Phyllotactic Patterns From Seed to Flower

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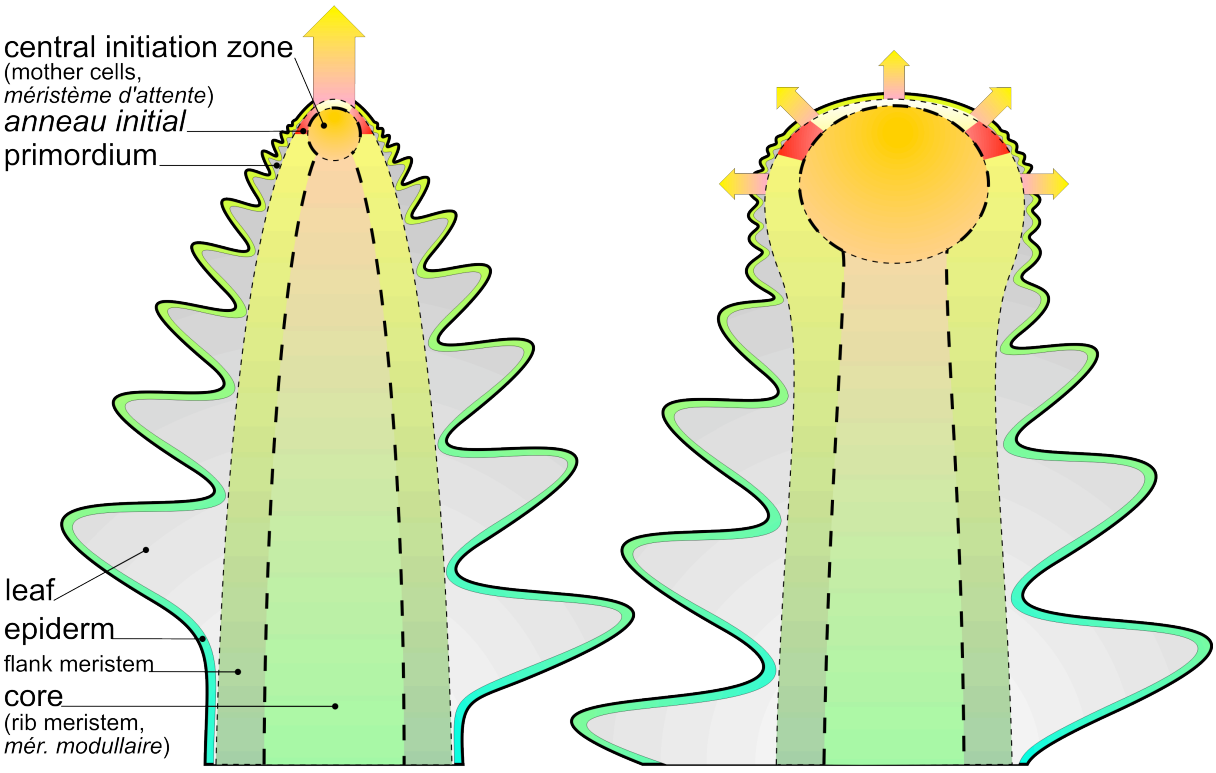
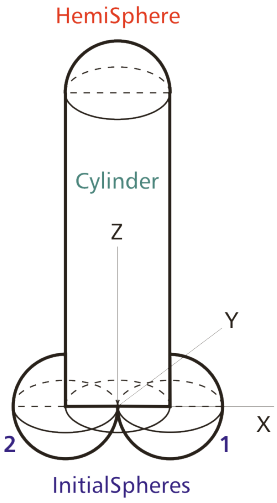
The genesis of *phyllotaxis*, the origin of the pattern of appendages on the surface just below the apical extreme of many plants, is an old unsolved puzzle. Whereas many scientific models (e.g. my *Dislodgement model*[*1]) generate helices, the *Stack-and-Drag model*[*2] is the first to achieve this in an integral construction *from seed to flower*[*3]. Combination of the principle of gnomonic growth, where consecutive additions have comparable positions, with a "dragging" principle, where the developing zone follows the apical tip, provides a powerful tool in simulating a wide range of phyllotactic manifestations. The influence of three vital parameters for primordial size, compressibility, and canalization (or annular arrangement) helps in understanding the problem's nature.

In architecture and structurele engineering, utilization of the mechanism has been investigated[*4,5].

[*1] in Mathematical Biosciences, Elsevier Publishers, New York 1990
[*2] in Mathematical Biosciences, Elsevier Publishers, New York 1996
[*3] in Symmetry in Plants, World Scientific Publishing, Singapore 1998
[*4] in International Journal Space Structures, London 1994
[*5] Thesis Phyllotactic Patterns for Domes, Nuenen 1994



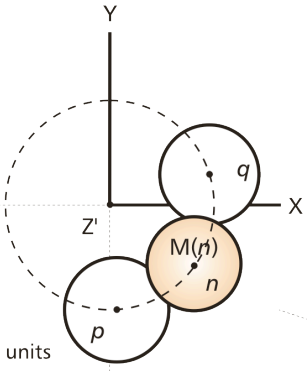
vegetative stage, with elongating stem generative stage, with expanding apex

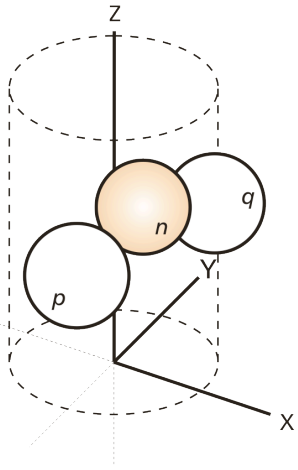


a. Initial Spheres *(left)*

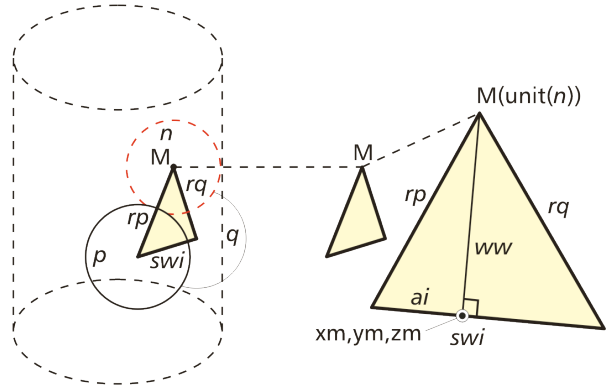
n	1	2
d	1	1
x	1	-1
y	0	0
z	0	0
p	0	1
q	0	0
r	(1)	(1)

b. Pattern Calculation
Left:
InitialSpheres, *r* =1 (cotyledons)
- other radii are possible
Cylinder, *r* =1 (stem)
- contains (a limited number) *tls* units
HemiSphere, *r* =1 (apical dome)
- contains a previously unknown number of units

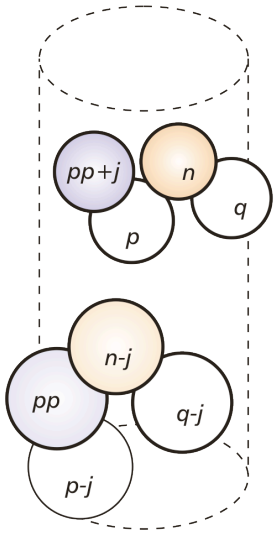




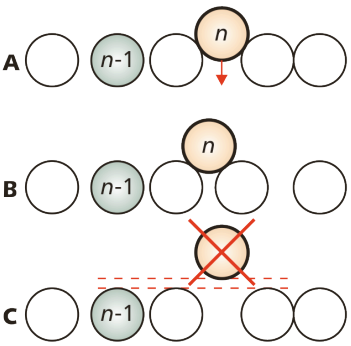
Center and right:
p: Support unit*(p)* lies in clockwise direction against unit*(n)*. Unit*(q)* is the other contact.

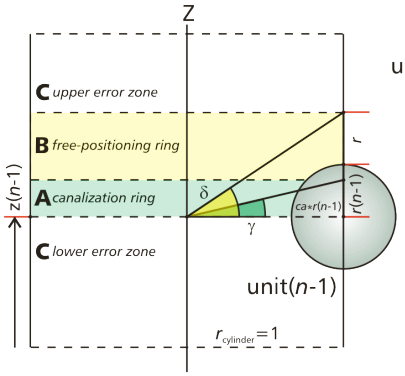


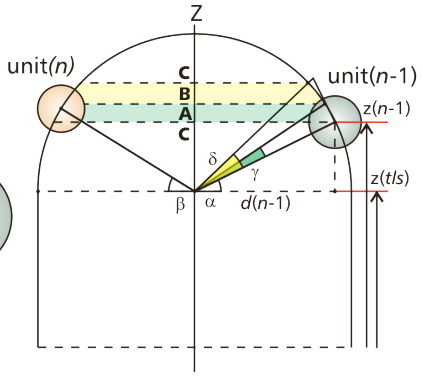
c. Propose Sphere
$ai = (swi^2+rp^2-rq^2) / (2*swi)$



d. Sensitivity *(right)*
The highlighted unit*(pp+j)* will be counted, for unit*(n-j)* has *pp* as one of its support units. Increase of *j* means decrease of sensitivity.







e. Canalization
Left (side view): A new unit, which fits, or nearly fits, between its predecessors (**A**) will be part of the existing ring. When it has been located significantly higher (**B**) (after lack of space below), it will be the first unit in a new ring. Extreme high (**C**) or low positions indicate an error. (This kind of error may occur in Nature as well.)
*Center (cylinder, cross section): Besides z(n-1), ca*r(n-1),* or angle γ, settles the upper border of the *canalization ring*. Angle δ, in $\tan(\delta)=(r+r(n-1))/r_{cylinder}$ determines the upper border of the *free-positioning ring*. A unit, which has been *proposed* within this ring, remains its calculated position. Higher *ca* values will narrow the ring.
Right (hemisphere, cross section): Angles α in $\tan(\alpha)=(z(n-1)-z(tls))/d(n-1)$ and β define a radial shift of the ring.

(a)

the plant body

hemisphere as apex, generative part

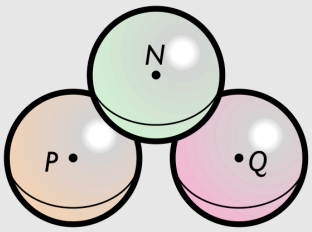
cylinder as stem, vegetative part

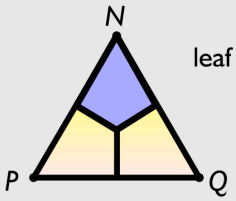
2 spheres as cotyledons, initiation

(b)

the morphogenic (vascular) unit

primordium *N* with contacts *P* en *Q*





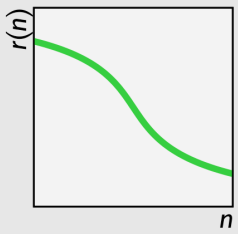
leaf part

stem part

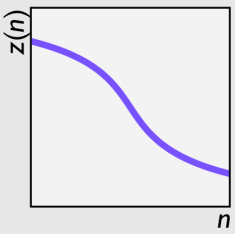
(c)

S-curves, $S_n = \dfrac{l + e}{l - base^{\,gradient\,.\,(halftime\,-\,n)}}$

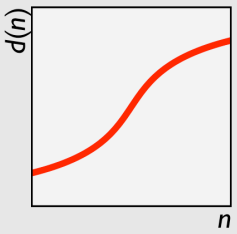
primordial rel.size
unit radii



stem/apical growth
axial translations



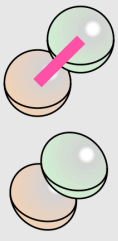
stem/apical growth
radial translations



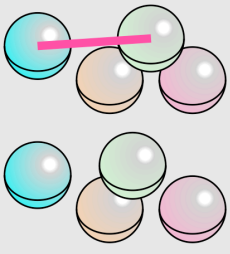
(d)

unit-positioning influences

expansion
compressable or
repulsive units



sensitivity
for young or old
neighbor units



canalisation
free or forced
positioning height