psi -- >40 atms on  
tree causes internal waves**



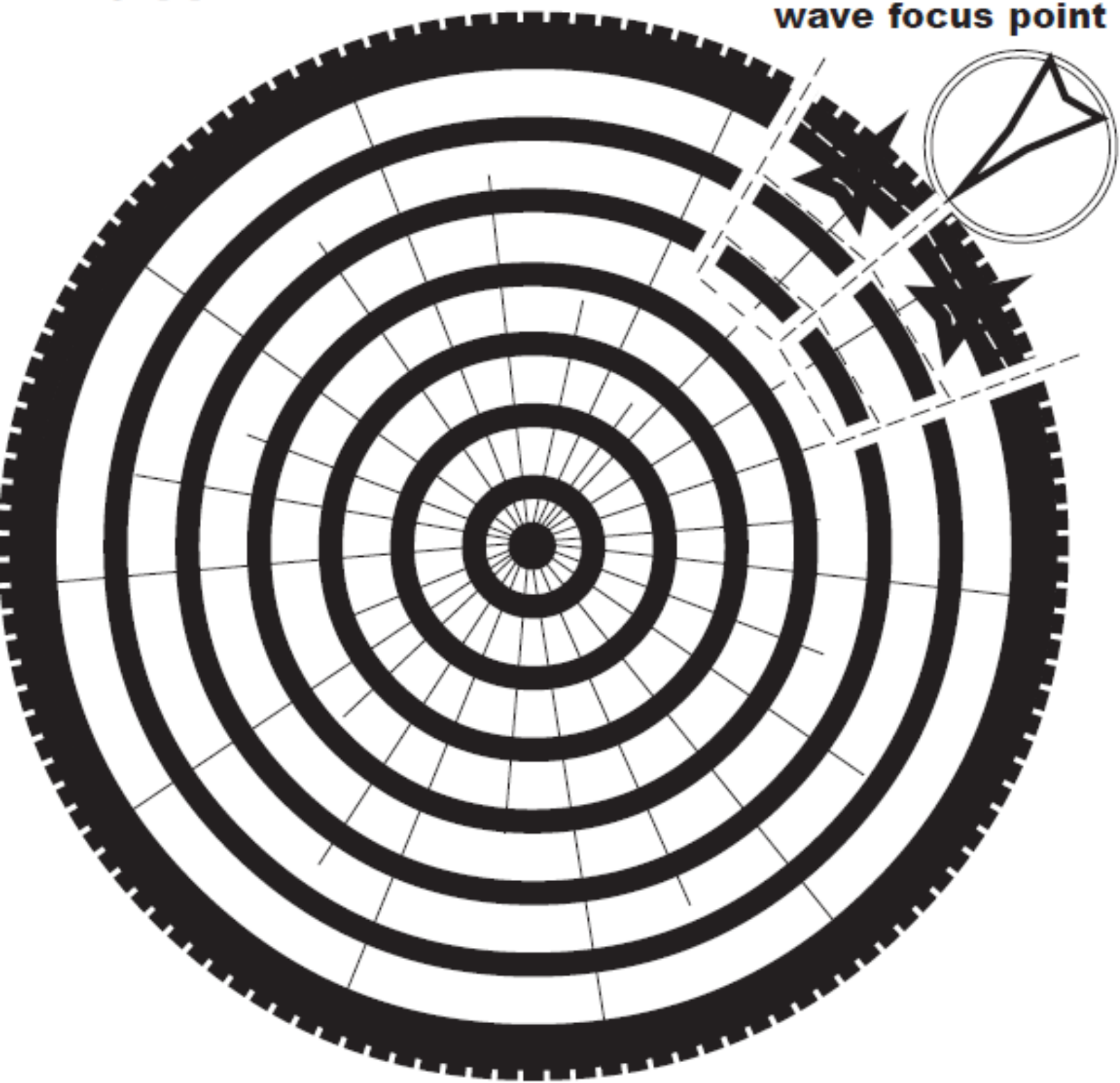
**tree cross-section**

**lightning shock  
wave focus point**



**tree cross-section**

**lightning shock  
wave focus point**



# **Strike**

# **Symptoms**

**permanent or  
recoverable  
leaf wilting**

**bark-resident  
pests attack**

**slow decline over 1-3 yrs**

# Pests

**secondary problem**

**attack physical  
injury sites**

**attracted by  
volatile materials  
released**

# **Fire!**

**~12,000 fires per year USA**

**constant current between  
strokes of 100-400 amps**

**~20% lightning strikes  
have constant current**

**most strikes char not ignite**



# **Lightning Conduction**

**&**

# **Tree Protection**

**CONCLUSIONS**

# **Therapeutics**

**installation of  
conductance  
system beforehand!**

**treatment ASAP  
afterwards**

***8 hours – reattachment  
& water***

***20 hours -- reinvigoration  
to whole tree***

# **Treatment BMPs**

**--tree lightning  
protection system  
for next time  
(if survives)**

**--water! zoned irrigation  
for 2 growing seasons  
(assure drainage !)**

**--crown misting & wind  
protection if severe**

# **Treatment BMPs**

- loosened tissues use pressure belt for 6 weeks**
- cover damage with water conserving covering**
- clean not prune!**
- preventative pesticide may be needed**
- delay nitrogen fertilization 1 season**

