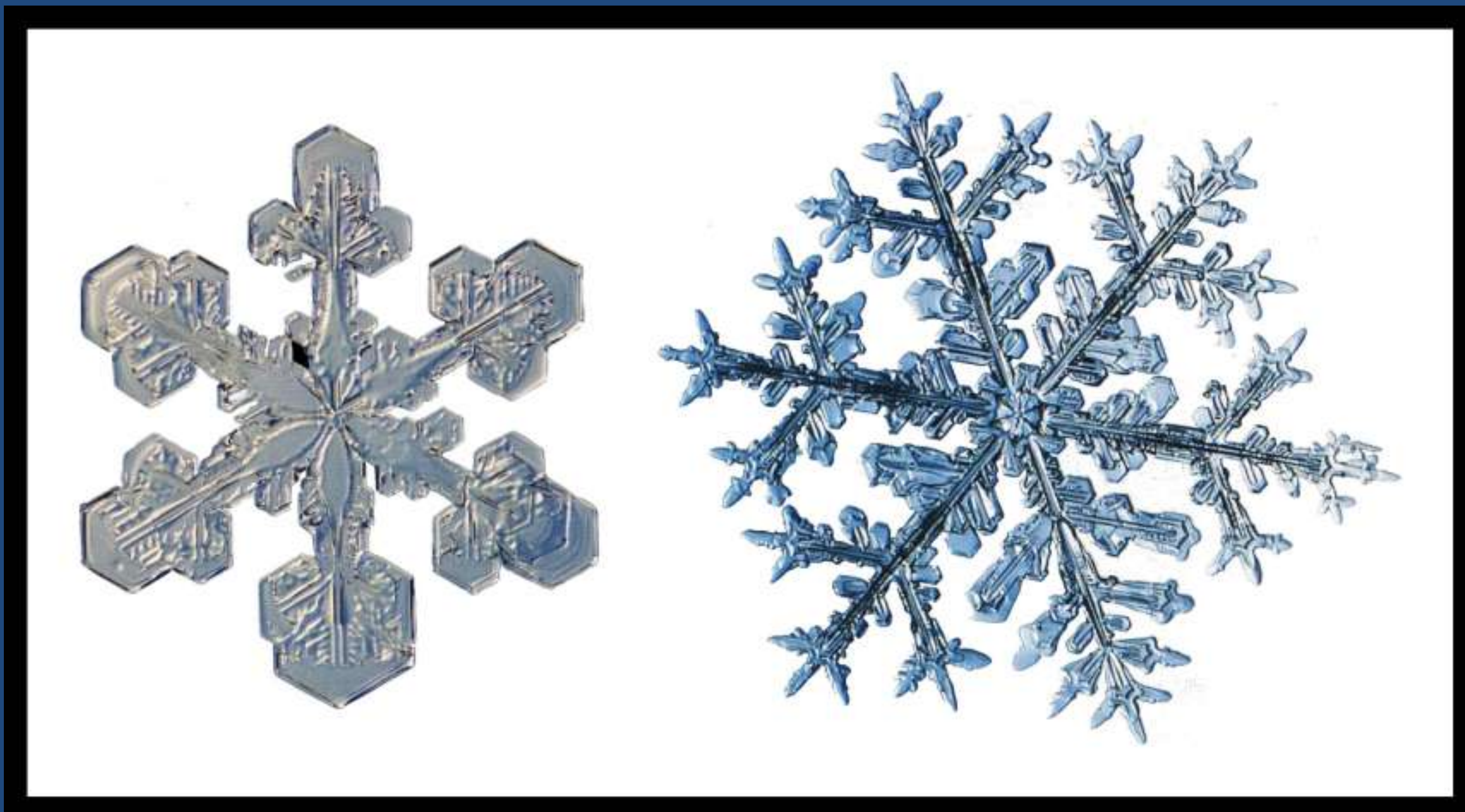
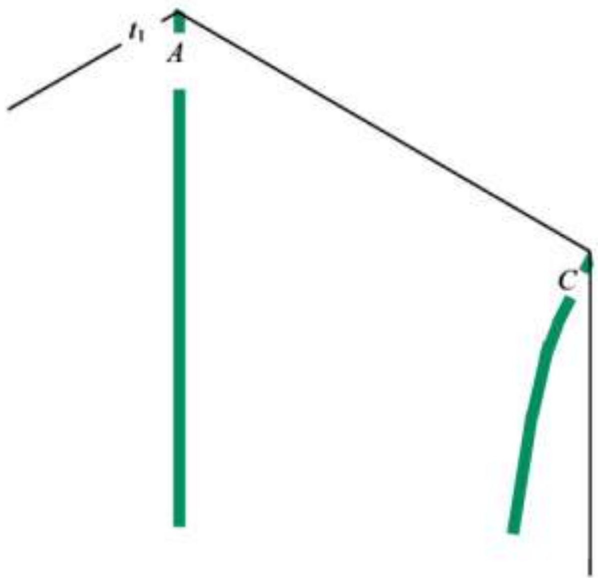
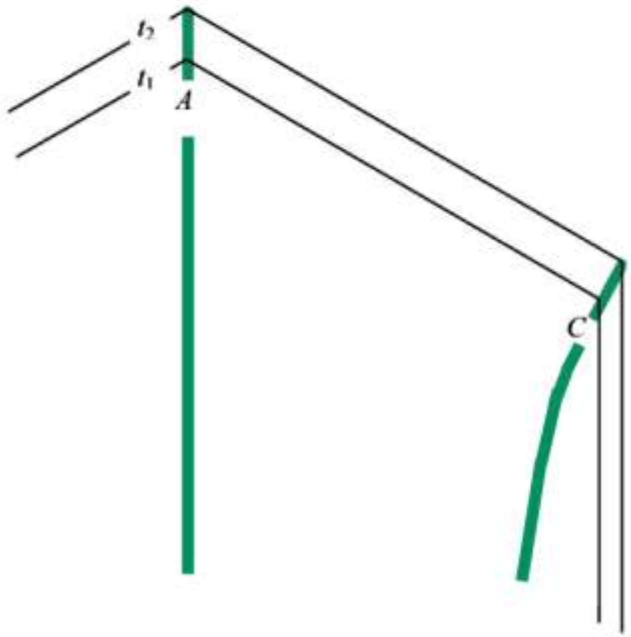
Sidebranching



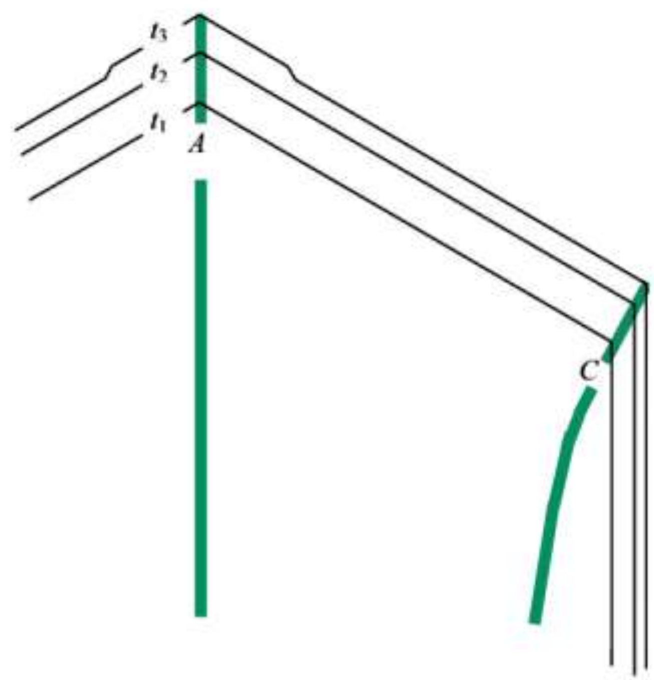
Sidebranching process



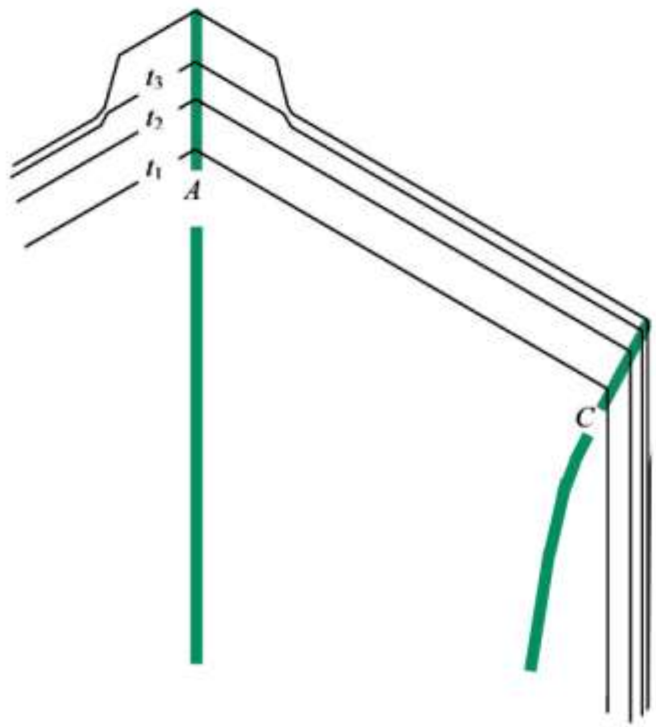
Sidebranching process



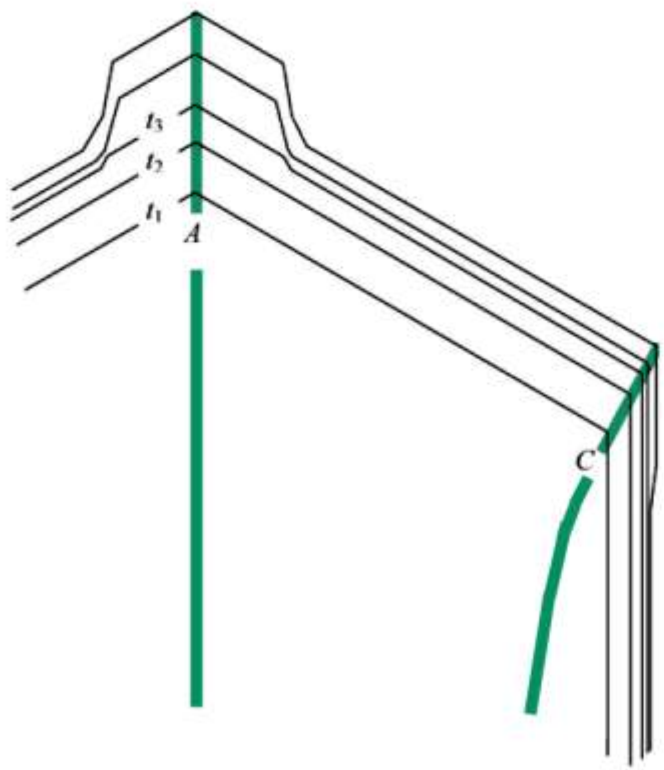
Sidebranching process



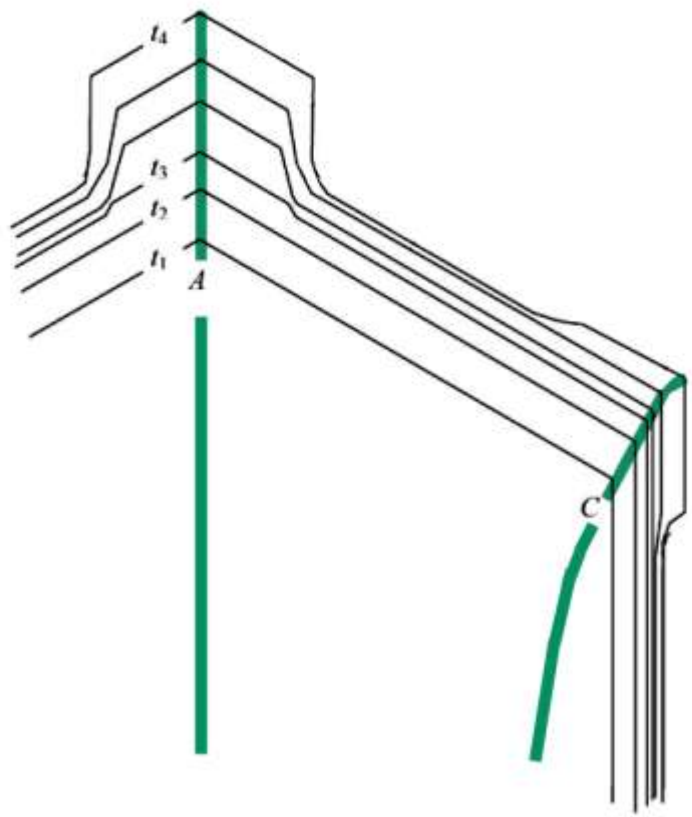
Sidebranching process



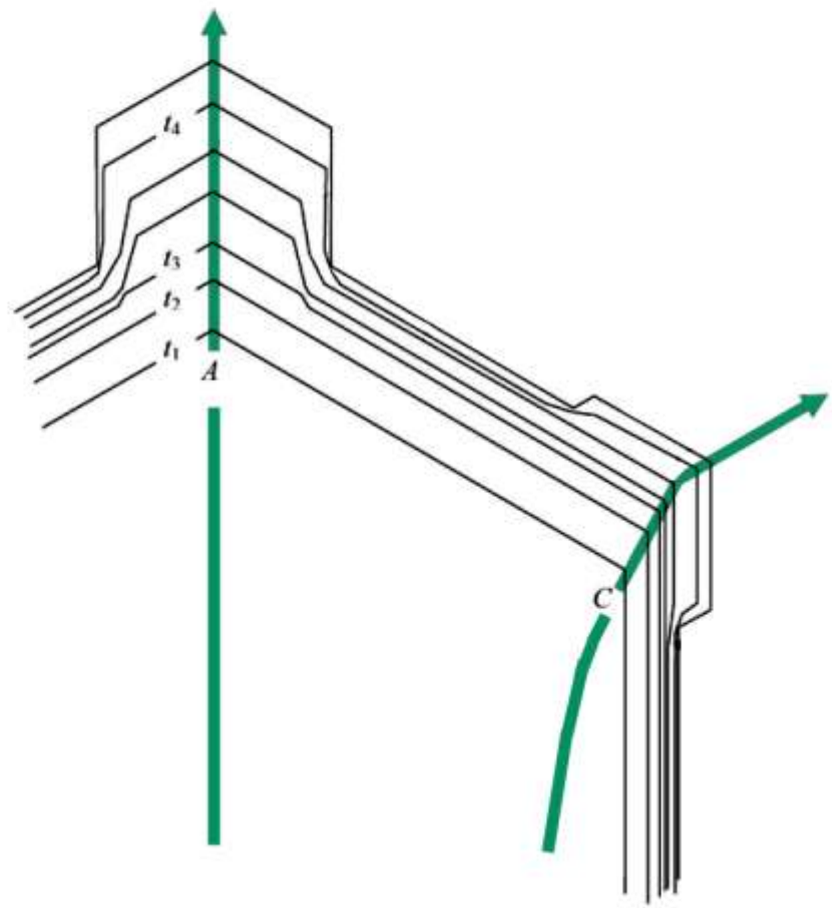
Sidebranching process



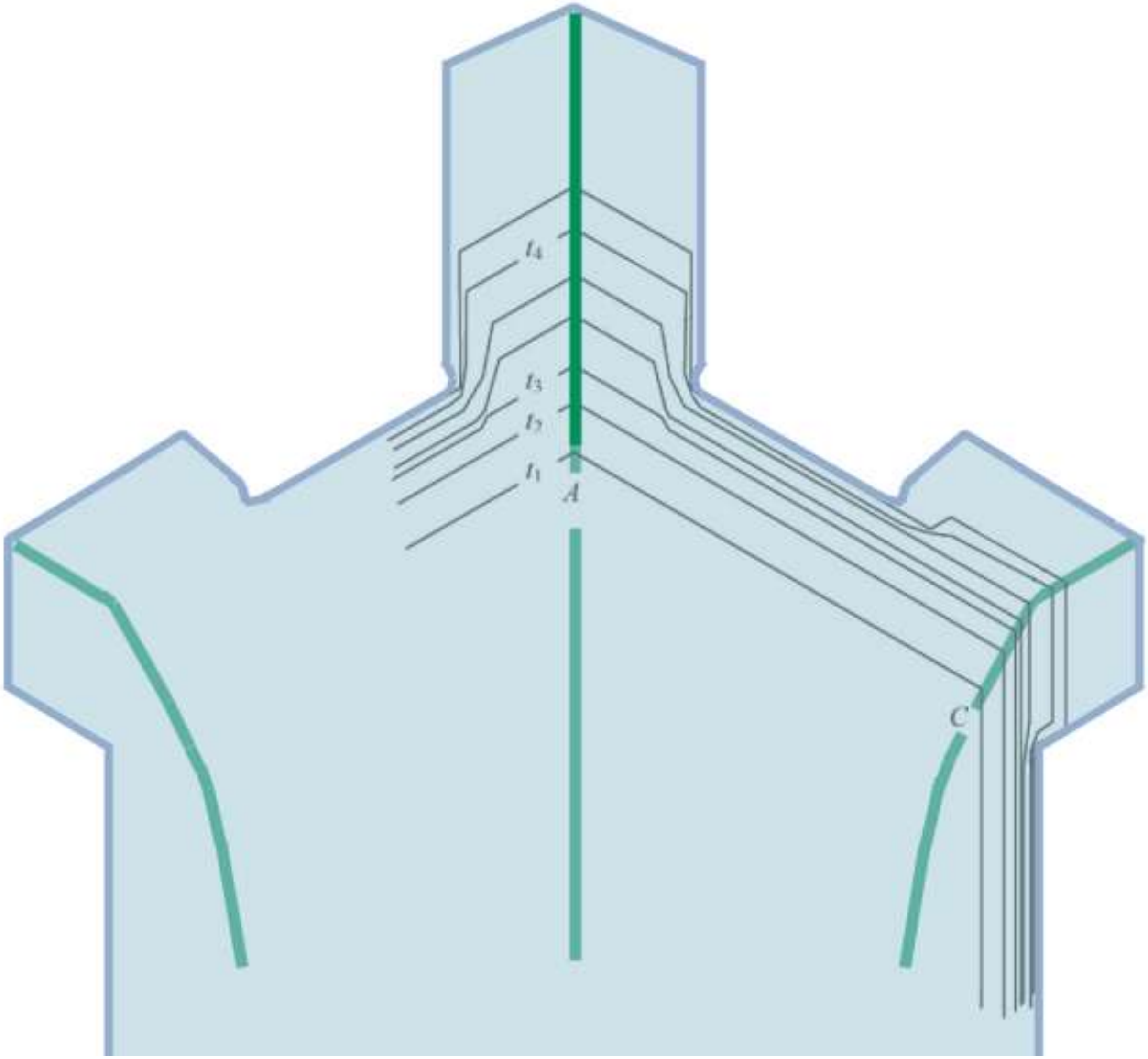
Sidebranching process



Sidebranching process

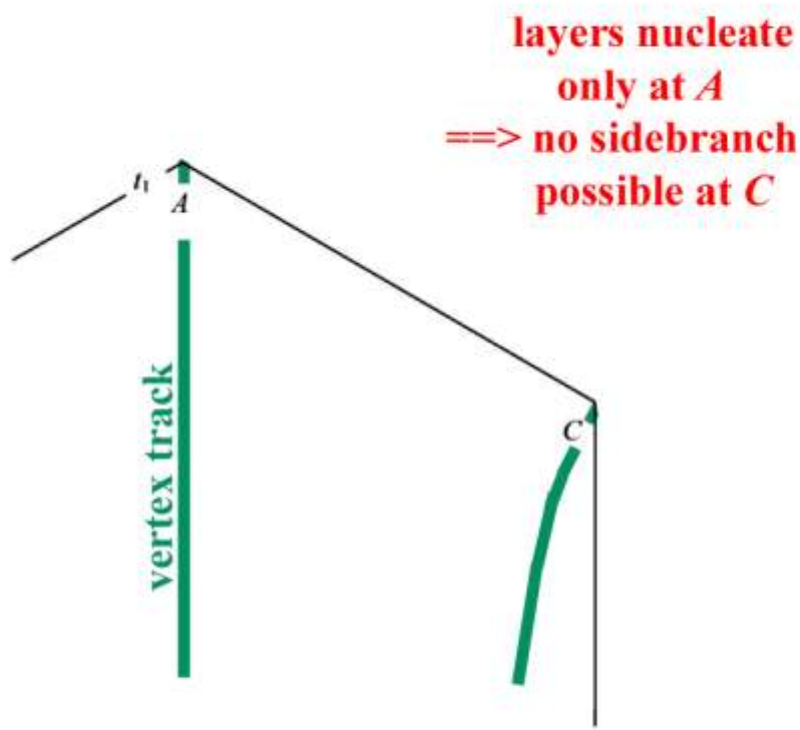


Sidebranching process

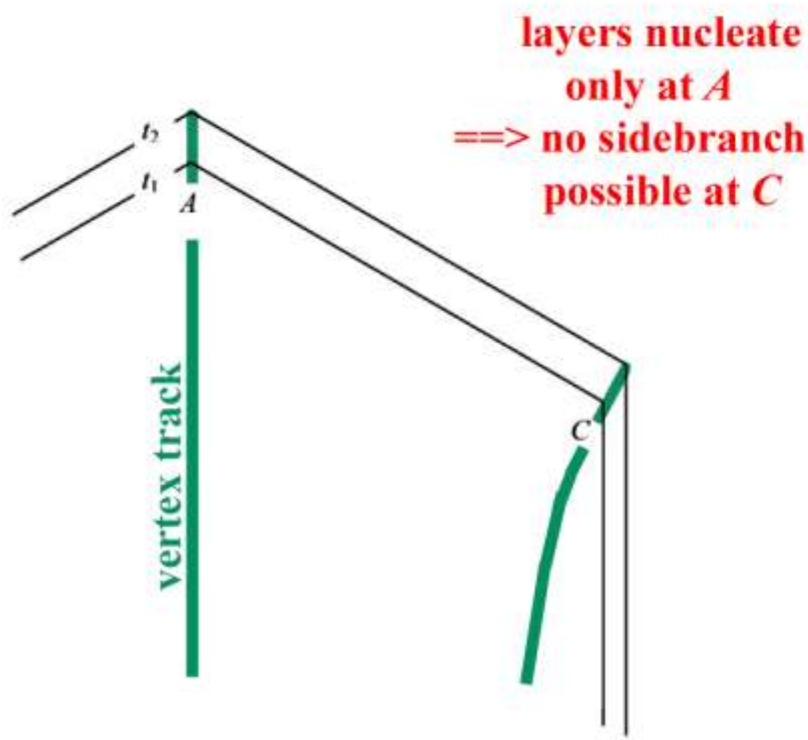


Sidebranching explanation (1 of 8)

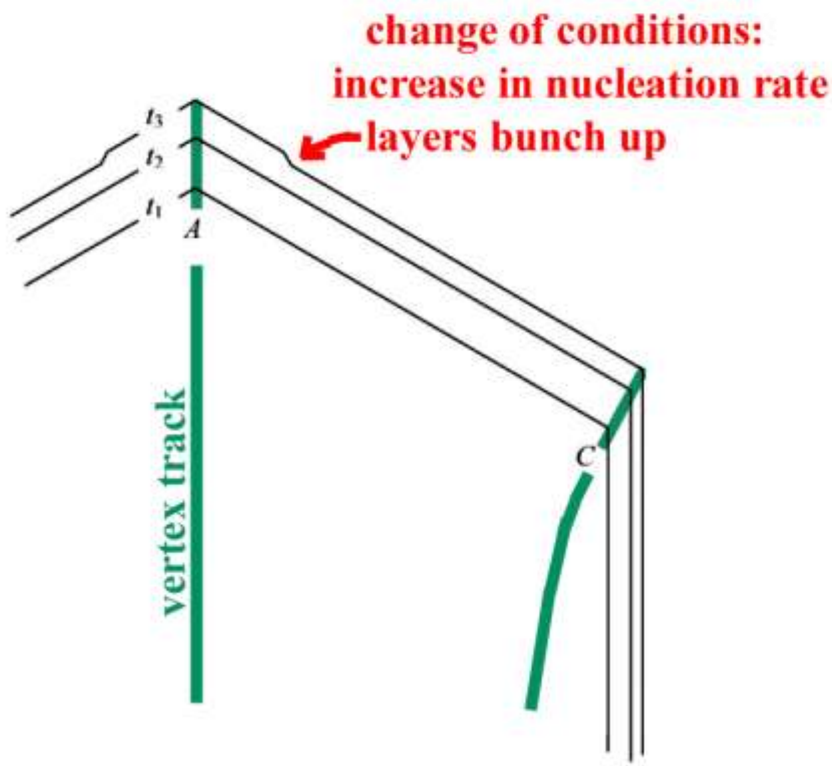
Profile of side of branch tip



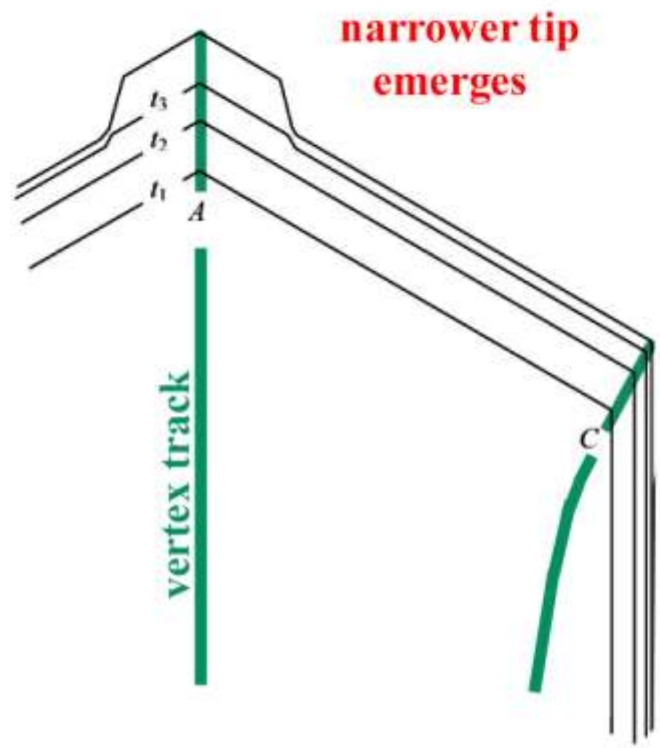
Sidebranching explanation (2 of 8)



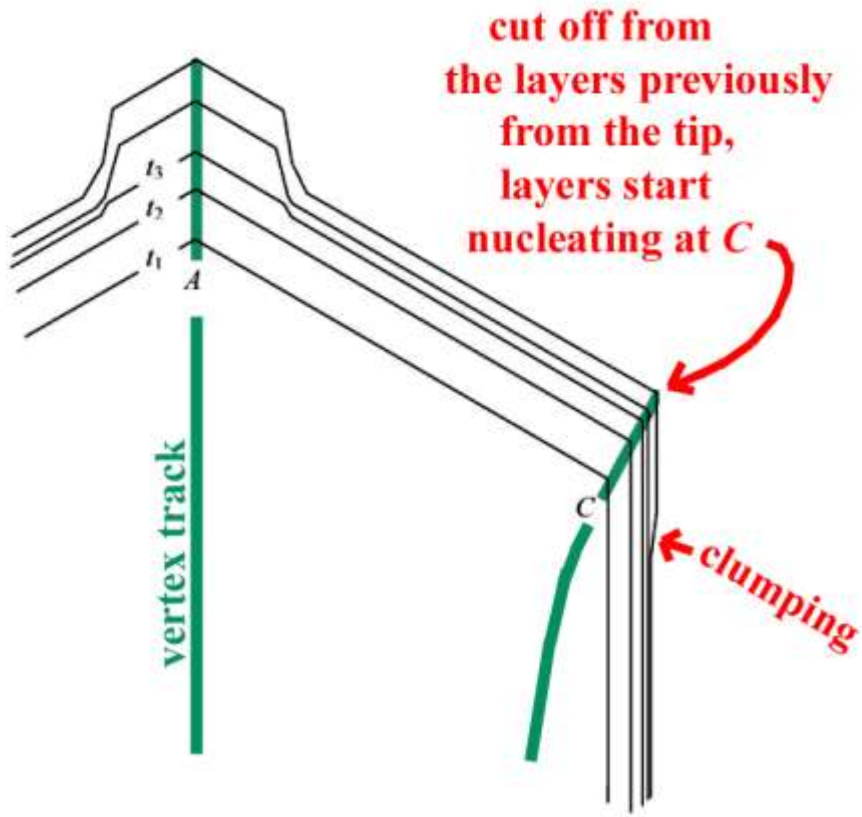
Sidebranching explanation (3 of 8)



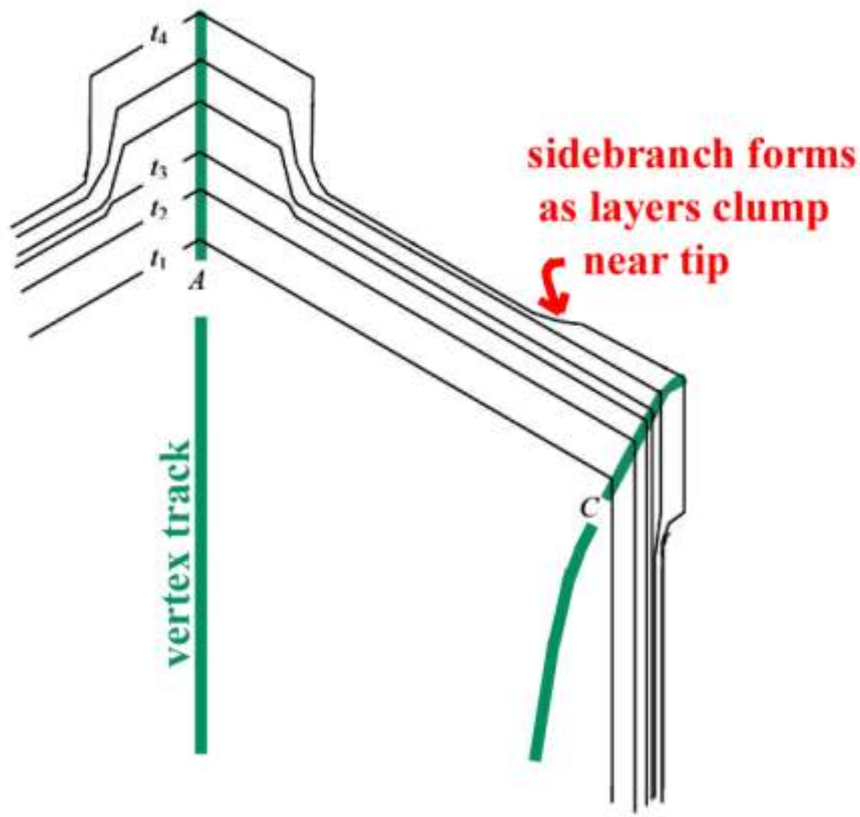
Sidebranching explanation (4 of 8)



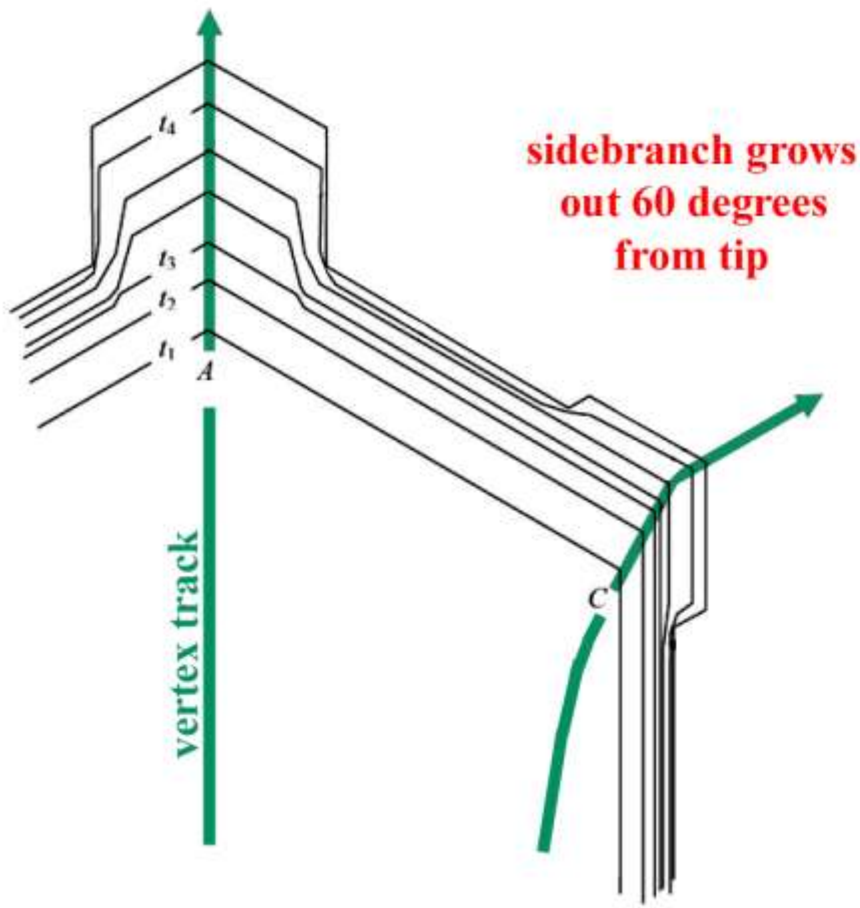
Sidebranching explanation (5 of 8)



Sidebranching explanation (6 of 8)

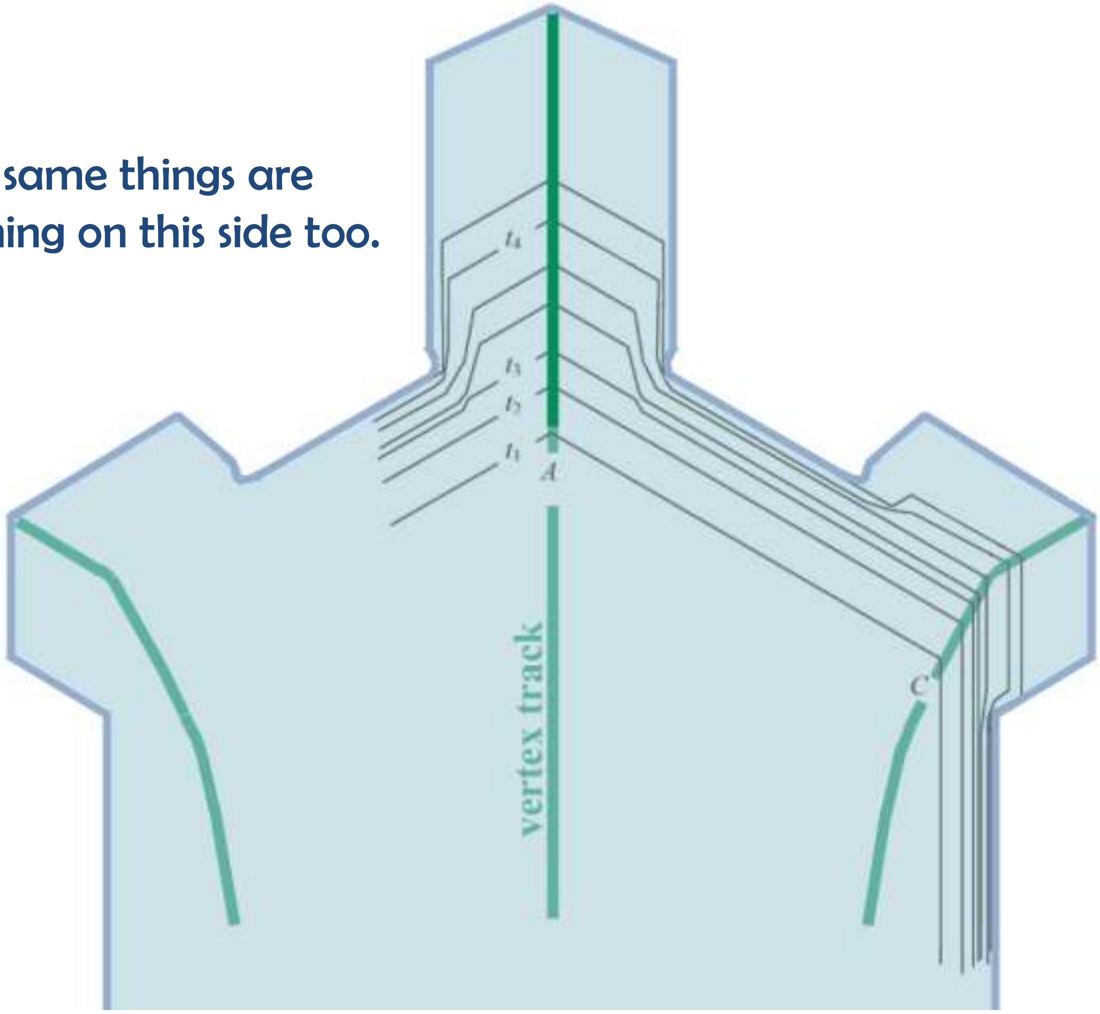


Sidebranching explanation (7 of 8)



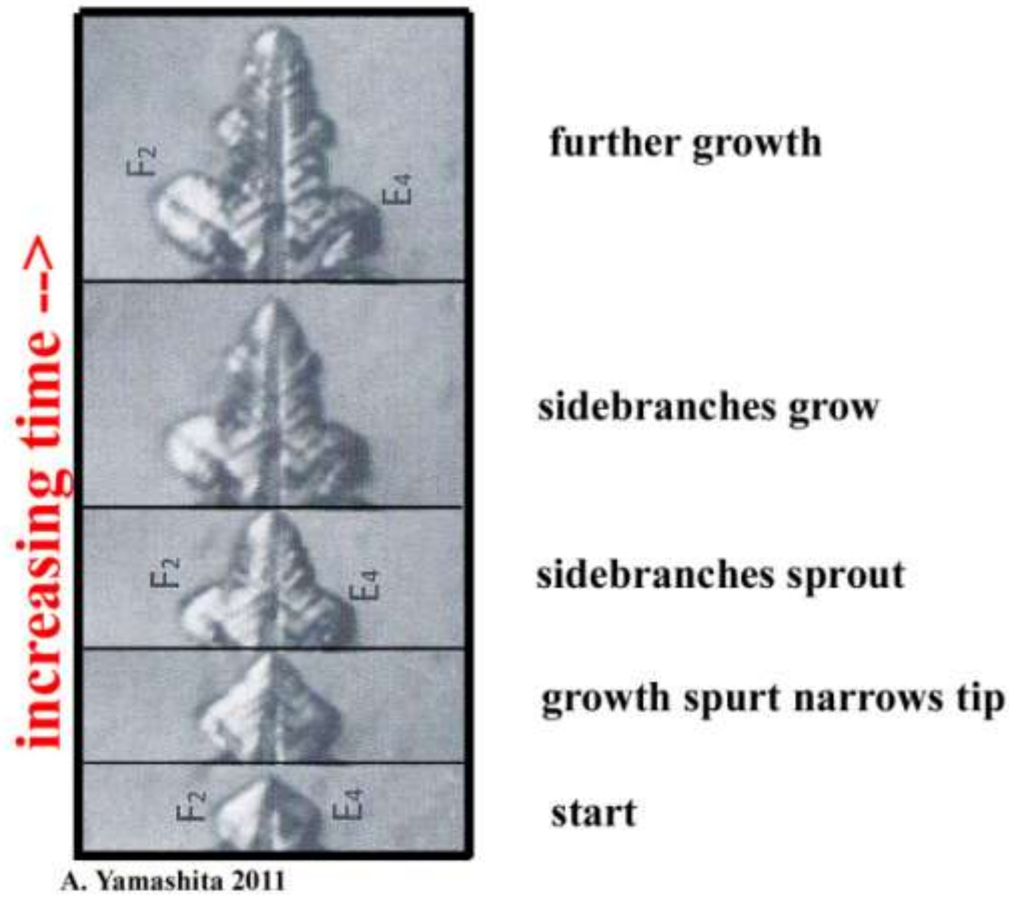
Sidebranching explanation (8 of 8)

The same things are
happening on this side too.



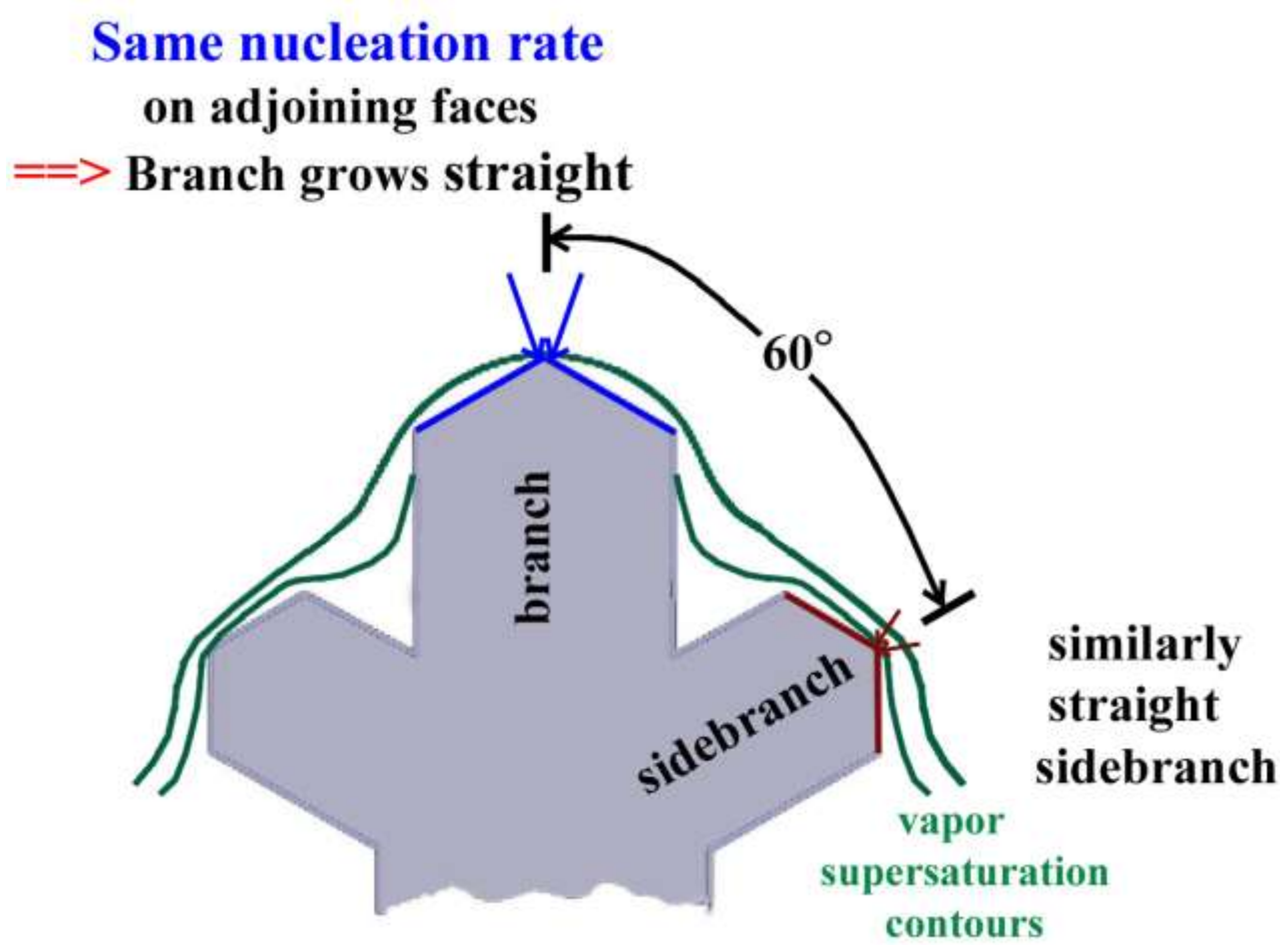
Growth rate increase causes sidebranch formation

Observation**



**From Nakaya data (1951), analyzed by A. Yamashita (2011)

Straight growth: branch & sidebranch



Layer nucleation explains the <u>straight, 60˚ sidebranches</u>

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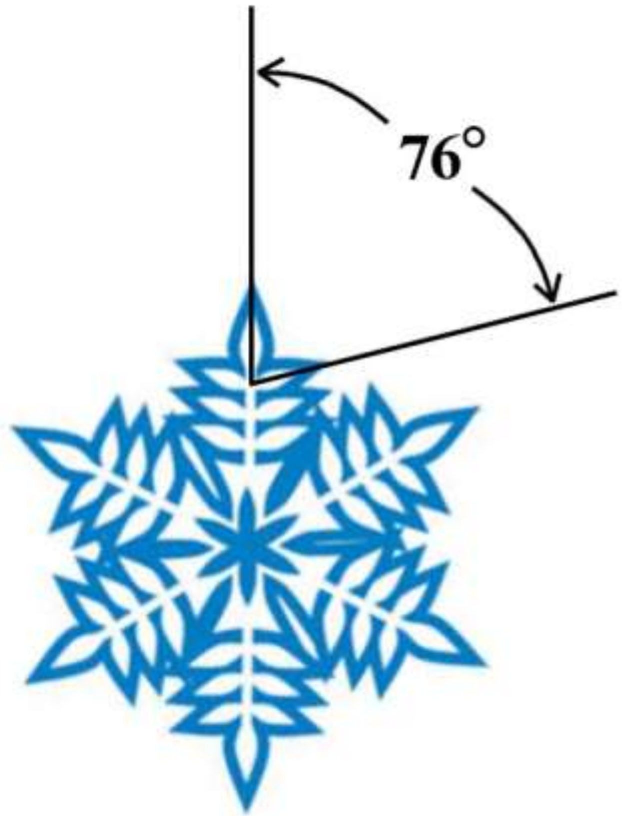
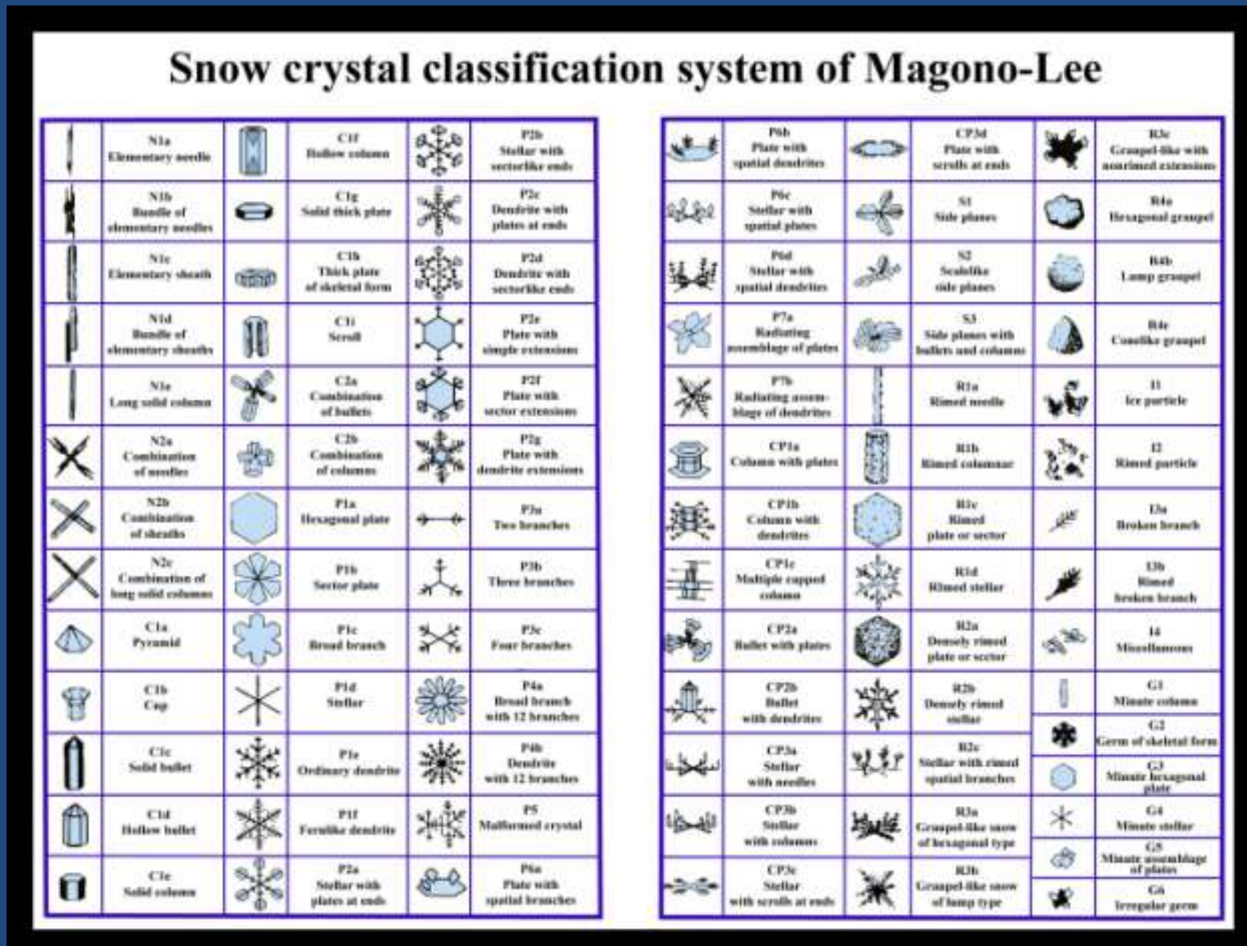


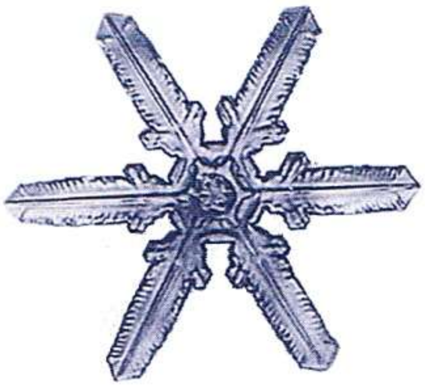
Variety



Snow crystal classification system of Magono-Lee
N1a Elementary needle
N1b Bundle of elementary needles
N1c Elementary sheath
N1d Bundle of elementary sheaths
N1e Long solid column
N2a Combination of needles
N2b Combination of sheaths
N2c Combination of long solid columns
C1a Pyramid
C1b Cup
C1c Solid bullet
C1d Hollow bullet
C1e Solid column
C1f Hollow column
C1g Solid thick plate
C1h Thick plate of skeletal form
C1i Scroll
C2a Combination of bullets
C2b Combination of columns
P1a Hexagonal plate
P1b Sector plate
P1c Broad branch
P1d Stellar
P1e Ordinary dendrite
P1f Fernlike dendrite
P2a Stellar with plates at ends
P2b Stellar with sectorlike ends
P2c Dendrite with plates at ends
P2d Dendrite with sectorlike ends
P2e Plate with simple extensions
P2f Plate with sector extensions
P2g Plate with dendrite extensions
P3a Two branches
P3b Three branches
P3c Four branches
P4a Broad branch with 12 branches
P4b Dendrite with 12 branches
P5 Malformed crystal
P6a Plate with spatial branches
P6b Plate with spatial dendrites
P6c Stellar with spatial plates
P6d Stellar with spatial dendrites
P7a Radiating assemblage of plates
P7b Radiating assemblage of dendrites
CP1a Column with plates
CP1b Column with dendrites
CP1c Multiple capped column
CP2a Bullet with plates
CP2b Bullet with dendrites
CP3a Stellar with needles
CP3b Stellar with columns
CP3c Stellar with scrolls at ends
CP3d Plate with scrolls at ends
S1 Side planes
S2 Scalelike side planes
S3 Side planes with bullets and columns
R1a Rimed needle
R1b Rimed columnar
R1c Rimed plate or sector
R1d Rimed stellar
R2a Densely rimed plate or sector
R2b Densely rimed stellar
R2c Stellar with rimed spatial branches
R3a Graupel-like snow of hexagonal type
R3b Graupel-like snow of lump type
R3c Graupel-like with nonrimed extensions
R4a Hexagonal graupel
R4b Lump graupel
R4c Conelike graupel
I1 Ice particle
I2 Rimed particle
I3a Broken branch
I3b Rimed broken branch
I4 Miscellaneous
G1 Minute column
G2 Germ of skeletal form
G3 Minute hexagonal plate
G4 Minute stellar
G5 Minute assemblage of plates
G6 Irregular germ

Unique features from *T* or *S* changes

VS



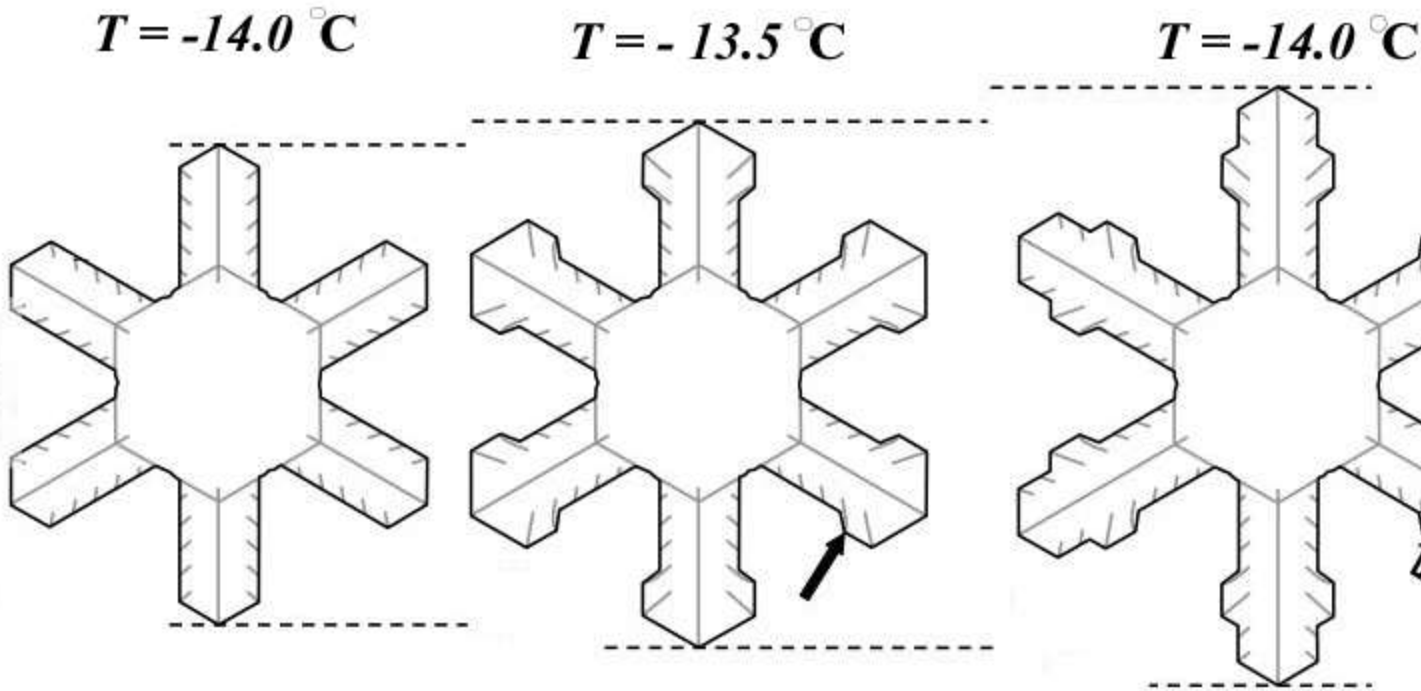
Natural $T \approx$ -15 ˚C
(small *T*, *S* changes)

Lab-grown $T =$ -15 ˚C
(constant *T*, *S*)

one ≈ 6 –7 ˚C change

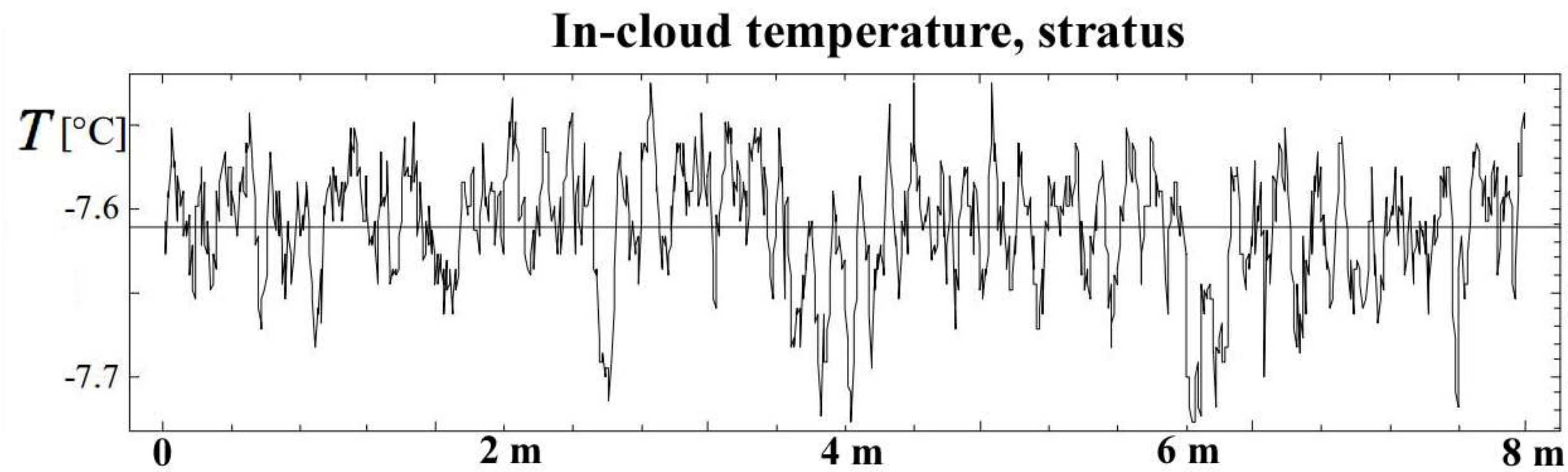
two ≈ 6 –7 ˚C changes

Example



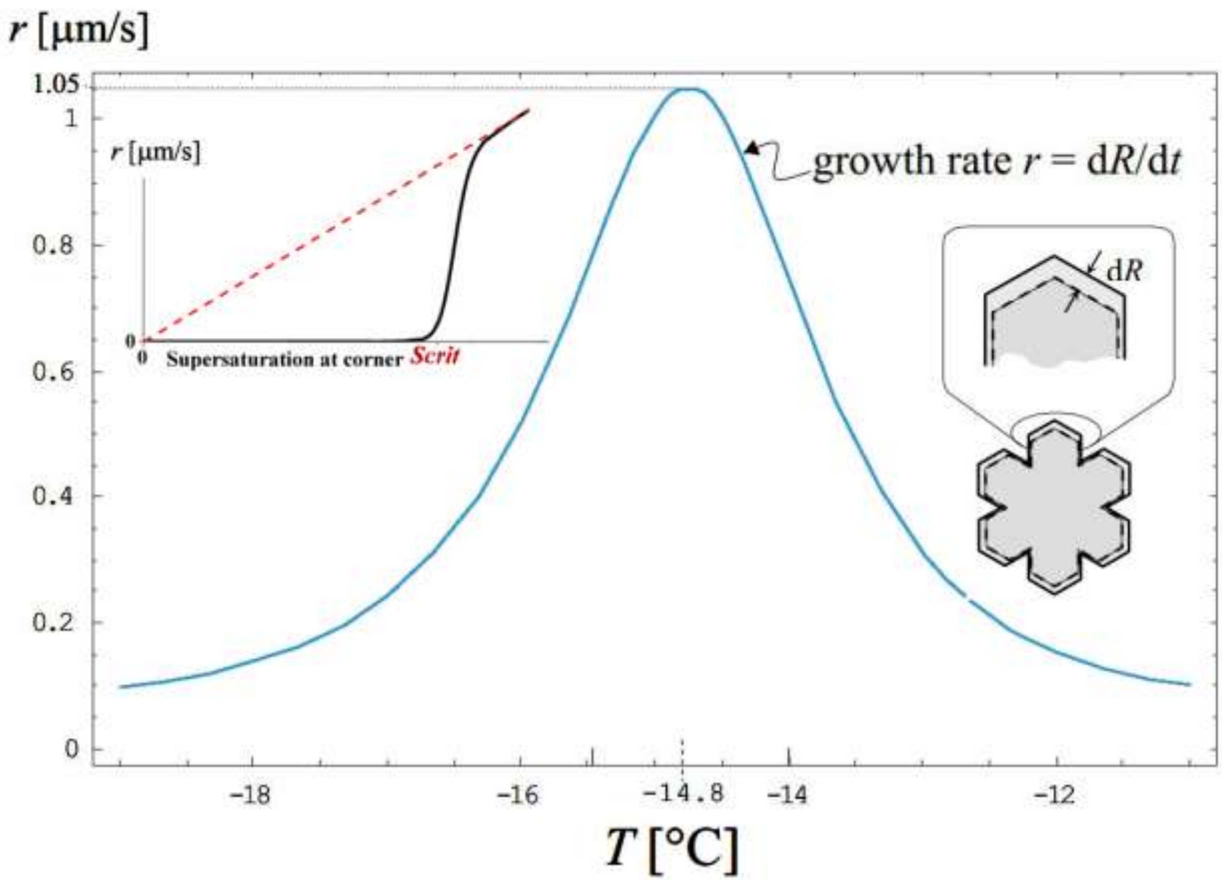
Even a small temperature change may visibly change the shape.

Cloud temperature heterogeneity



Even stratus clouds have highly variable temperature.
Snow crystals respond to such temperature fluctuations.

Growth rate sensitivity

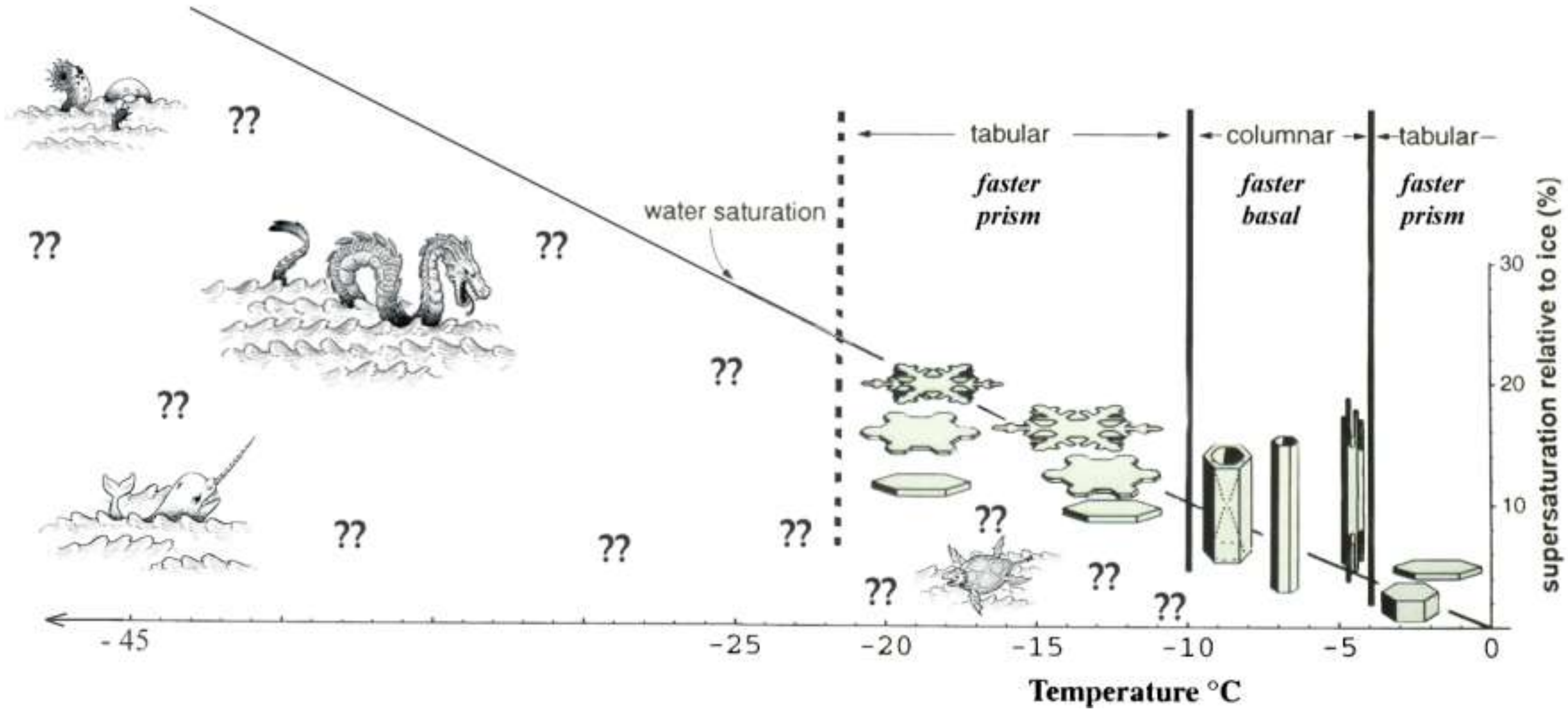


Data from Takahashi et al. 1991

Layer nucleation produces a very temperature-sensitive growth rate

Mystery

Uncharted *T* and *S* territory



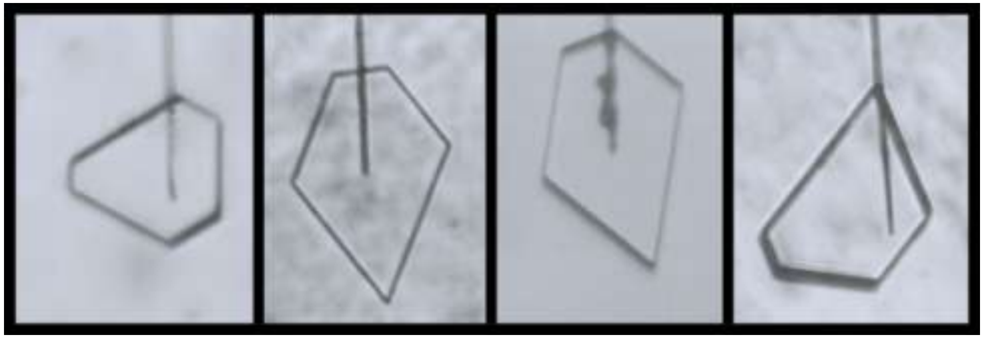
Sea monsters © Amy Saunders

Nakaya's habit 'map' still has a lot of 'sea monsters':

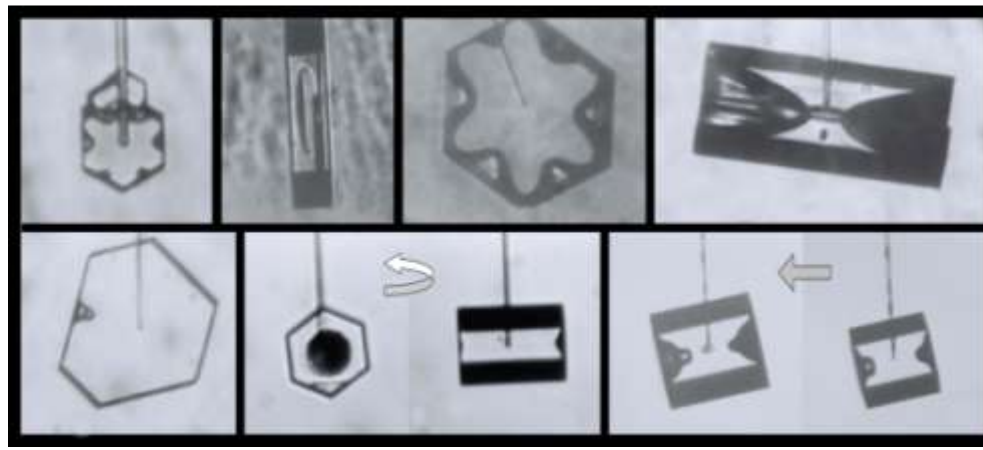
(Much of the habit diagram is under dispute or unexplored.)

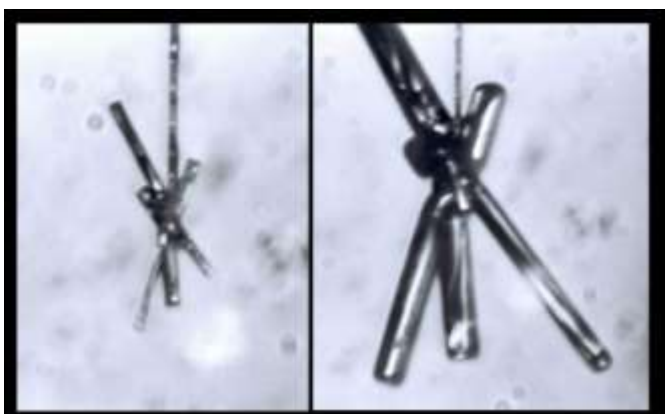
Other unknowns …

When do defects control growth?



When does hollowing occur?





How does the initial nucleation affect habit?

… and

How does microscale variability in clouds affect the crystals?

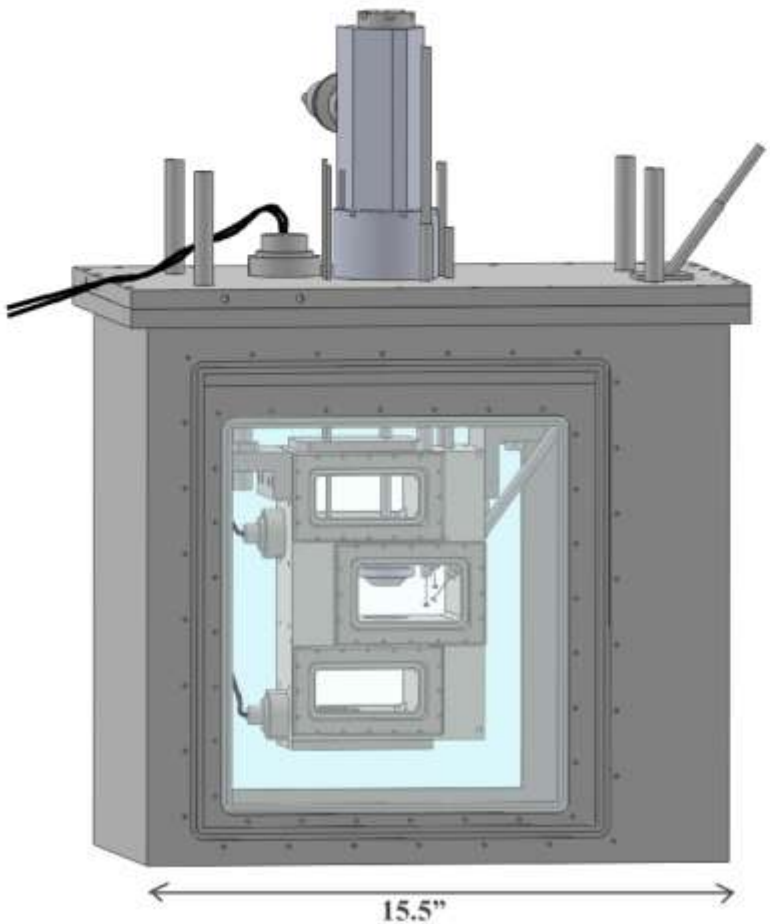
How do pollutants & proximity effects change rates and habits?

What fundamentally is causing the strange behavior of *S*crit?

Big mysteries that

require new experiments!

Experimental apparatus, version 2



- to lower temperatures *T*

- greater control of *T*, *S*

- study initial nucleation, …

Messages in water?

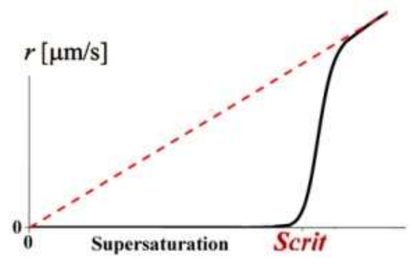
In 2006, a popular book was published, saying that water responded to our appreciation by making nice crystals.


From happy vapor?


"dainty hieroglyphics"

But the idea of snow crystals carrying messages is neither new nor altogether wrong.

Because growth occurs by layer nucleation, habit is reproducible and ultra-sensitive to conditions, allowing us to decipher its life history.



Knowledge from the new experiments may allow us to decipher further order, improve cloud modeling, and maybe solve a microscale mystery or two.

Much thanks to
Mark Cassino, Tsuneya Takahashi, Akira Yamashita, Tadanori Sei, Charles Knight for the images, Amy Saunders for the art, &Yoshinori Furukawa for the old filmstrip.