

A P E X

25.07



THE  
PLANT  
FROM SEED TO FLOWER  
PATTERN GENERATOR

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## **INTRODUCTION**

**Apex** is based on the Stack-and-Drag model, which is basically topological, not physiological. It uses a geometric feature called gnomonic growth, where consecutive additions have comparable positions. Another property of Apex is that spheres of influence are just spherical units. And phyllotactic patterns are created through the whole plant, from seed to flower or composite.

Follow the steps in QUICK DIRECTIONS. After installing the software on your computer, you can use Apex instantly. You perform some main possibilities of this program. There is an unlimited amount of variations, and each pattern is transformable to an unlimited amount of structures. Note, that there are many 'unnatural' variable settings and combinations. 'Rare' settings may cause strange structures. This is the result of experimenting, much the way Nature does. In Nature, errors arise very frequently.

For interactive features in forms and functions, see FUNCTIONS SUMMARY.

## QUICK DIRECTIONS

### Getting started

Apex needs MS Windows. It is not allowed to make copies of the software or to install it on others than on your own system.

~~Before using Apex, it is necessary to choose the decimal point in your Windows settings.~~

**Extract** the files with extension **.ZIP**. Put all the files in one directory, which you may name Apex.

Activate **APEXe.EXE**. The Intro form appears.

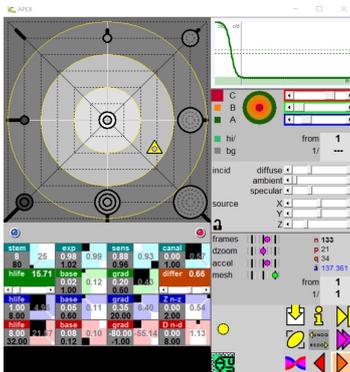


Check **remind** to remember intro settings.

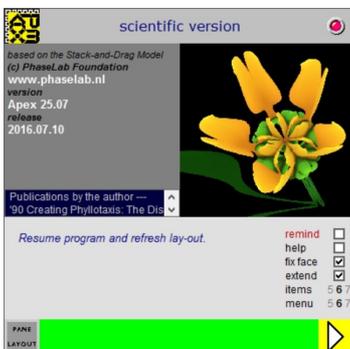
Check **help**. You will be guided by your mouse positions.

Uncheck **extend** to hide extra options.

Click the **D option** (for default lay-out; U for user lay-out). The Stack-and-Drag working environment appears.

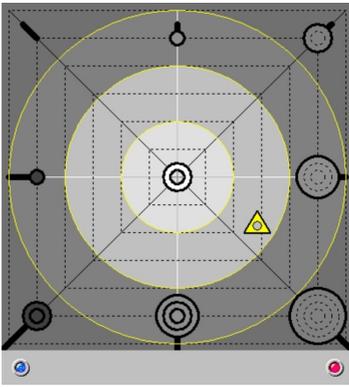


Click the yellow **APEX icon**, changing to green, below left in the Shape menu (below right). The Intro form reappears.



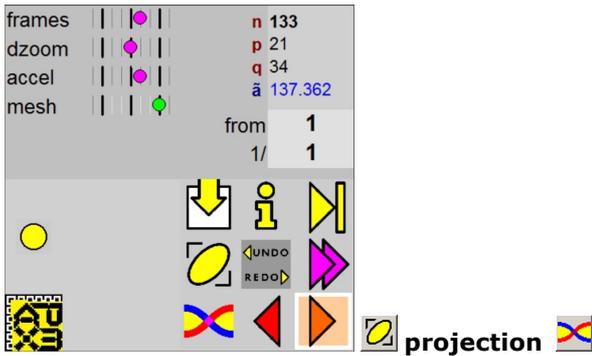
Click the **layout option**, below left. The working environment changes. If your display is small, you may rearrange forms manually. Therefore, you should uncheck **fix face** first.

Click the yellow **> button**. You are back in the working environment.



Click anywhere near the center in the top **GEO menu**.  
*A calculation is executed and a drawing is made. If you checked the help option in the Intro menu, the grey banner below will show hints.*

## Shape and Light



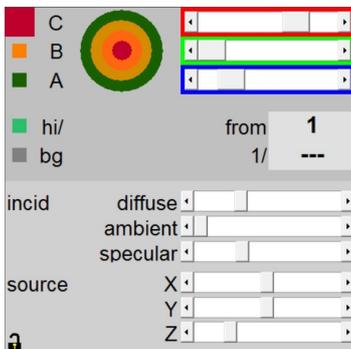
### trans/basis

In the Shape menu, click on **projection**. *The view point changes* (oblique, top, or right click for side view).

Click on **trans/basis**. *The structure's basic spheres modeling is shown.*

Click the orange **draw** triangle below right, or doubleclick on the **drawing area**. *A new drawing is made.*

Click the magenta **movies** triangles. *The movies mode is chosen, and a structure develops from seed to flowering.*



In the Light menu, choose color **A**, **B**, or **C**, and mix with each of the **RGB bars**. *Flower colors change.*

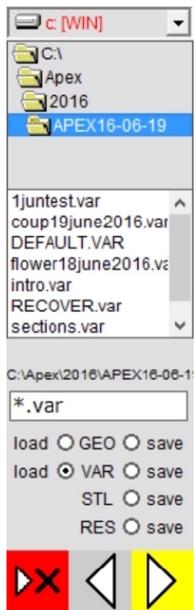
Type something like 5 in the box next to **1/**. Then, click on the **Draw area**. *In the structure, every 5th unit gets the color next to hi/.*

Change the **diffuse** bar. *Intensity of colors changes instantly.*

Hold a mouse button while moving on the **Draw area**. *The structure is turned or panned. Use the mouse wheel to zoom. (If these keys don't work, activate the Draw area with a click on it.)*

## File Handling

(not applicable in the evaluation version)



Click Shape/ **'Files'**, top left in the buttons square. *The Files form appears.*

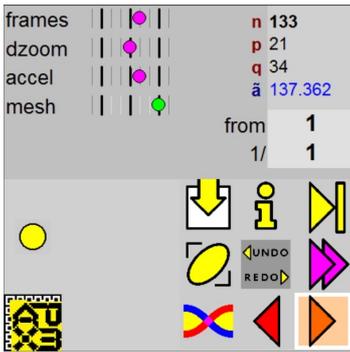
Click on **load VAR**. *Option 'load' for variables is selected.*

Doubleclick a .var-file, e.g. in **Apex/Results**. *Tell the computer to look in the right directory, and affirm it.*

Click **OK** in message forms. *Variable-values are loaded, and a new structure is drawn.*

In order to *print models*, choose **STL**.

## Exiting the Program



*Layout the application by dragging child forms within the sizeable mother form. Save a new look, if you want to start-up with it after the next program call.*

Click in Shape the red **exit** backwards triangle, then the **X** or **U** button to exit. After **U**, user settings are saved in file 'USER.VAR'.

# FUNCTIONS SUMMARY

## Main menus



### Intro

~~It is important to choose the decimal point in your Windows settings.~~

**U>** (green, only at startup) go on with lay-out and parameter values of last program quit-and-save.

**D>** (cyan, only at startup) begins with default lay-out and parameter values.

**>** (yellow, only while running Apex) resumes program use.

**remind** the intro preferences for next startup.

**help** You will be informed continuously about the interface.

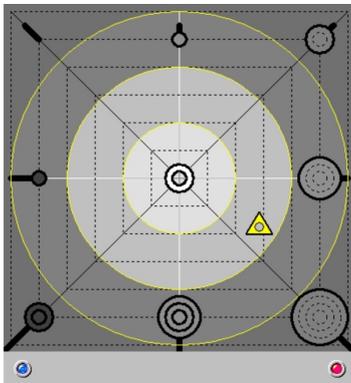
**fix face** To change positions of menu windows, uncheck.

**extend** Show some extra menu options.

**items, menu** to resize them.

**pane** (only while running Apex) changes the Draw area.

**layout** (only while running Apex) changes the arrangement of forms.



### GEO

The behavior of the GEO menu is adjusted by the settings in the TUNE menu.

**red knob** aborts a calculation, or leaves Apex

**blue knob** connects all variables in the TUNE Menu

Drag and drop the little **triangle**, or click anywhere in the square field. A new pattern is calculated, and depending on your option in Shape, a structure is drawn, a new unit is added on a structure, or a structure is built-up in a movie.

stem	8	25	0.98	0.99	0.88	0.93	0.00	0.67
	80		1.02		0.96		1.00	
hlife	15.71	base	0.02	0.12	0.20	0.43	differ	0.66
			1.00		0.60			
hlife	1.00	base	0.05	0.11	0.35	6.40	Z n-z	0.54
	8.00		0.60		20.00		2.00	
hlife	8.00	base	0.08	0.10	-80.00	55.14	D n-d	1.13
	32.00		0.12		-1.00		8.00	

### TUNE

The TUNE menu is divided into 16 cells, with two squares each. These cells are variables, and they are stuck to the GEO menu. See below for the changing technique of a cell. (In the example above, after clicking the caption, the green hlife and differ are fixed.)

There are 7 pattern determining variables, all of them are in cyan and green. There are 9 S-curve parameters: the green, pattern forming ones, for unit size, the blue ones for axial translations, and the red ones for radial translations. The three remaining variables will be declared below. While the blue and red values may change structures dramatically, they do not affect topological positions in patterns.

**stem** number of units on the stem (or, spheres on the cylinder). **first2** cotyledons sizes or switches their ordinal numbers. Default values are **1 = +**, for sizes 1, similar, counter-clockwise generative spiral. **S** (for **1**) calculates S-curve values.

**exp** (expansion) spheres are compressible to repulsive **sens** (sensitivity) the depth of feed-backing while placing new units. Without feed-back (maximum *sens*), units arise at locally fixed places. The system behaves 'nervous'. Profound feed-back results in almost predictable unit locating, or 'sluggish' behaviour.

**canal** (canalization) breadth of the 'anneau initial' of Buvat. New units may arise only within this ring - *canal* towards 1 narrows the ring. This sharp canalization is found in strong differentiations in plants, e.g. flowers. Here, rings with similar organs are formed. In composites, like the sunflower, low values for *sens* avoid annatural center rings.

**hlife** half-life of the current S-graph (*n*-position of slope)

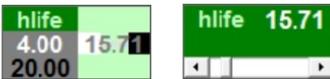
**base** minimum of the current S-graph

**grad** gradient of the current S-graph (steepness of slope)

**differ** (differentiation) momentum of leaf formation, which depends on the settings in *stem* and *hlife*

**Z n-z** links axial translations with (left) ordinal *n* to (right) height *z*

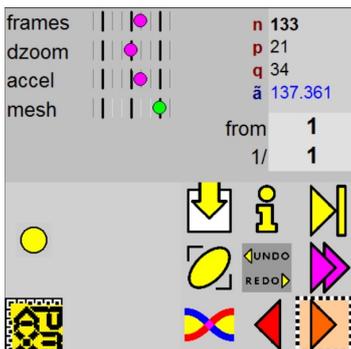
**D n-d** links radial translations with (left) ordinal *n* to (right) distance *d*



### TUNE element

In each cell of the TUNE menu, in the left square, you can edit the extreme values of the variable's traject: from minimum (white, 4.00 here) to maximum (black). In the right square the actual value of the variable is shown in grey. Moreover, the behaviour of the variable in the GEO menu is shown by two little squares, the white one for minimum, the black one for maximum. You can change this behaviour by a left mouse click anywhere on the right square, which represents the GEO field. Equal sized minimum and maximum squares result in linear variable values, unequal sized minimum and maximum squares gives quadratic change. In the example, the green unit growth curve has a hlife value of 4 in the extreme left of the GEO menu, and 20 far right. In the center, the value will be 12. You can change the size of the white and black squares by a right mouse click.

Click on the caption for the scrollbar, with which you can fix values independently from the GEO menu.



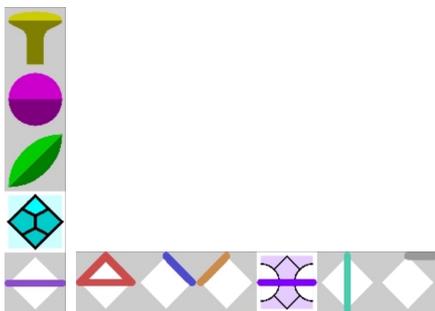
### Shape

**frames** number of movie frames  
**dzoom** dynamical zoom factor, so initial structures are magnified more  
**accel** accelerates the movie, once the phyllotactic pattern is established  
**mesh** number of mesh triangles  
**from** first unit of the range to be drawn (A doubleclick automatically switches to flower and it's parts.)  
**1/..th** unit of the range to be drawn  
**9 icons** files---info---(yellow arrow) step mode  
projection---undo+redo---(magenta arrows) grow mode  
basic model---stop/quit---(orange arrow) draw mode  
**files** load and save files, export data  
**info** show results in graphs and tables  
**projection** switch between oblique projection, top view, and side view  
**trans/basic** switch between translated structure and spheres stacking  
**<** (red arrow) leaves program, and...  
**X** ...forgets all (except intro settings)  
**U** ...saves structure and working environment

*The three arrows start or pause a drawing process. A drawing process can be a step-by-step stacking, a series of pictures of the growth process, or simply a drawing. During the process, the arrow is bordered by a black-and-white dotted square. Always, one of the three modes is opted, which is indicated by a colored background. Changing a drawing mode always starts the drawing process. During this process, a click on the arrow causes a pause. This is indicated by a color dotted square and a grey background. To stop the drawing process, you can click the red back arrow. Alternatively, you can click another arrow to stop, switch the drawing mode, and start a new process instantly.*

## Draw Area

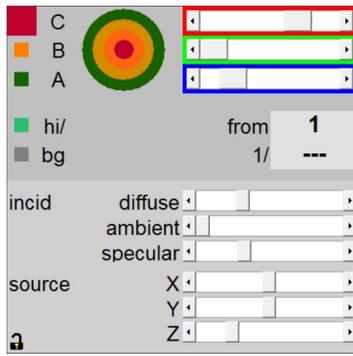
A mouse click on the drawing pane or hitting the spacebar has the same effect as clicking one of the right arrows in the Shape menu .  
This form is resizable by dragging its borders, or by clicking the layout button or pane button in the Intro form. Turn the displayed structure with the left mouse key, pan it with the right mouse key or pressing WASD keys, zoom with the mouse wheel or with the +- keys. Resize the 3D-world with the hidden bar in the bottom right corner of the drawing.



## Shape Items

A click highlights the shape-item, a second click starts drawing. Shape items are the receptacle, units in a structure, or connections between units. Vertical items are: receptacle, sphere, leaf, polygon, and contact. Horizontal items are: the  $n-p-q$ -triangle, and connections  $n-p$ ,  $n-q$ ,  $n-z$ ,  $p-q$ ,  $n-(n-part)$ . ( $n$  is unit ordinal,  $p$  and  $q$  are ordinals of support units,  $z$  is ordinal of (mutual) secondary support unit,  $part$  is set in the Shape menu).  
All four vertical shape items have popup menus - see details below.

**size** zooms by resizing the 3D world.



## **Light**

**C, B, A** center of structure / periphery to top / base  
**colored bars** red, green, and blue part of selected color

**hi** highlighted units

**bg** background

**from** first highlighted unit

**1/..th** highlighted unit

**(incid)**

**diffuse** light from a source is reflected in all directions

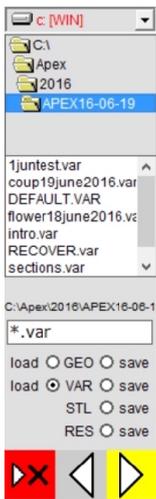
**ambient** light from everywhere is reflected in all directions

**specular** light from a source is reflected in a preferred direction

**(source) X, Y and Z** are the spatial coordinates of the light source

**lock** opened: the light source follows the structure

## Secondary menus



### Files

**disk drive** box shows and chooses a disk drive

**directory** box shows and chooses directories

**file list** shows and chooses files

**\*.var** box shows the file to be saved or loaded. A new filename may be typed, or clicking a name in the file list box proposes that file.

**load VAR** loads parameter values from a disk file with extension .var

**VAR save** saves parameter values to a disk file with extension .var

**GEO** only GEO menu settings

**STL** 3D-print file

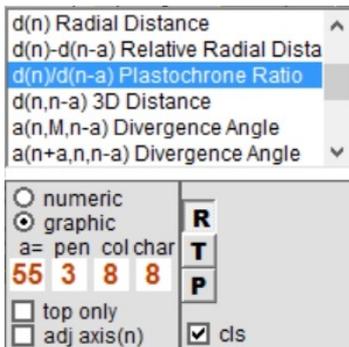
**RES** results listing, in shape-item adjusted format

**DEL** deletes a selected file, only after affirmation in a Message form

< leaves Files form without files handling

> like double clicking a file name, this permits file handling

>X delete file from disk



### Characteristics

**list box** characteristics of a calculated pattern. Click to select the subject, double-click to activate it.

**pen** graph's line width

**a** ordinal difference, while unit( $n$ ) will be compared with unit( $n-a$ ) and/or unit( $n+a$ )

**col** a tabel's number of columns

**char** character size in tables

**numeric** information will be presented in tables

**graphic** information will be presented in graphs

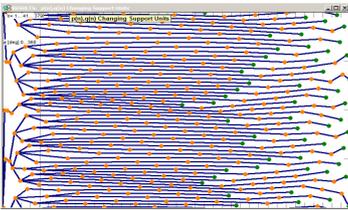
**R** show calculated results

**T** show scientific theory

**P** show description of Apex

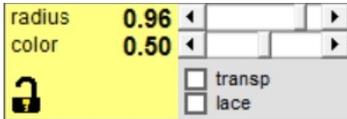
**adj axis(n)** the definition of a structure's axis is absolute, or is continuously adjusted by the positions of the last units

**cls** clears the Results area whenever a new graph is drawn



## Results

**area** shows information about the model or the program, or shows graphical or numerical output (The three labels can be dragged and dropped.)



## Receptacle

**radius** shrinks the receptacle  
**color** structural coloring, or grey  
**transp** transparent  
**lace** line drawing  
**lock** always draw receptacle



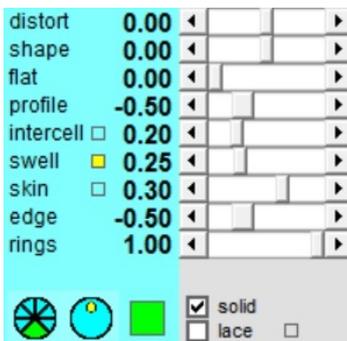
## Sphere

**size** changes unit radii  
**axis** show model's axis  
**R-transl** connects radius sizing with radial translation  
**lock** always draw spheres



## Leaf

**size** length  
**shape** position of the maximum leaf width - from tip to base  
**width** related to size  
**along** -  
**across** cross section, with edges high to low  
**angle** -  
**base** length of leaf stalk  
**edge** relative thickness of edges



## Polygon

**distort** contact pressure from tangential to radial  
**shape** from rectangle to rhomb  
**flat** top flattening  
**profile** cross section shape  
**intercell** intermediate spaces  
**swell** elevation

**skin** surfacial thickness, below or on top  
**edge** relative thickness of edges  
**rings** from zero to all

## **LITERATURE**

*Apex is based on  
publications of Frank M.J. van der Linden:*

**'Creating Phyllotaxis: The Stack-and-Drag Model'**

in: Mathematical Biosciences 133:21-50, ISSN 0025-5564/96, Elsevier Science Inc., NY 1996

**'Creating Phyllotaxis from Seed to Flower'** in:

Symmetry in Plants, World Scientific Series no.4 /  
Mathematical Biology and Medicine, ISBN 981-02-2621-7, Singapore 1998

(from science and art to play)

**'Phyllotactische schoonheid'**, private publication, NL 2016

(translation of the Stack-and-Drag Model)

**'Wiskunde in de kiem'** in: Natuur en Techniek, 12/97, ISSN 0028-1093, Segment, NL 1997