INTRODUCTION TO TREE RINGS & DENDROCHRONOLOGY

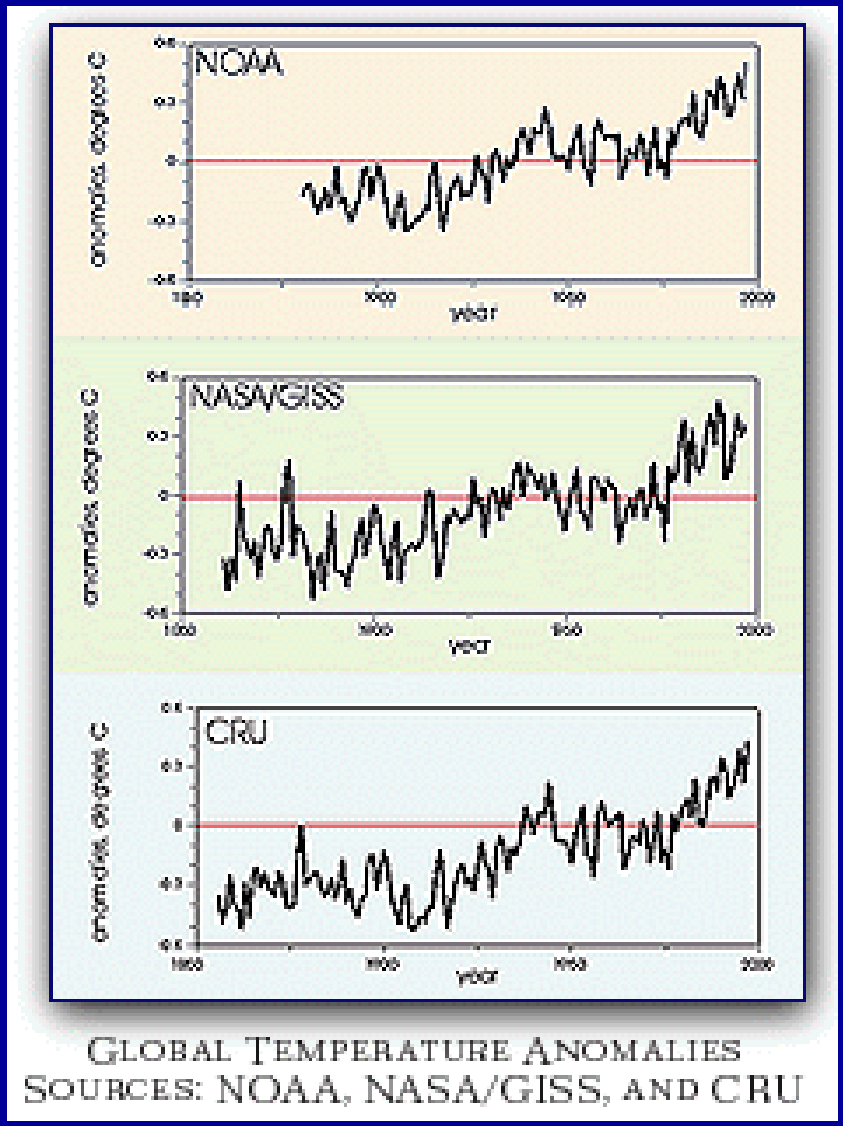
Trees and stones will teach you that which you can never learn from masters.

~ St. Bernard of Clairvaux

DETECTING GLOBAL WARMING:

INSTRUMENTAL RECORD

Thermometer-based Temperature Trends



Global Temperature Anomalies
Sources: NOAA, NASA/GISS, and CRU

To make an incontrovertible case about the role that humans play in global warming, what do scientists need?

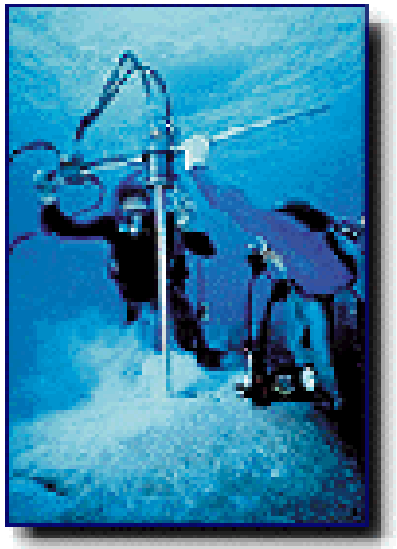
(a) a long-term temperature record (many centuries)

(b) that represents a large part of the globe

(c) . . . . so we can look over the long term record and say, “What's the average been for several hundred years, and is recent warming a significant departure from that average?”

So how do we get long-term temperature records?

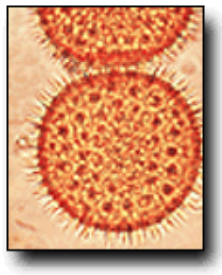
FROM TOOLS CALLED: "PROXY" DATA *or* "NATURAL ARCHIVES" of CLIMATE



Corals

Ice cores

Lake, bog & ocean sediments



Pollen

Dendrochronology is the dating and study of annual rings in trees:

- ***chronos***: time, or more specifically events in past time
- ***dendros***: from trees, or more specifically the growth rings of trees
- ***ology***: the study of . . .

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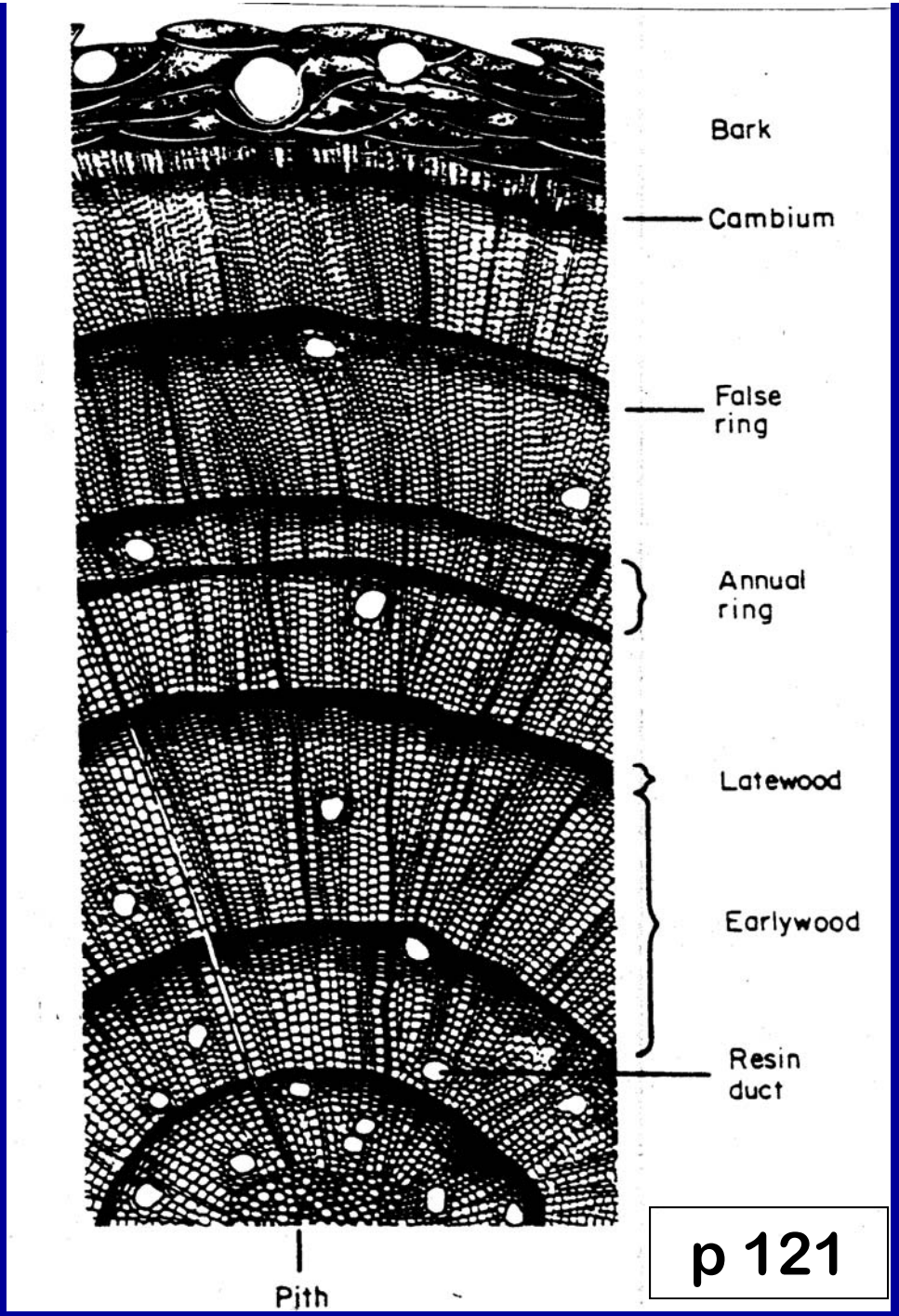
Partial cross-section of a coniferous tree

How old is it? (in complete years)

7 years old

(now in 8th year of growth)



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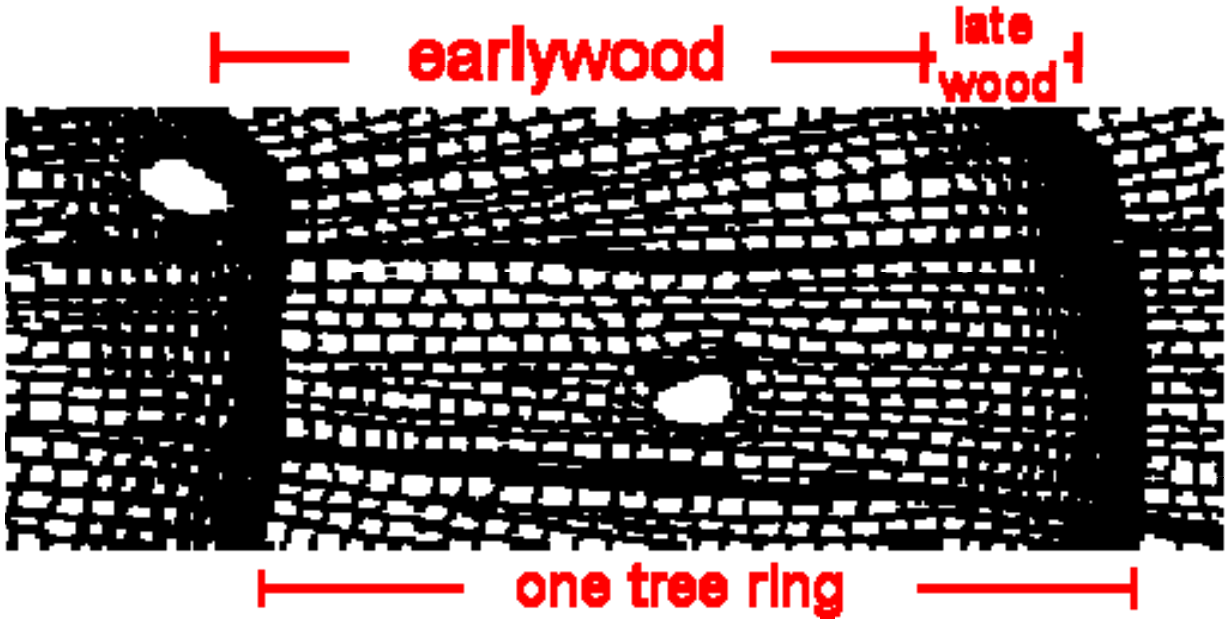
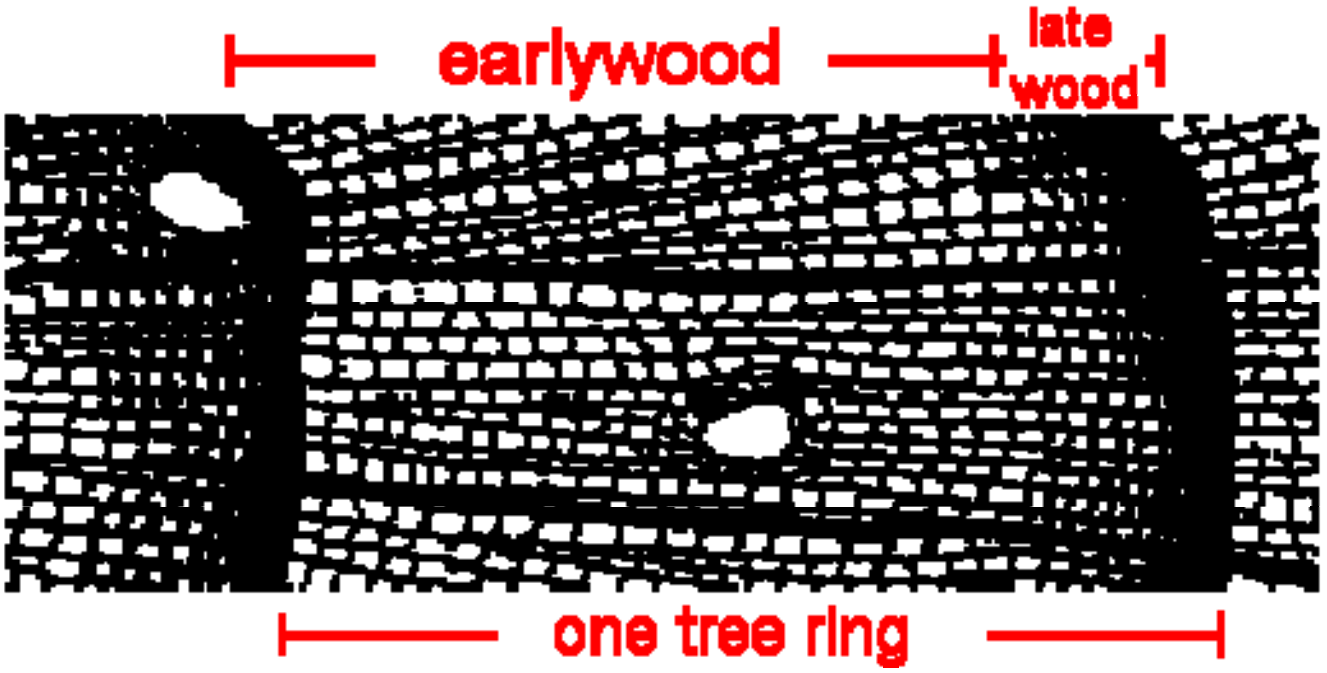
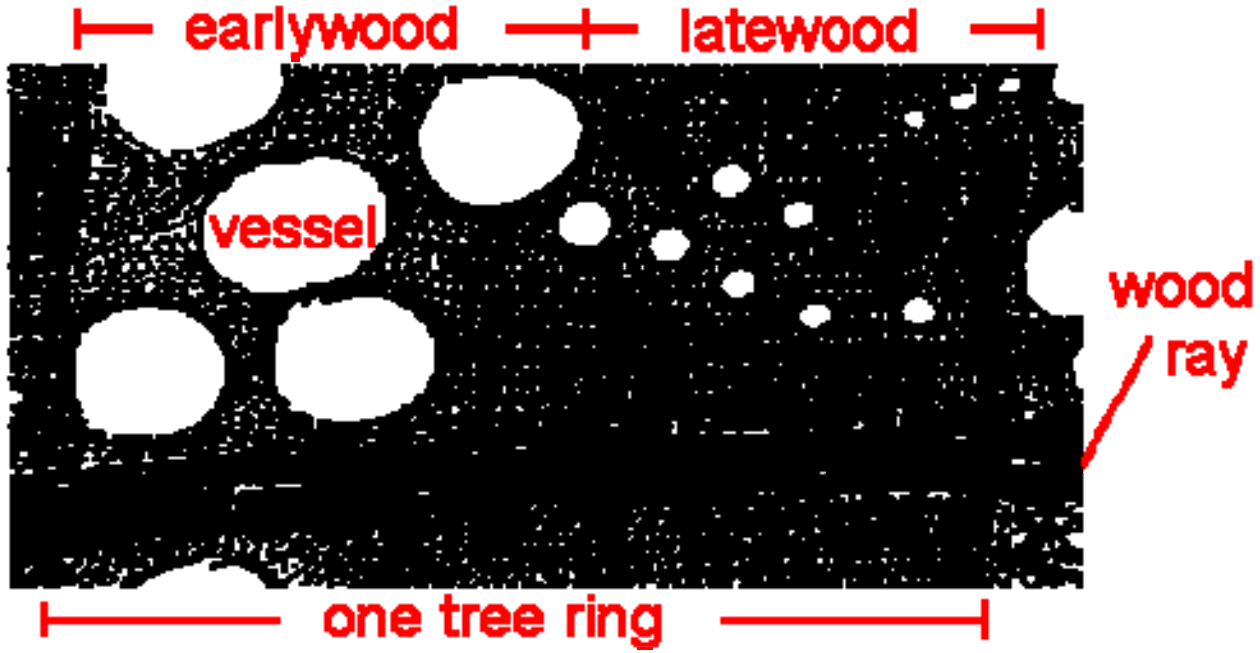
Conifer Tree Ring (cross-section view)



- Earlywood:
  - Cells: thin walls, large diameter
  - Appears light in color
- Latewood:
  - Cells: thick walls, small diameter
  - Appears dark in color



Ring Porous Angiosperm Tree Ring (cross-section, view)



- Earlywood:
  - Cells: large diameter vessels
- Latewood:
  - Cells: small diameter vessels

But not all trees have rings!

☺

The image below shows a conifer tree-ring sample with about thirty rings (every tenth ring is marked) – growing from left to right.

The rings display much variation:

Tree growth (adding new cells) is this way

← Pith
(center of tree)

Bark →
(outside of tree)

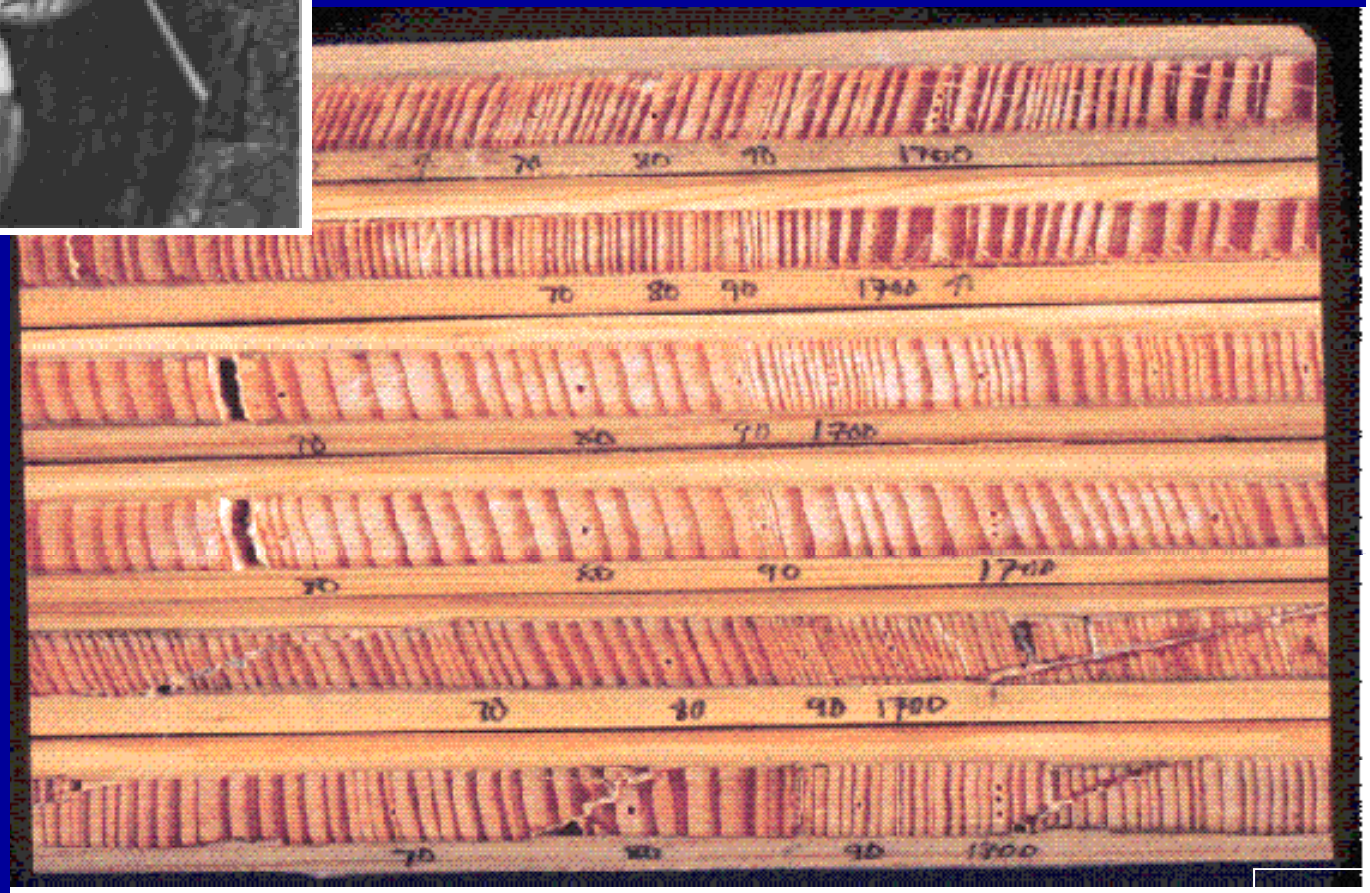
☺

Variation in these rings is due to variation in environmental conditions when they were formed.

(cold or warm temperatures / dry or moist soil conditions, etc. – even insect outbreaks and non-climatic factors, too)

Thus, studying this variation leads to improved understanding of past environmental conditions and is the basis for many research applications of dendrochronology.

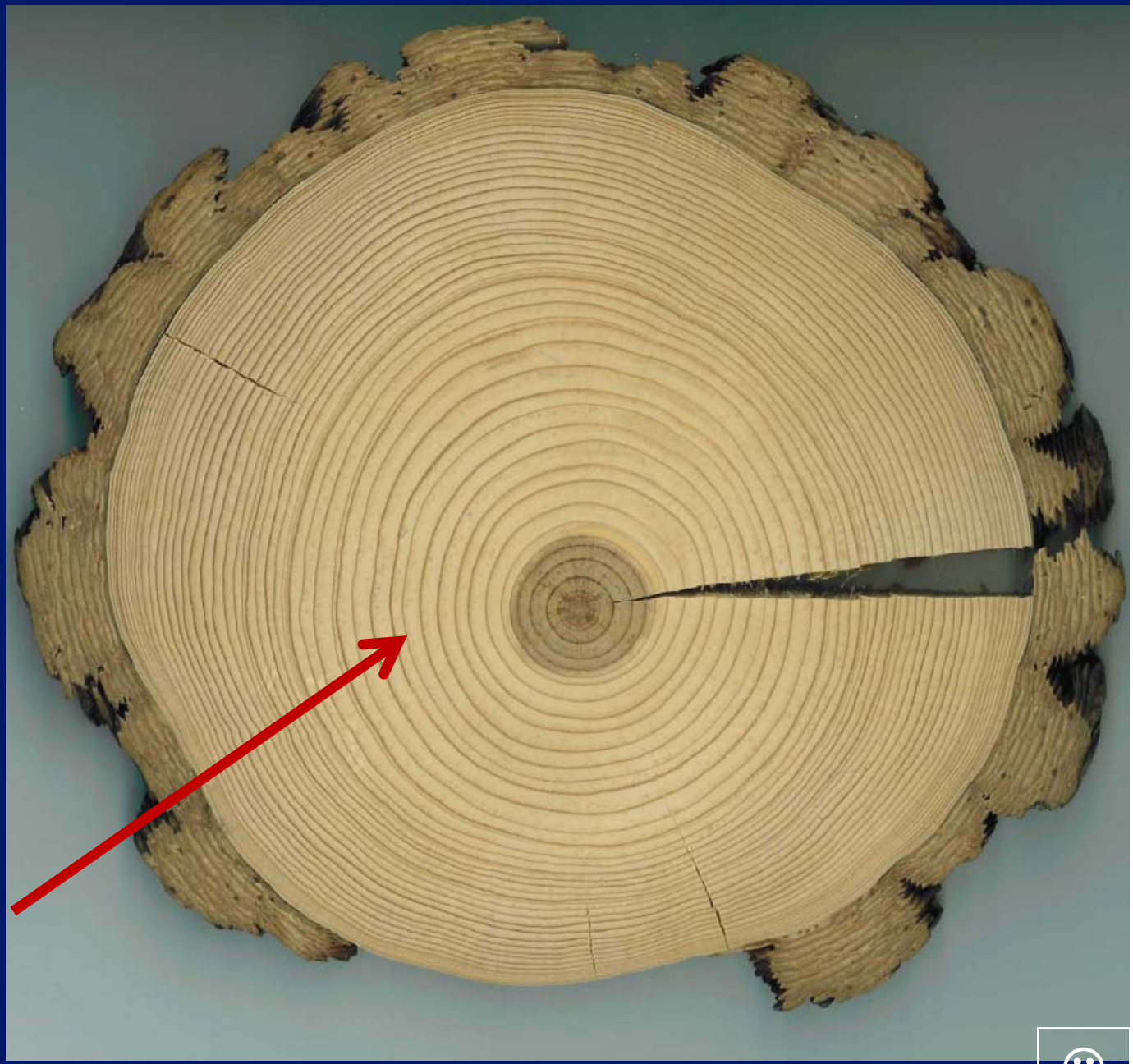
How do we get the tree rings without killing the trees!

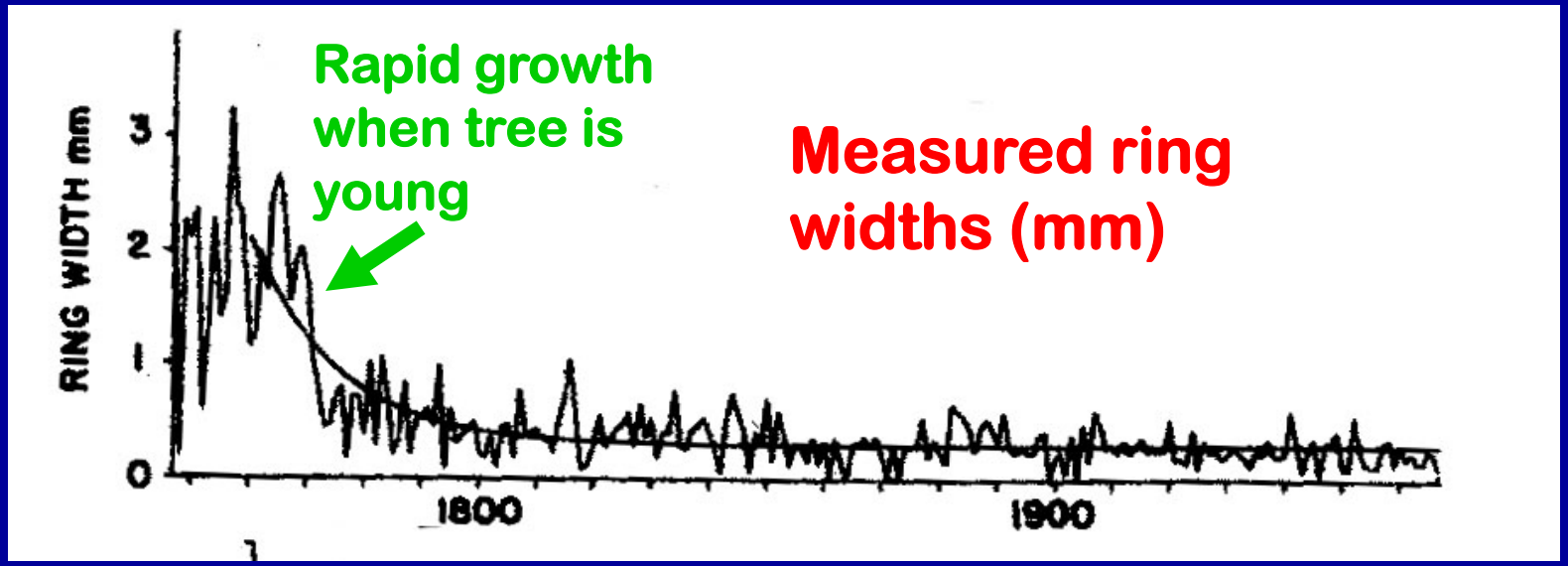


Extract cores with an increment borer

If the tree is already dead or cut down, we can take cross-sections from the tree or its stump ➔

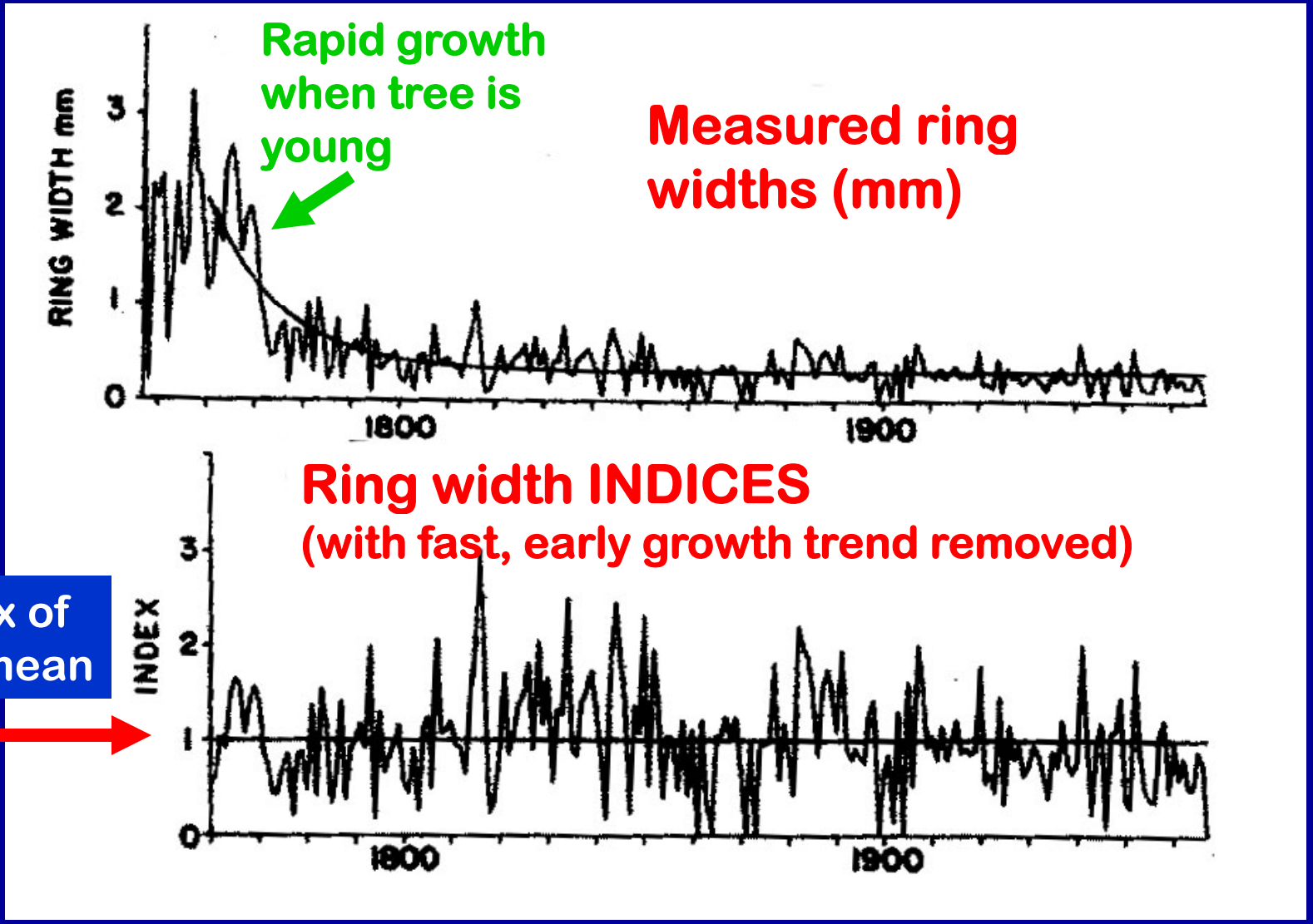
Notice how wide the rings in the center are – this was when the tree was young and growing faster!





TREE-RING WIDTH CHRONOLOGY

A time series plot!



TREE-RING WIDTH CHRONOLOGY

KEY PRINCIPLES OF DENDROCHRONOLOGY

UNIFORMITARIANISM –

"The present is the key to the past"

(this is a key principle for many other natural archives as well)

Key Principles p 121

LIMITING FACTORS –

growth can occur only as fast as allowed by the factor that is most limiting, e.g.

- "too dry" – the amount rainfall is the limiting factor
- "too cold" or "too hot" – the temperature is the limiting factor
- NOTE: the limiting factor can vary from site to site, even in the same species of tree!

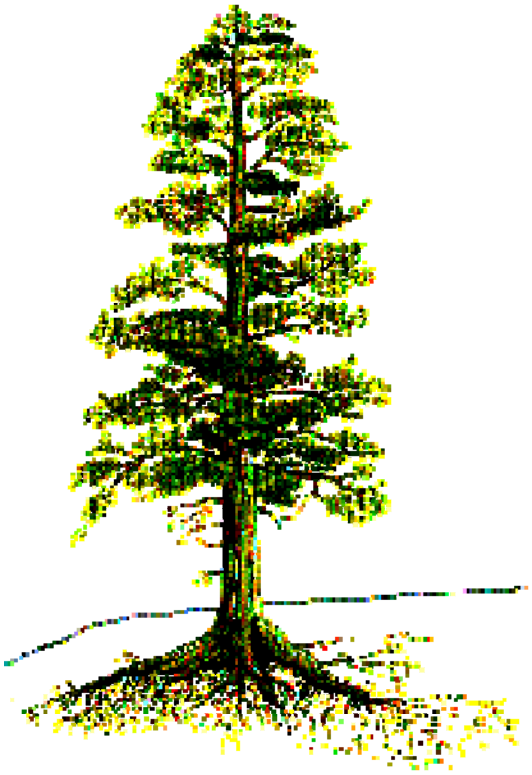
Key Principles p 121

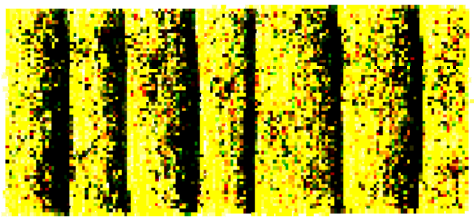
SITE SELECTION --

sites are selected based on criteria of tree-ring sensitivity to an environmental variable

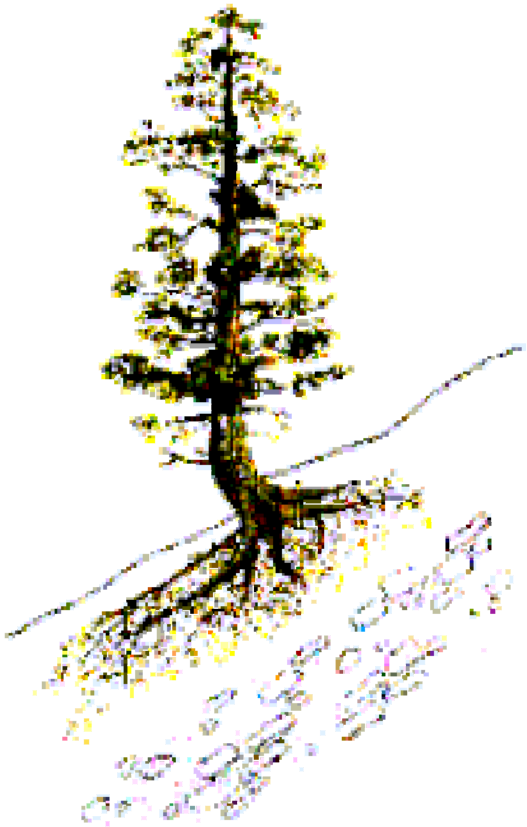
(temperature, precipitation, etc.)

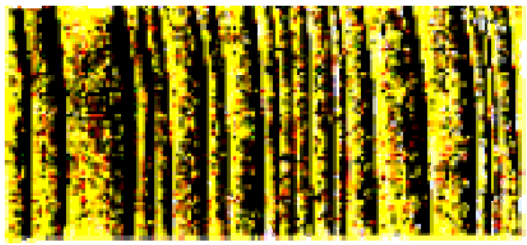
Key Principles p 121





Complacent

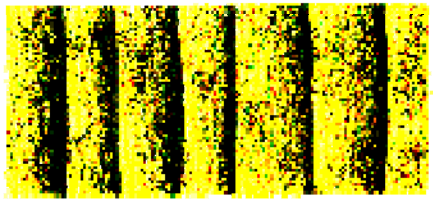




Sensitive

"Sensitive" tree growth:

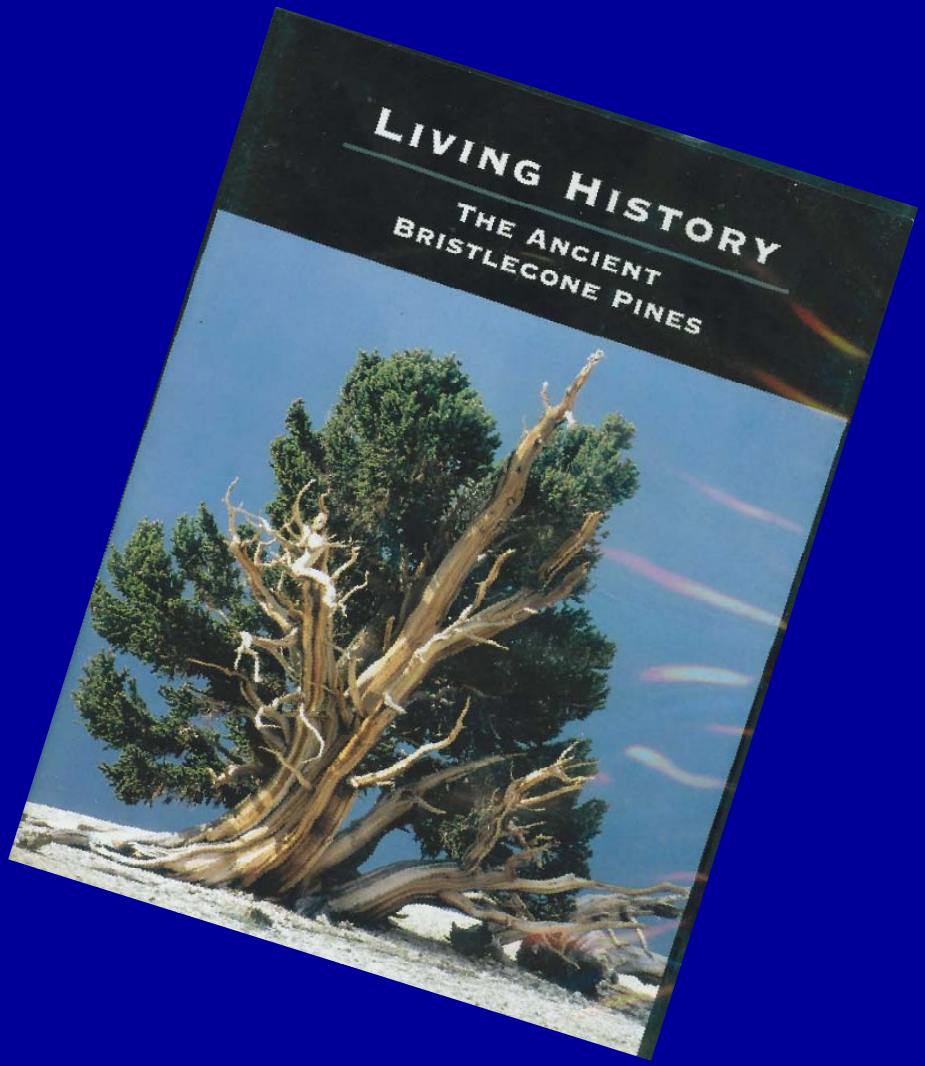
- •High degree of annual variation
- •Wide and narrow rings intermixed through time
- •Limiting growth factor (e.g., rainfall) is highly variable year to year
- •Especially true for harsh sites (steep/rocky for moisture sensitivity; see figure at left)
- •Reasonably sensitive ring growth is good:
  - •Matching patterns of relatively wide and narrows rings across trees is easier when ample variation exists



"Complacent" tree growth:

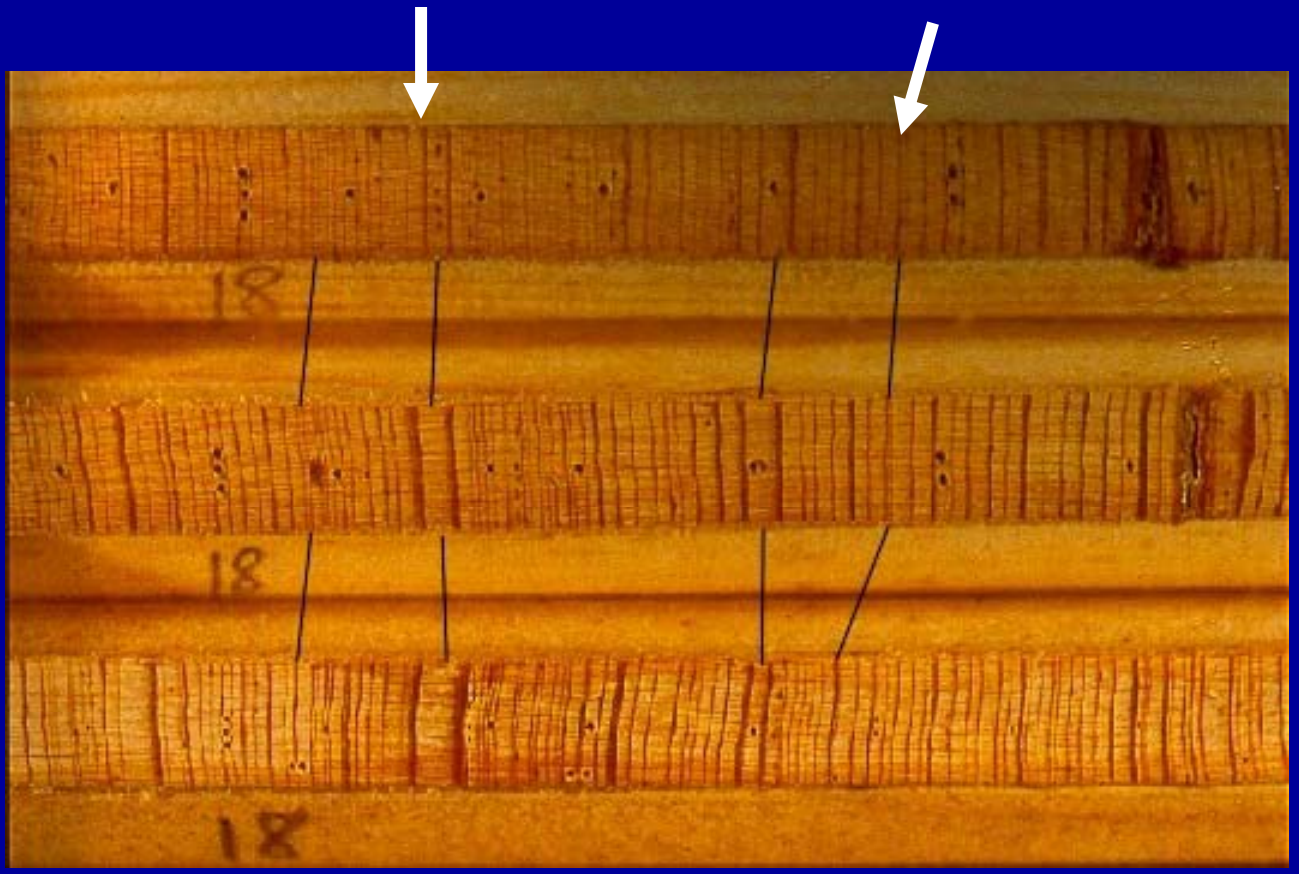
- Low degree of annual variation
- Rings are roughly the same for many years consecutively
- limiting growth factor is not variable from year to year
- Especially true for benign sites (flat with deep soil for moisture complacency; see figure at left)
- Complacent ring growth can be difficult to crossdate:
  - matching patterns of relatively wide and narrows rings across trees is harder when not much variation exists

VIDEO BREAK:



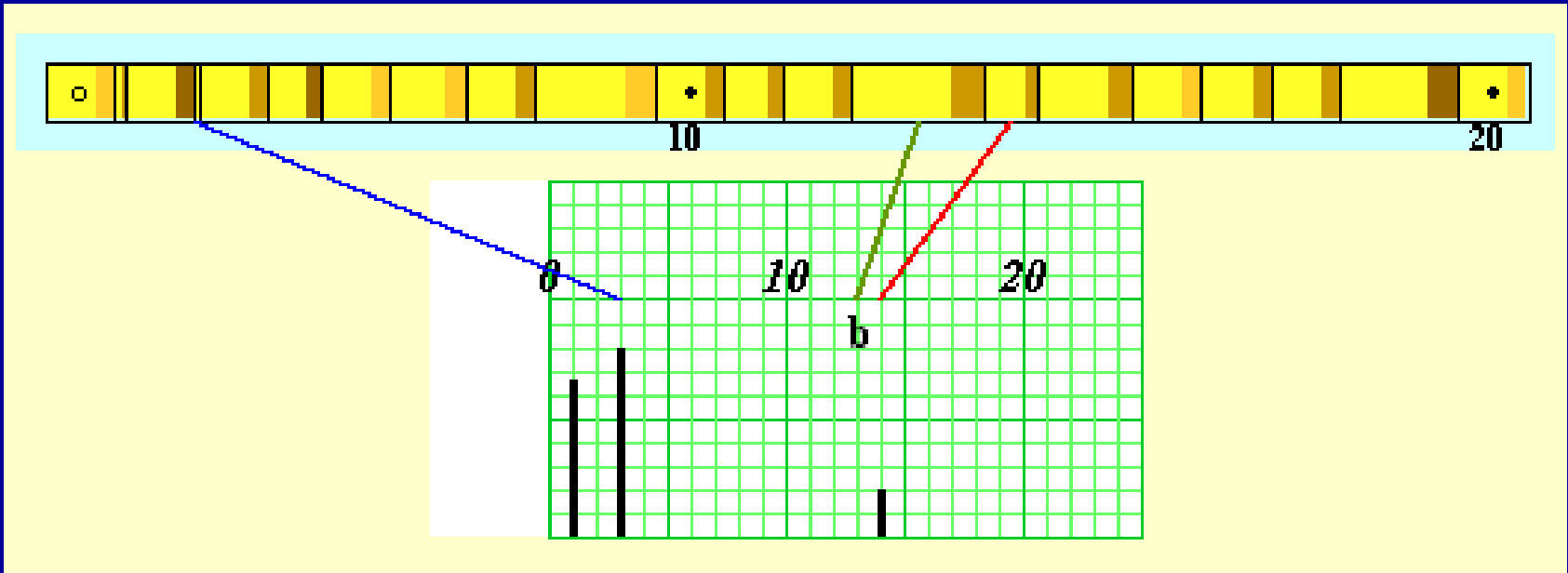
CROSSDATING –

matching patterns in rings of several tree-ring series will allow precise dating to exact year – HOW????



Key Principles p 121

MAKING SKELETON PLOTS OF A TREE-RING CORE

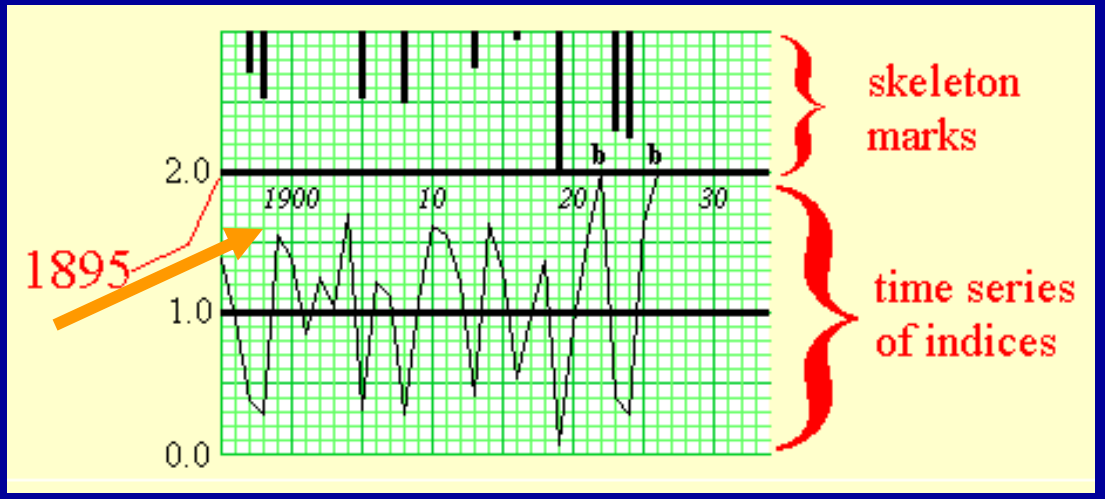


You plot a line for each NARROW ring, the narrower the ring, the longer the line!

http://www.ltrr.arizona.edu/skeletonplot/plotting.htm

DATED MASTER CHRONOLOGY

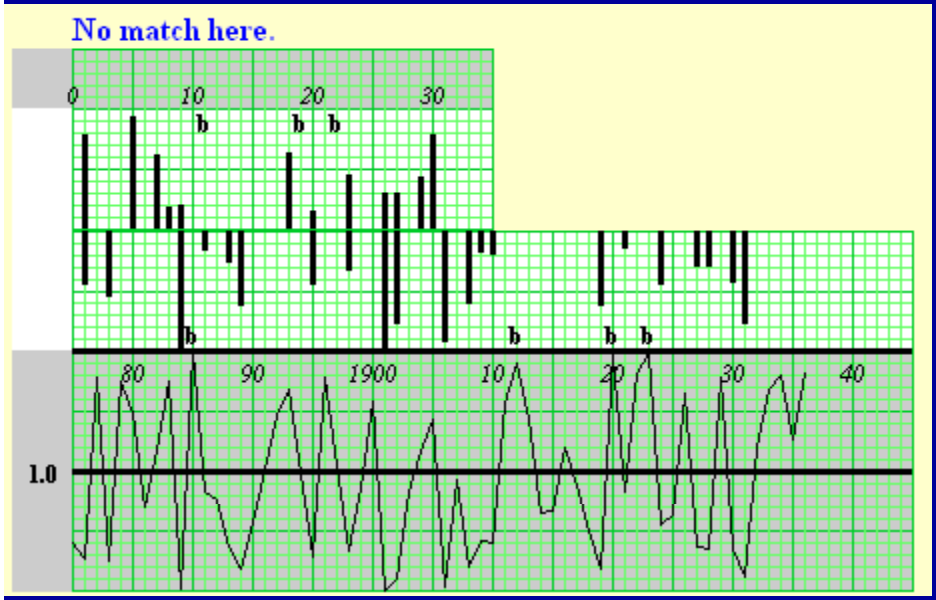
The master chronology is based on previously measured and dated tree rings from the same area

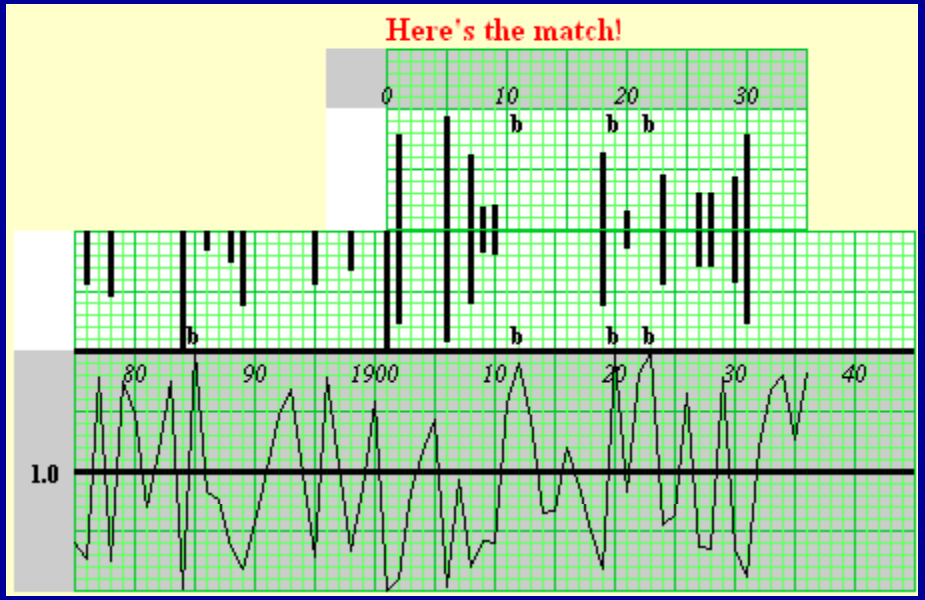


Actual calendar dates

PATTERN MATCHING

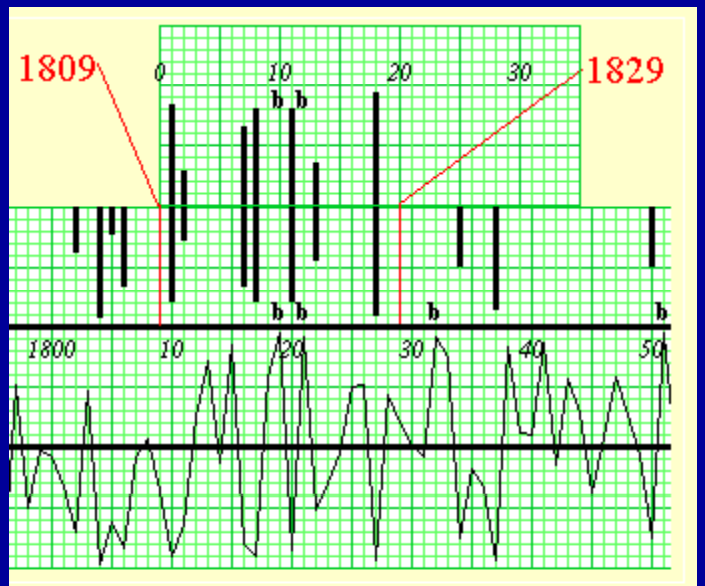
You match the pattern of the skeleton plot from the undated core with the skeleton plot of the dated master chronology:





http://www.ltrr.arizona.edu/skeletonplot/patternmatching.htm

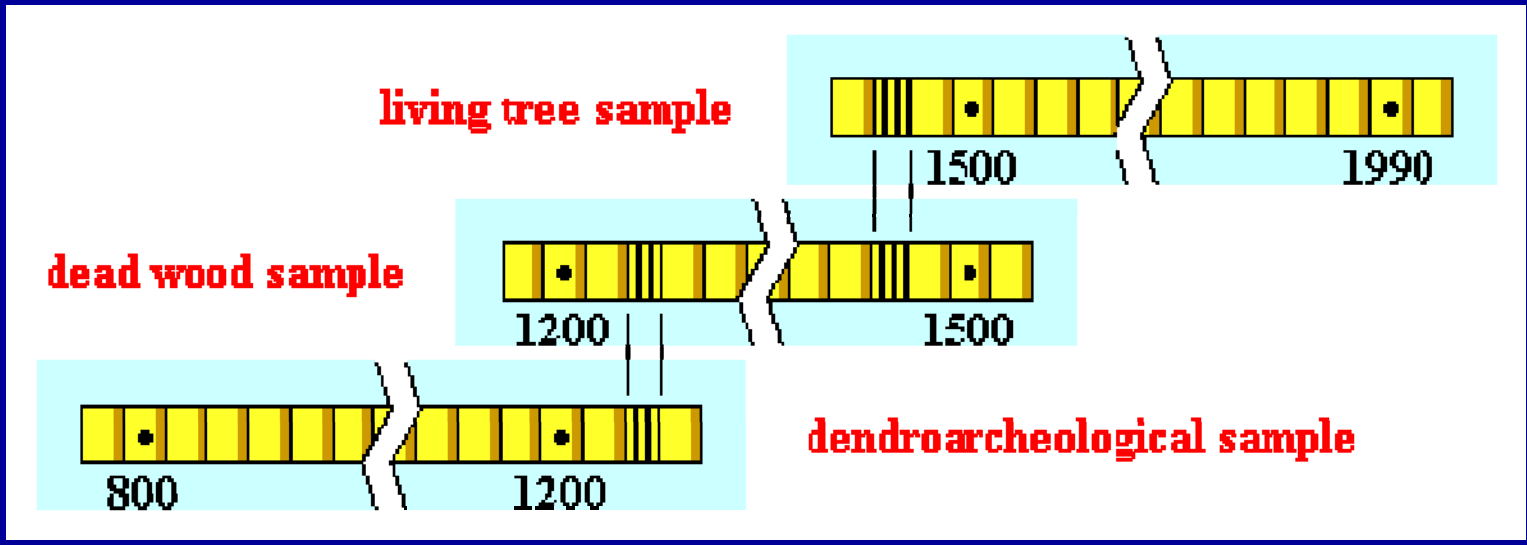
After the pattern matches with the MASTER CHRONOLOGY, you can **ASSIGN ACTUAL CALENDAR DATES** to the skeleton plot & core



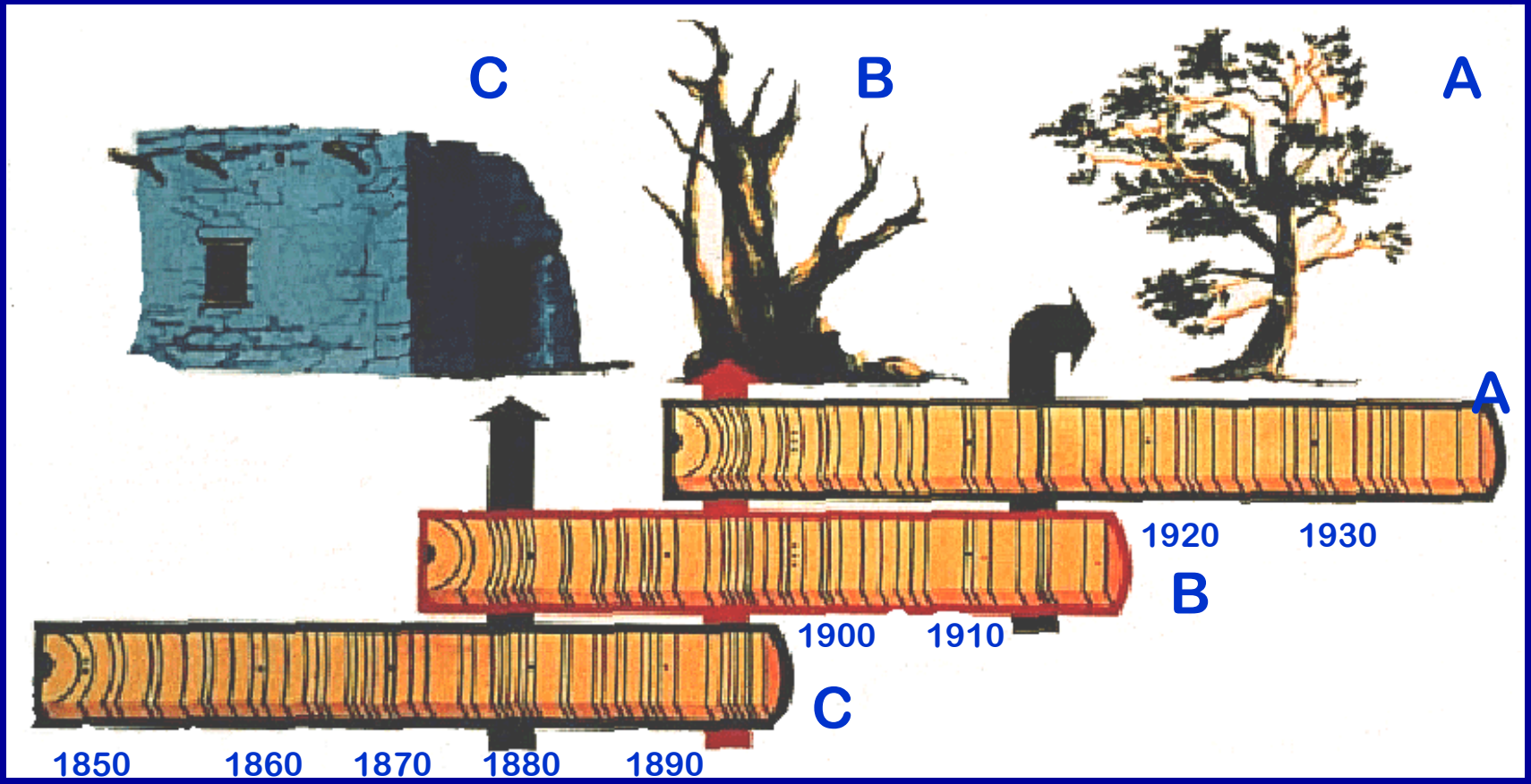
This is CROSSDATING!

After crossdating, dendrochronologists can:

- **Assign the true year of formation for every ring of each sample**
- **Analyze past environmental and/or human events.**
- **Overlap crossdated samples, as shown to extend the record back in time:**



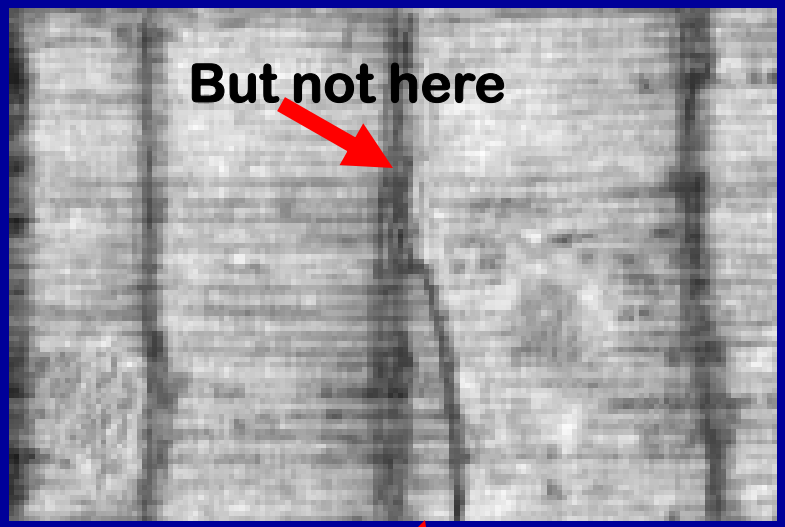
Crossdating: The Basic Principle of Dendrochronology

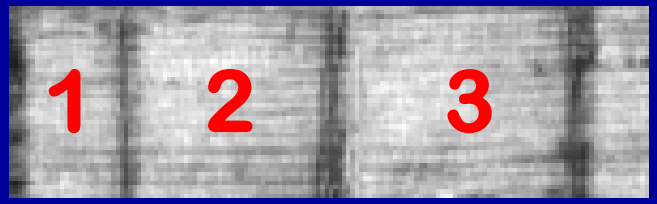


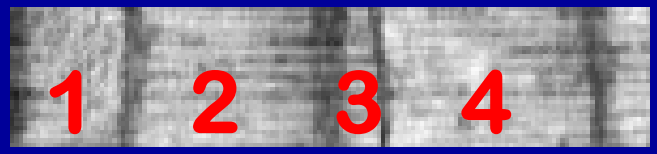
<<<<<<< "Bridging" the record back in time <<<<<<<

Two Crossdating Challenges:

MISSING RINGS
("locally absent"rings)

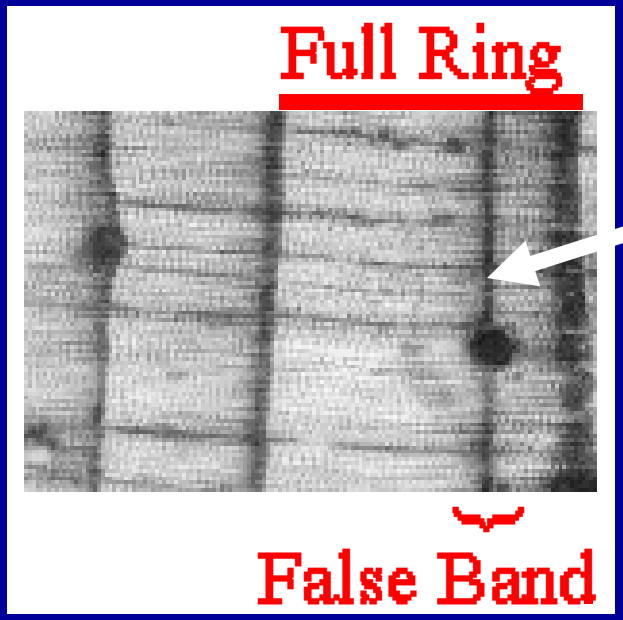






Two Crossdating Challenges:

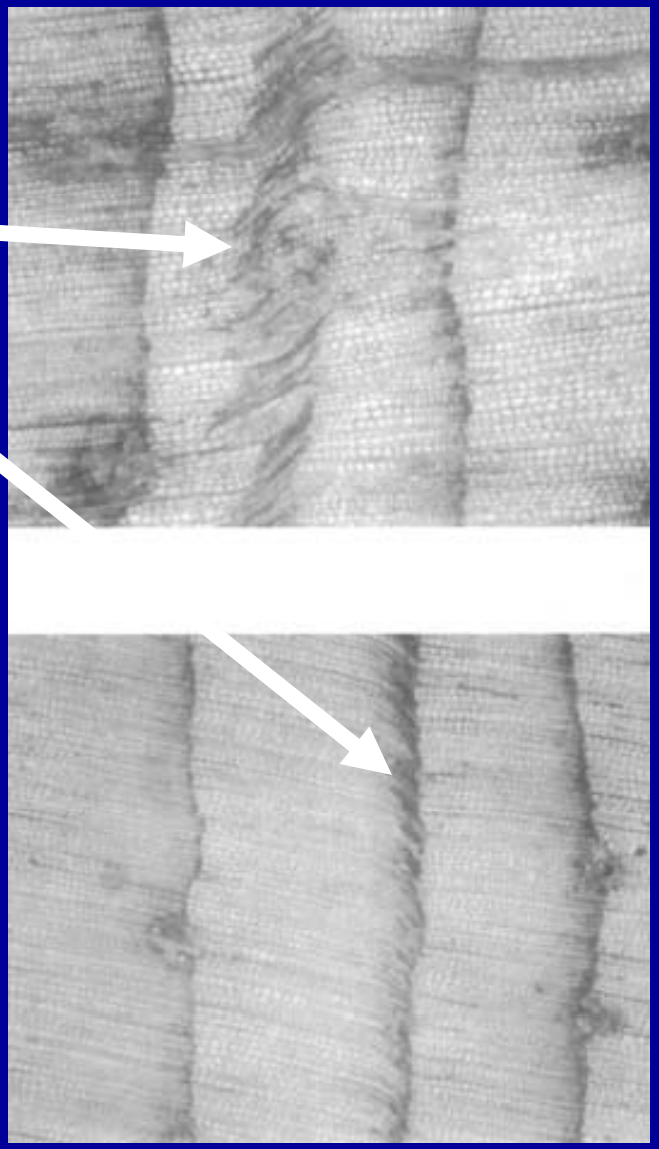
"FALSE" RINGS



During stressful time during growing season, tree begins to shut down growth, then growth resumes – so looks like two annual rings, when all the growth occurred during the same year!

One more type of ring, that is a very useful crossdating aid:

"Frost Rings"



Growing cells get crushed and damaged during an unseasonable FREEZE event (1 -2 days) of below freezing temperatures ➔ leaves permanent mark in the wood!
AIDS PATTERN MATCHING!

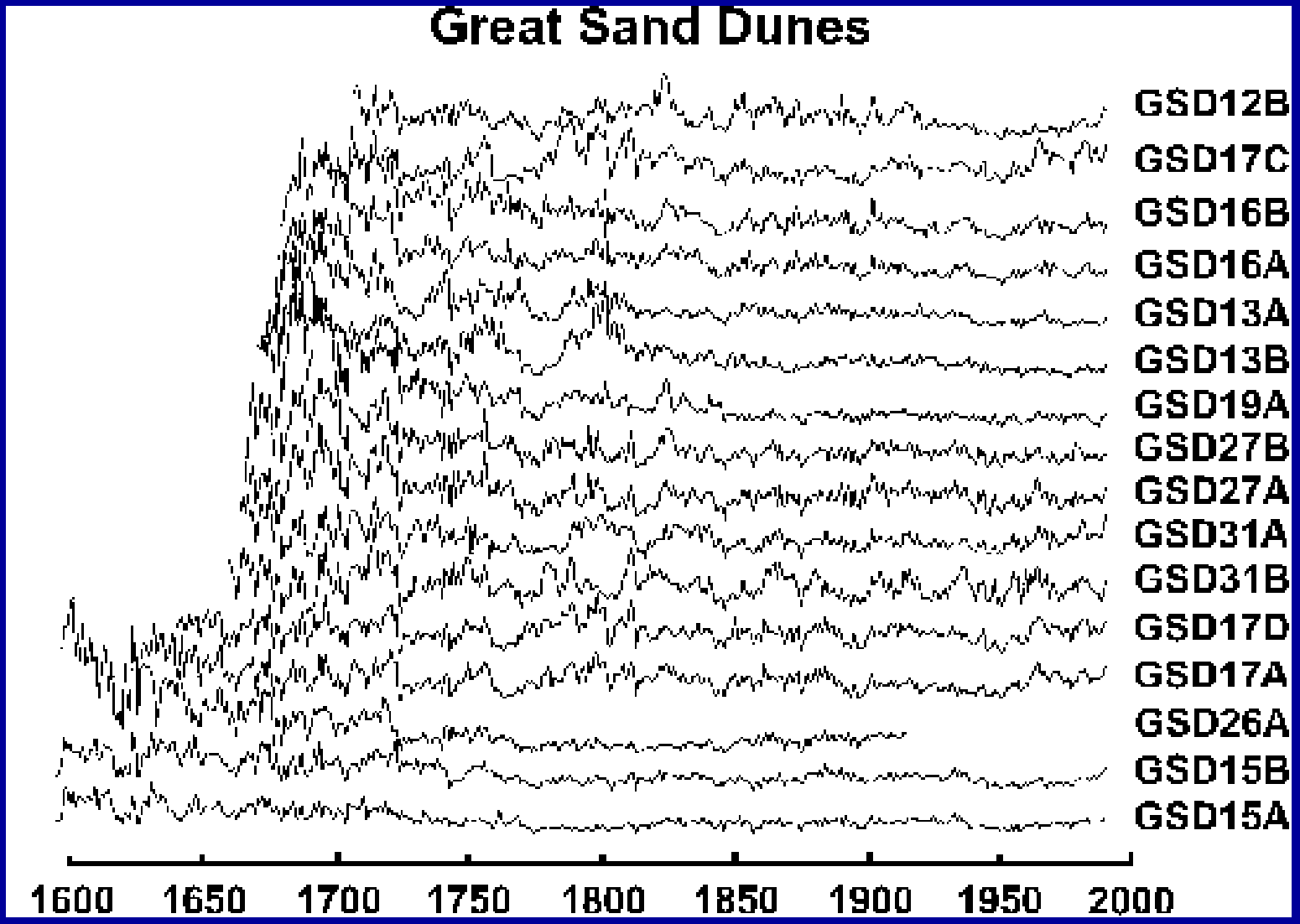
☺

Now, back to the principles:

REPLICATION –

"noise" minimized by sampling many trees at a site + more than one core per tree

Key Principles p 121


Great Sand Dunes
GSD12B
GSD17C
GSD16B
GSD16A
GSD13A
GSD13B
GSD19A
GSD27B
GSD27A
GSD31A
GSD31B
GSD17D
GSD17A
GSD26A
GSD15B
GSD15A
1600
1650
1700
1750
1800
1850
1900
1950
2000

ECOLOGICAL AMPLITUDE –

trees are more sensitive to their environment at latitudinal and elevational limits of the tree species' range

Very old tree on Mt Graham, SE Arizona
inner ring date: A.D. 1101

Key Principles p 121

KEY SCIENTIFIC ISSUES

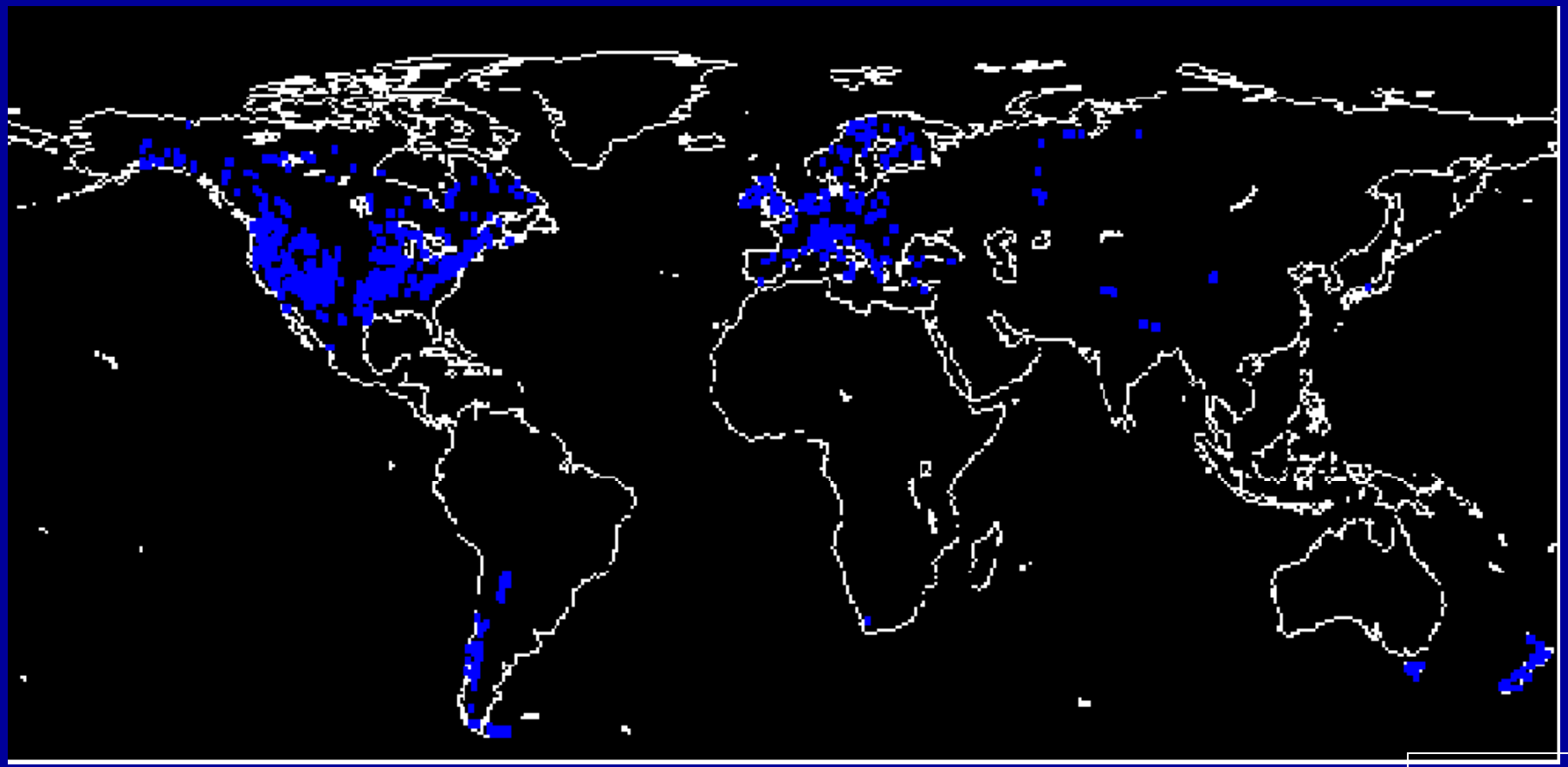
- **Missing rings & false rings** (to identify these, need a "master chronology")
- **Species limitations** (some trees have no rings, non-annual rings, or poorly defined rings)
- **Trees must crossdate!** (can't develop a chronology or link to climate without this)

Today's class activity

Top of p 122

- **Geographical limitations**

tropics, deserts and other treeless areas, oceans, etc.)



- **Age limitations**

(old trees hard to find; oldest living trees = Bristlecone Pines

> 4,000 years old: 4,780+)

- **Value of precise dating**

(long chronologies, climate reconstructions, archaeology, radiocarbon dating)

I-2 ASSIGNMENT
TREE-RING CROSDATING DEMO

ASSIGNMENT I-2 LINK:

http://fp.arizona.edu/khirschboeck/nats101gc/i-1_skeleton.htm

CROSSDATING TUTORIAL LINK:

http://www.ltrr.arizona.edu/skeletonplot/introcrossdate.htm

MAKING YOUR OWN SKELETON PLOT ONLINE FOR I-2

http://www.ltrr.arizona.edu/skeletonplot/SkeletonPlot19.htm

See p 126 – 127 and D2L ASSIGNMENT I-2

ASSIGNMENT I-2 on
Tree-Ring Crossdating will be
DUE THURSDAY OCT 1
(in the D2L Dropbox)

HELP SESSIONS
to be held next week"

Monday Sep 28 between 4:00 - 5:00
Wednesday Sep 30 between 1:30 - 3:00 pm
Wednesday Sep 30 between 5:30 - 6:30 pm

in SCIENCE LIBRARY 308