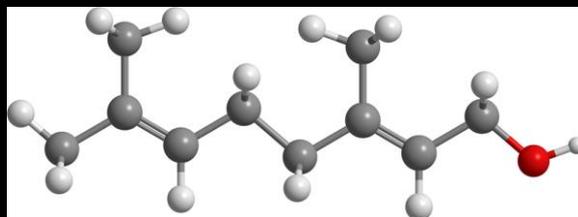


# Plant Smells



# and Molecules



Margareta Séquin

[msequin@sfsu.edu](mailto:msequin@sfsu.edu)

[chemistry.sfsu.edu/~msequin/](http://chemistry.sfsu.edu/~msequin/)



**Smells of Flowers**

Carnation



Lemon blossoms

# Smells of Ripe Fruits





# Smells of Leaves ....

Lemon mint



Rosemary

A photograph of three types of spices: nutmeg, cloves, and cinnamon. On the left, there are four whole nutmegs with their characteristic mottled, brownish-grey skin. In the center, there is a pile of dark brown, dried cloves, each consisting of a small, rounded head and a thin, dark stem. At the bottom, there are several cinnamon sticks of varying lengths and thicknesses, showing a reddish-brown, fibrous texture. The entire arrangement is set against a light yellow, woven fabric background. The text "Smells of Spices" is overlaid in white, bold, sans-serif font across the middle of the image.

# Smells of Spices

Nutmeg,  
Cloves,  
Cinnamon



# What Composes a Plant Smell??

MANY (50, 100, >200) different  
**Compounds\***.

Plant smells are **mixtures**.



**Compounds**  
are composed of the  
**same type of molecules.**



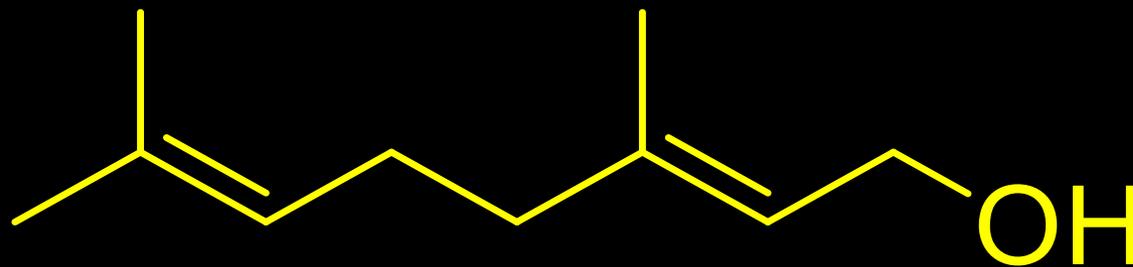
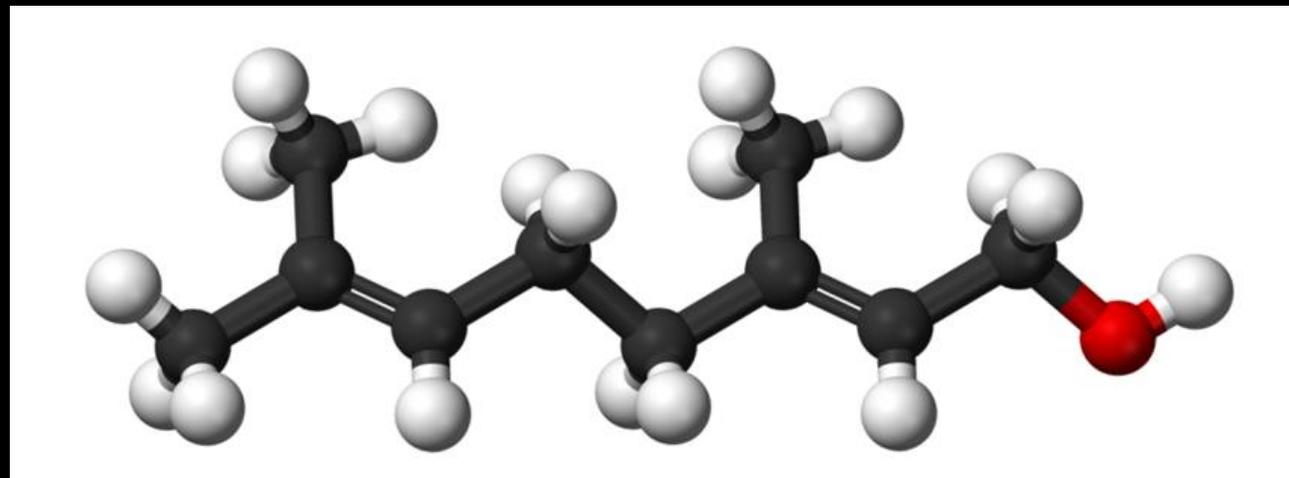
# What Composes a Plant Smell??

MANY (50, 100, >200) different  
**organic\*** (carbon-containing)  
compounds



*Rosa rugosa*

## Example of a Molecule of an Organic Compound

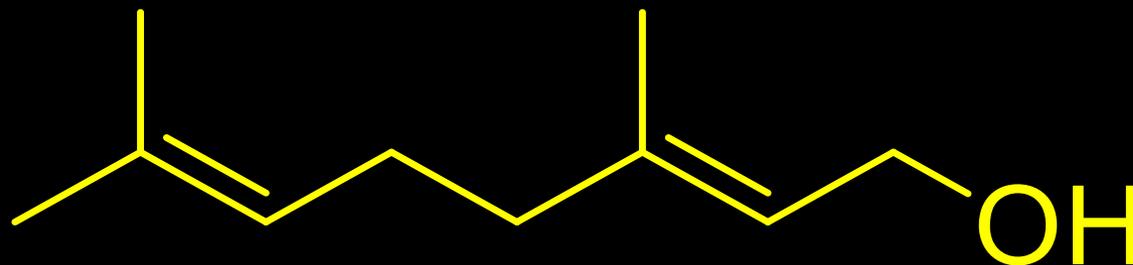
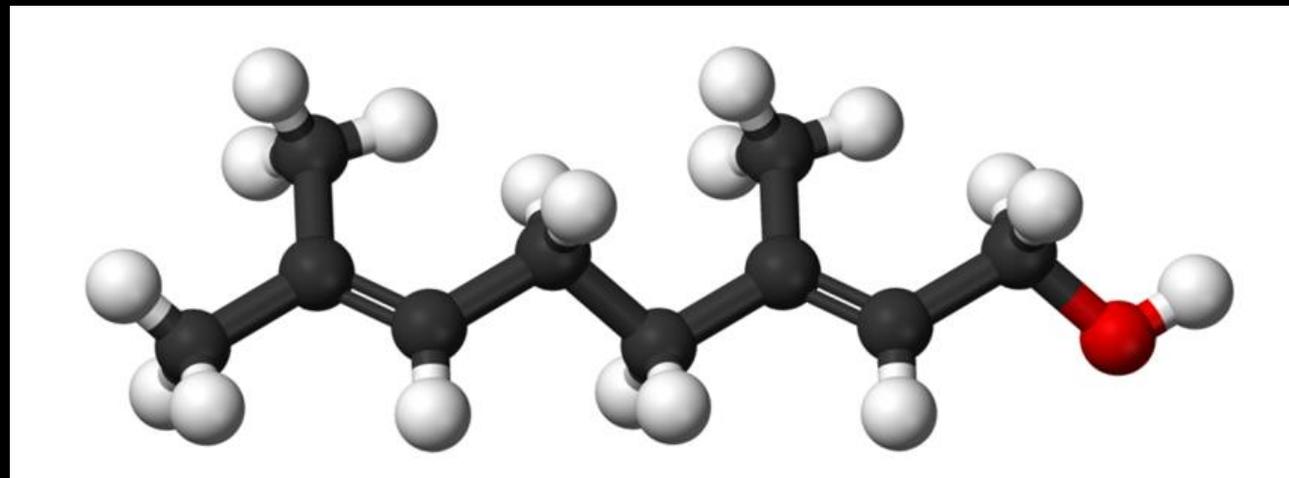


A molecule of  
Geraniol  $C_{10}H_{18}O$



*Rosa rugosa*

## Example of a Molecule of an Organic Compound



Geraniol is a  
sweet-smelling compound found in many flowers.

# Periodic Table of the Elements

1 <b>H</b> Hydrogen 1.01																	18 <b>He</b> Helium 4.00
3 <b>Li</b> Lithium 6.94	4 <b>Be</b> Beryllium 9.01											5 <b>B</b> Boron 10.81	6 <b>C</b> Carbon 12.01	7 <b>N</b> Nitrogen 14.01	8 <b>O</b> Oxygen 16.00	9 <b>F</b> Fluorine 19.00	10 <b>Ne</b> Neon 20.18
11 <b>Na</b> Sodium 22.99	12 <b>Mg</b> Magnesium 24.31											13 <b>Al</b> Aluminum 26.98	14 <b>Si</b> Silicon 28.09	15 <b>P</b> Phosphorus 30.97	16 <b>S</b> Sulfur 32.06	17 <b>Cl</b> Chlorine 35.45	18 <b>Ar</b> Argon 39.95
19 <b>K</b> Potassium 39.10	20 <b>Ca</b> Calcium 40.08	21 <b>Sc</b> Scandium 44.96	22 <b>Ti</b> Titanium 47.88	23 <b>V</b> Vanadium 50.94	24 <b>Cr</b> Chromium 51.99	25 <b>Mn</b> Manganese 54.94	26 <b>Fe</b> Iron 55.85	27 <b>Co</b> Cobalt 58.93	28 <b>Ni</b> Nickel 58.69	29 <b>Cu</b> Copper 63.55	30 <b>Zn</b> Zinc 65.38	31 <b>Ga</b> Gallium 69.72	32 <b>Ge</b> Germanium 72.63	33 <b>As</b> Arsenic 74.92	34 <b>Se</b> Selenium 78.97	35 <b>Br</b> Bromine 79.90	36 <b>Kr</b> Krypton 84.80
37 <b>Rb</b> Rubidium 85.47	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.91	40 <b>Zr</b> Zirconium 91.22	41 <b>Nb</b> Niobium 92.91	42 <b>Mo</b> Molybdenum 95.95	43 <b>Tc</b> Technetium 98.91	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.91	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.87	48 <b>Cd</b> Cadmium 112.41	49 <b>In</b> Indium 114.82	50 <b>Sn</b> Tin 118.71	51 <b>Sb</b> Antimony 121.76	52 <b>Te</b> Tellurium 127.6	53 <b>I</b> Iodine 126.90	54 <b>Xe</b> Xenon 131.29
55 <b>Cs</b> Cesium 132.91	56 <b>Ba</b> Barium 137.33	57-71 Lanthanides	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.95	74 <b>W</b> Tungsten 183.85	75 <b>Re</b> Rhenium 186.21	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.22	78 <b>Pt</b> Platinum 195.08	79 <b>Au</b> Gold 196.97	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.38	82 <b>Pb</b> Lead 207.20	83 <b>Bi</b> Bismuth 208.98	84 <b>Po</b> Polonium [208.98]	85 <b>At</b> Astatine 209.98	86 <b>Rn</b> Radon 222.02
87 <b>Fr</b> Francium 223.02	88 <b>Ra</b> Radium 226.03	89-103 Actinides	104 <b>Rf</b> Rutherfordium [261]	105 <b>Db</b> Dubnium [262]	106 <b>Sg</b> Seaborgium [266]	107 <b>Bh</b> Bohrium [264]	108 <b>Hs</b> Hassium [269]	109 <b>Mt</b> Meitnerium [278]	110 <b>Ds</b> Darmstadtium [281]	111 <b>Rg</b> Roentgenium [280]	112 <b>Cn</b> Copernicium [285]	113 <b>Nh</b> Nihonium [286]	114 <b>Fl</b> Flerovium [289]	115 <b>Mc</b> Moscovium [289]	116 <b>Lv</b> Livermorium [293]	117 <b>Ts</b> Tennessine [294]	118 <b>Og</b> Oganesson [294]

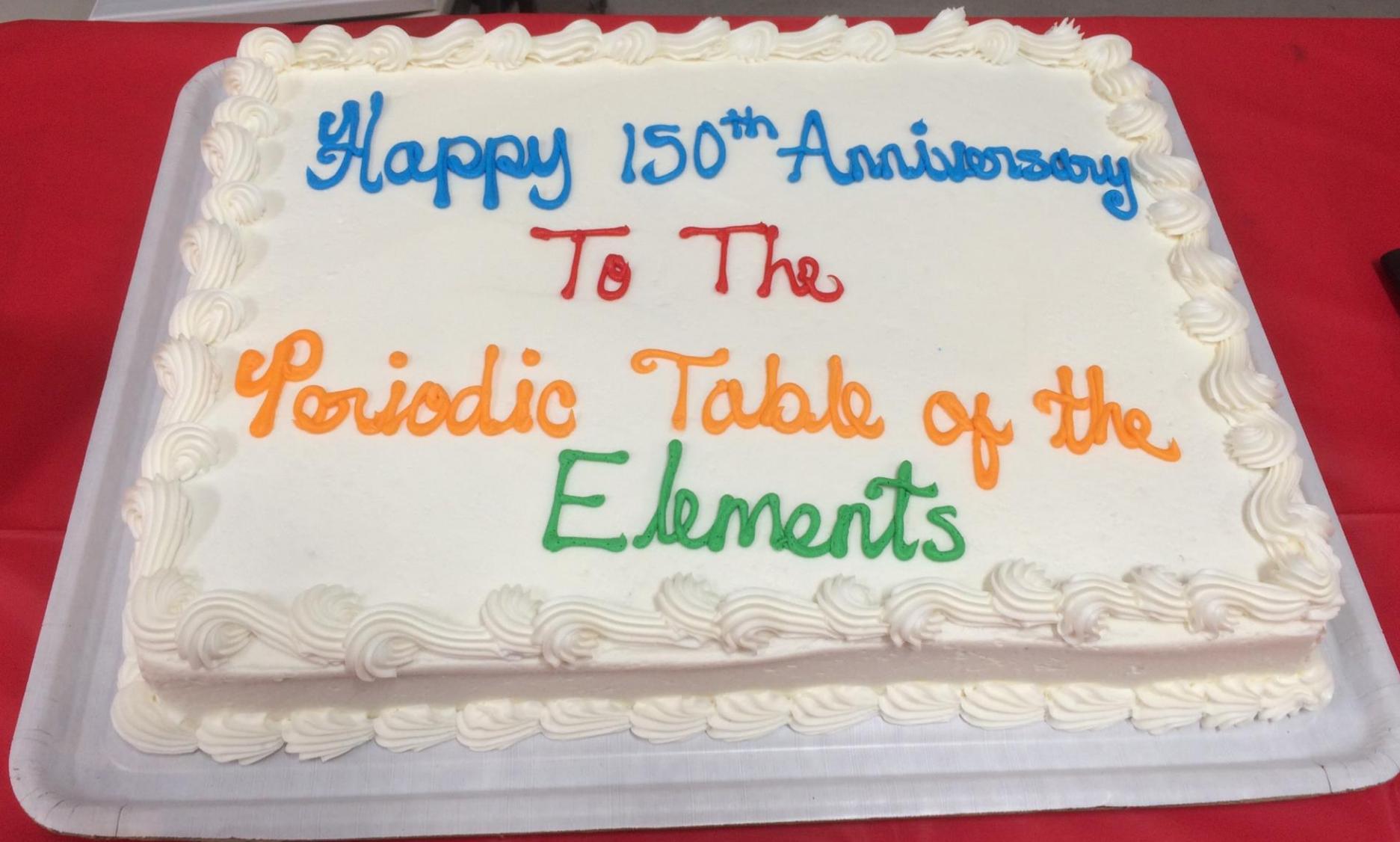
57 <b>La</b> Lanthanum 138.91	58 <b>Ce</b> Cerium 140.12	59 <b>Pr</b> Praseodymium 140.91	60 <b>Nd</b> Neodymium 144.24	61 <b>Pm</b> Promethium 144.91	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.96	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.93	66 <b>Dy</b> Dysprosium 162.50	67 <b>Ho</b> Holmium 164.93	68 <b>Er</b> Erbium 167.26	69 <b>Tm</b> Thulium 168.93	70 <b>Yb</b> Ytterbium 173.06	71 <b>Lu</b> Lutetium 174.97
89 <b>Ac</b> Actinium 227.03	90 <b>Th</b> Thorium 232.04	91 <b>Pa</b> Protactinium 231.04	92 <b>U</b> Uranium 238.03	93 <b>Np</b> Neptunium 237.05	94 <b>Pu</b> Plutonium 244.06	95 <b>Am</b> Americium 243.06	96 <b>Cm</b> Curium 247.07	97 <b>Bk</b> Berkelium 247.07	98 <b>Cf</b> Californium 251.08	99 <b>Es</b> Einsteinium [254]	100 <b>Fm</b> Fermium 257.10	101 <b>Md</b> Mendelevium 258.10	102 <b>No</b> Nobelium 259.10	103 <b>Lr</b> Lawrencium [262]

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Metalloid
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

# Periodic Table of the Elements

1 <b>H*</b> Hydrogen 1.01																	18 <b>He</b> Helium 4.00
3 <b>Li</b> Lithium 6.94	4 <b>Be</b> Beryllium 9.01											5 <b>B</b> Boron 10.81	6 <b>C*</b> Carbon 12.01	7 <b>N*</b> Nitrogen 14.01	8 <b>O*</b> Oxygen 16.00	9 <b>F</b> Fluorine 19.00	10 <b>Ne</b> Neon 20.18
11 <b>Na</b> Sodium 22.99	12 <b>Mg</b> Magnesium 24.31											13 <b>Al</b> Aluminum 26.98	14 <b>Si</b> Silicon 28.09	15 <b>P*</b> Phosphorus 30.97	16 <b>S*</b> Sulfur 32.06	17 <b>Cl</b> Chlorine 35.45	18 <b>Ar</b> Argon 39.95
19 <b>K</b> Potassium 39.10	20 <b>Ca</b> Calcium 40.08	21 <b>Sc</b> Scandium 44.96	22 <b>Ti</b> Titanium 47.88	23 <b>V</b> Vanadium 50.94	24 <b>Cr</b> Chromium 51.99	25 <b>Mn</b> Manganese 54.94	26 <b>Fe</b> Iron 55.85	27 <b>Co</b> Cobalt 58.93	28 <b>Ni</b> Nickel 58.69	29 <b>Cu</b> Copper 63.55	30 <b>Zn</b> Zinc 65.38	31 <b>Ga</b> Gallium 69.72	32 <b>Ge</b> Germanium 72.63	33 <b>As</b> Arsenic 74.92	34 <b>Se</b> Selenium 78.97	35 <b>Br</b> Bromine 79.90	36 <b>Kr</b> Krypton 84.80
37 <b>Rb</b> Rubidium 85.47	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.91	40 <b>Zr</b> Zirconium 91.22	41 <b>Nb</b> Niobium 92.91	42 <b>Mo</b> Molybdenum 95.95	43 <b>Tc</b> Technetium 98.91	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.91	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.87	48 <b>Cd</b> Cadmium 112.41	49 <b>In</b> Indium 114.82	50 <b>Sn</b> Tin 118.71	51 <b>Sb</b> Antimony 121.76	52 <b>Te</b> Tellurium 127.6	53 <b>I</b> Iodine 126.90	54 <b>Xe</b> Xenon 131.29
55 <b>Cs</b> Cesium 132.91	56 <b>Ba</b> Barium 137.33	57-71 Lanthanides	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.95	74 <b>W</b> Tungsten 183.85	75 <b>Re</b> Rhenium 186.21	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.22	78 <b>Pt</b> Platinum 195.08	79 <b>Au</b> Gold 196.97	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.38	82 <b>Pb</b> Lead 207.20	83 <b>Bi</b> Bismuth 208.98	84 <b>Po</b> Polonium [208.98]	85 <b>At</b> Astatine 209.98	86 <b>Rn</b> Radon 222.02
87 <b>Fr</b> Francium 223.02	88 <b>Ra</b> Radium 226.03	89-103 Actinides	104 <b>Rf</b> Rutherfordium [261]	105 <b>Db</b> Dubnium [262]	106 <b>Sg</b> Seaborgium [266]	107 <b>Bh</b> Bohrium [264]	108 <b>Hs</b> Hassium [269]	109 <b>Mt</b> Meitnerium [278]	110 <b>Ds</b> Darmstadtium [281]	111 <b>Rg</b> Roentgenium [280]	112 <b>Cn</b> Copernicium [285]	113 <b>Nh</b> Nihonium [286]	114 <b>Fl</b> Flerovium [289]	115 <b>Mc</b> Moscovium [289]	116 <b>Lv</b> Livermorium [293]	117 <b>Ts</b> Tennessine [294]	118 <b>Og</b> Oganesson [294]
57 <b>La</b> Lanthanum 138.91	58 <b>Ce</b> Cerium 140.12	59 <b>Pr</b> Praseodymium 140.91	60 <b>Nd</b> Neodymium 144.24	61 <b>Pm</b> Promethium 144.91	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.96	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.93	66 <b>Dy</b> Dysprosium 162.50	67 <b>Ho</b> Holmium 164.93	68 <b>Er</b> Erbium 167.26	69 <b>Tm</b> Thulium 168.93	70 <b>Yb</b> Ytterbium 173.06	71 <b>Lu</b> Lutetium 174.97			
89 <b>Ac</b> Actinium 227.03	90 <b>Th</b> Thorium 232.04	91 <b>Pa</b> Protactinium 231.04	92 <b>U</b> Uranium 238.03	93 <b>Np</b> Neptunium 237.05	94 <b>Pu</b> Plutonium 244.06	95 <b>Am</b> Americium 243.06	96 <b>Cm</b> Curium 247.07	97 <b>Bk</b> Berkelium 247.07	98 <b>Cf</b> Californium 251.08	99 <b>Es</b> Einsteinium [254]	100 <b>Fm</b> Fermium 257.10	101 <b>Md</b> Mendelevium 258.10	102 <b>No</b> Nobelium 259.10	103 <b>Lr</b> Lawrencium [262]			

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Metalloid
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide



At "Elements" Art Exhibit, Marin Society of Artists, San Rafael



# The Components of Plant Smells



are organic compounds that

- Are composed of molecules with a **low number of C's** (up to about 12)
- Evaporate easily (i.e. are **volatile**), especially on a warm days
- Are mostly **nonpolar\***, *i.e.* do not dissolve in water (“**essential oils**”)

# Compounds in Plant Smells



- are mostly **nonpolar**,
- *i.e.* they do not dissolve in water (**“essential oils”**)



**Oil** on water



Plant smells are  
mixtures\* .

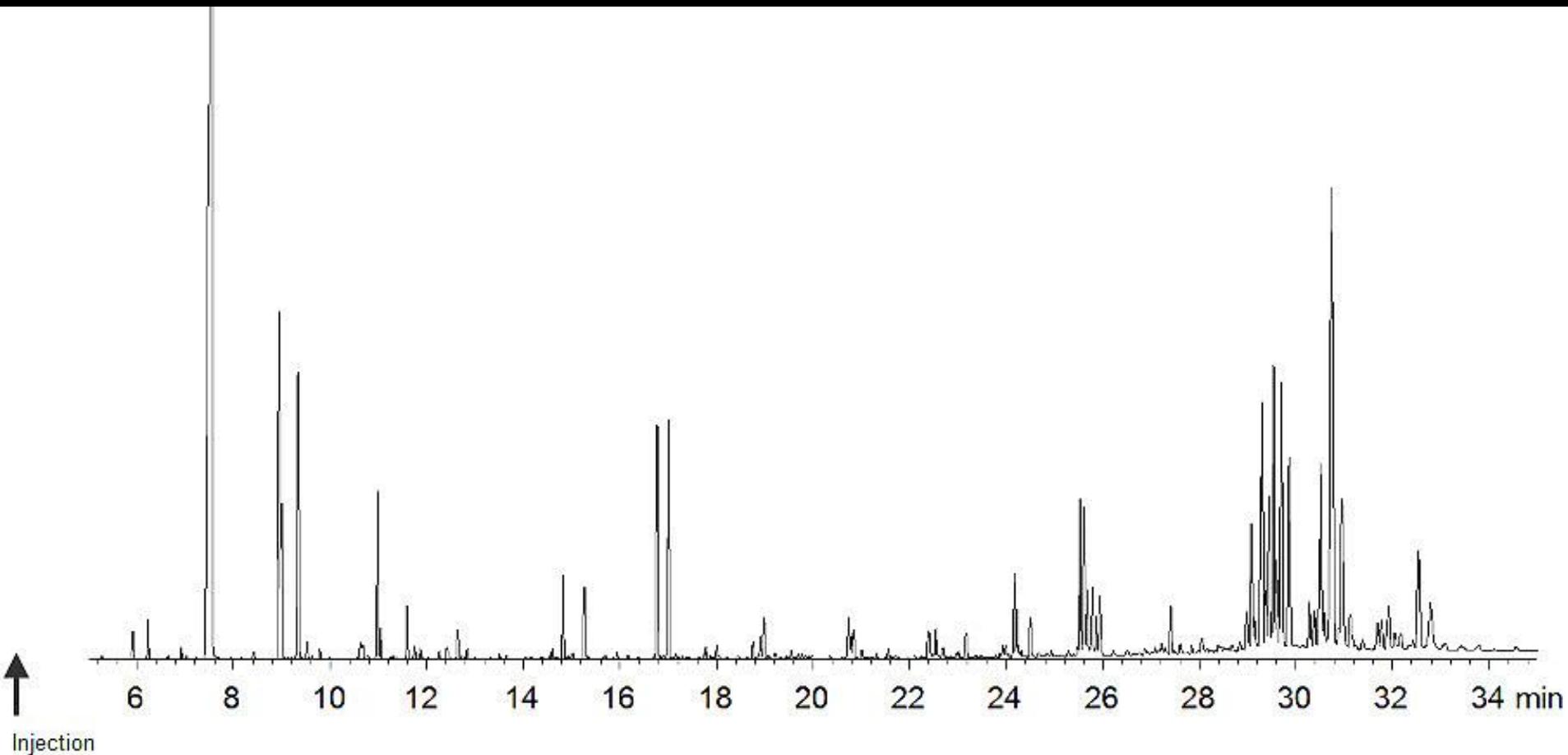
# Separating and Identifying Plant Smells: Headspace Analysis/GC-MS



Headspace Analysis Display at Longwood Gardens PA

Collection of volatiles from fragrant flower  
of an Ylang Ylang shrub (*Cananga odorata*)

# Components of Rose Oil



Gas chromatogram of a rose oil

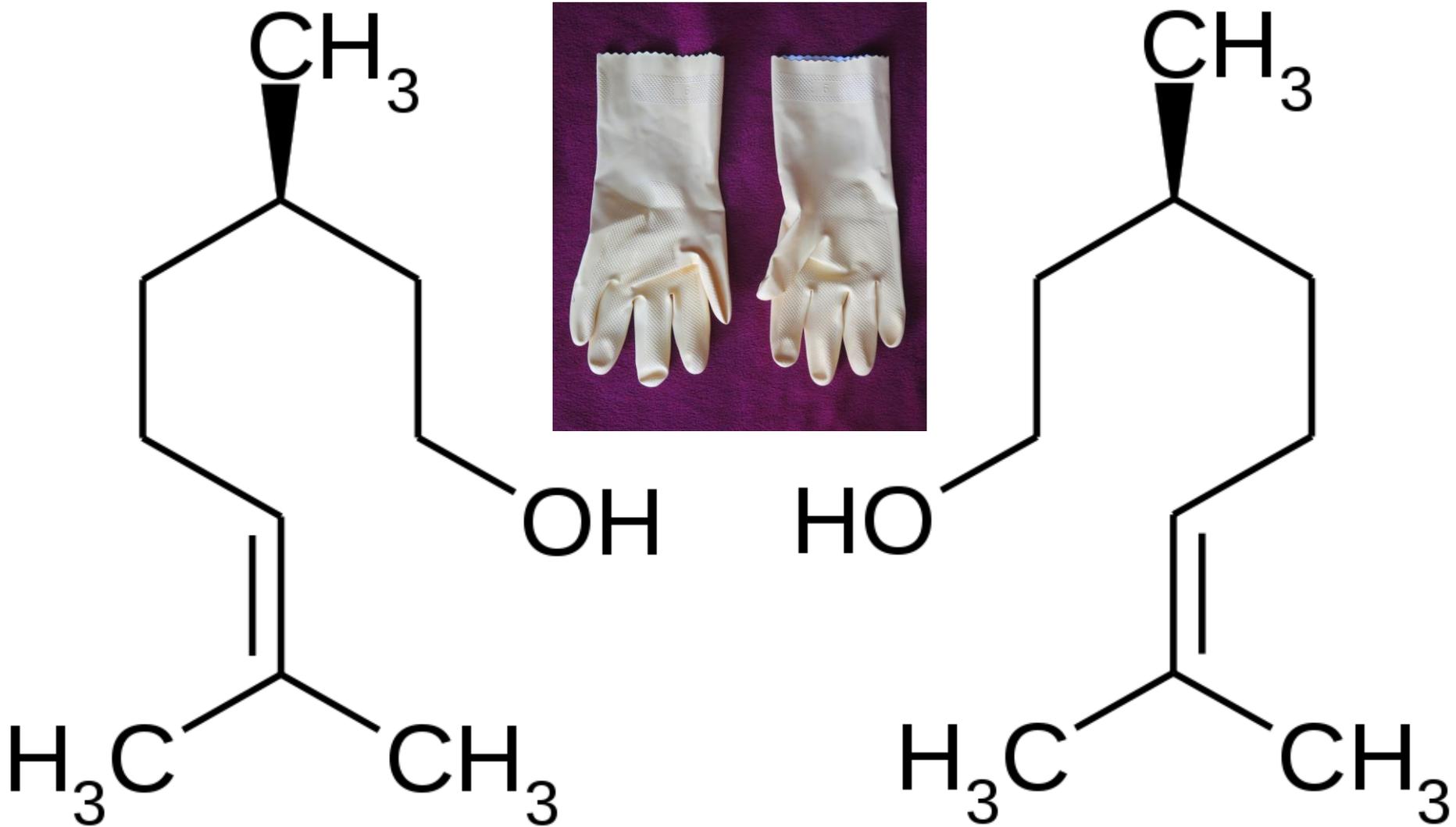
## Compounds in the essential oil of *Rosa damascena* (% -age)

<u><math>\alpha</math>-Pinene</u>	1.46
2-Methyl propanol	0.01
Hexanal	tr
$\beta$ -Pinene	0.13
Sabinene	0.04
Myrcene	0.18
$\delta$ -3-Carene	0.02
Heptanal	0.04
<i>iso</i> -Amyl alcohol	tr
<u>Limonene</u>	0.02
1,8-Cineole	tr

Determined by GC–MS Analysis



<u>Citronellol</u>	30.71
Nerol	7.57
2-Phenylethyl acetate	0.08
$\alpha$ -Cadinene	tr
<i>cis</i> - $\beta$ -Damascenone	0.04
<u>Geraniol</u>	16.11
<i>iso</i> -Geraniol	0.19
Damascone	tr



In Citronella oil

Citronellol  $C_{10}H_{20}O$

In rose oil

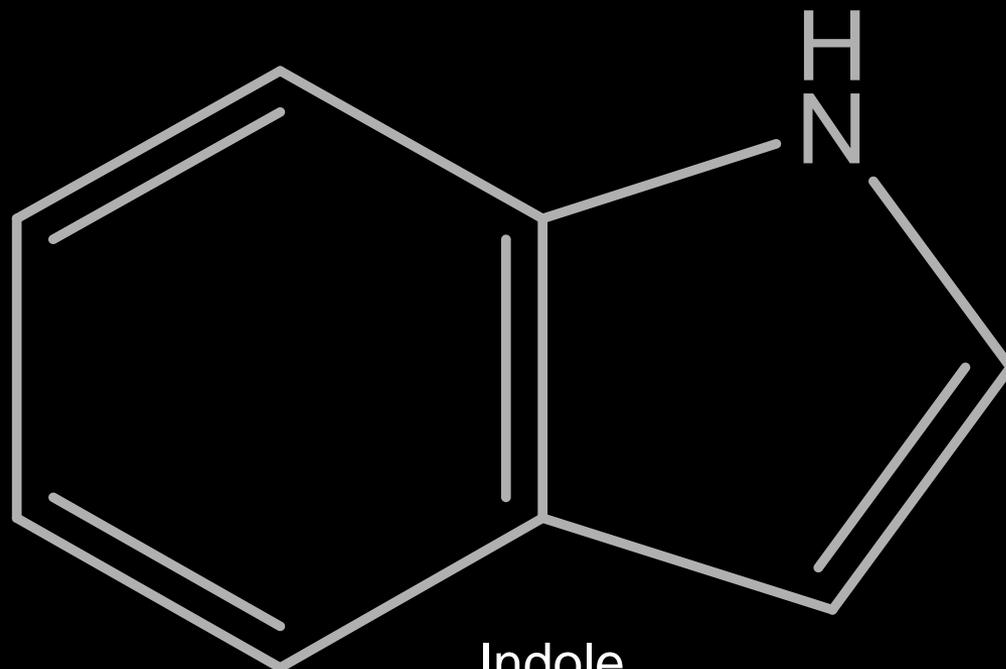


Hyacinths



Table 2. 'Vacuum headspace' analysis of freshly picked white hyacinth flowers (two samples)

Peak no.	Constituents	GC area (%)	
		1	2
4	<u><math>\alpha</math>-Pinene</u>	0.08	0.16
5	Camphene	0.01	0.05
6	Hexanal	0.02	0.02
7	( <i>E</i> )-2-Methylbut-2-enal?	0.01	0.01
8	$\beta$ -Pinene	0.06	0.05
9	Pent-1-en-3-ol	0.01	0.02
10	Myrcene	1.80	2.05
11	$\alpha$ -Phellandrene	Trace	0.01
15	<u>Limonene</u>	0.53	1.10
16	$\beta$ -Phellandrene	0.01	0.01
17	1,8-Cineole	0.01	0.01
19	( <i>Z</i> )- $\beta$ -Ocimene	0.75	1.01
21	( <i>E</i> )- $\beta$ -Ocimene $C_{10}H_{16}$	13.72	14.93
136	( <i>E</i> )-Cinnamyl alcohol	4.04	3.46
139	2-(4-Methoxyphenyl) ethyl alcohol	—	Trace
145	<u>Indole</u>	0.05	0.08
150	Benzyl benzoate	3.06	2.94
153	$\beta$ -Phenylethyl benzoate	0.53	0.40



Indole  
 $C_8H_7N$

Occurs naturally in human feces,  
has an intense fecal odor.  
At very low concentrations it has a flowery smell.

Stinky  
Flowers ...



*Amorphophallus  
titanum*



Photo by Ch'ien C. Lee

Corpse flower  
*Rafflesia* sp.

# Plant compounds with pleasant or unpleasant scents

(from a human point of view!)

- Have typical chemical structures

- Pleasant:



In flowers: attract bees, butterflies, moths, ...

- Unpleasant: a wide range of volatiles that have nitrogen (N) or sulfur atoms (S) in their organic molecules.

In flowers: attract flies, beetles, gnats ...



A photograph of a Western Spicebush (Calycanthus occidentalis) in a wooded area. The plant has large, vibrant green, ovate leaves and several reddish, pointed flower buds. The background shows a dense forest with sunlight filtering through the trees. The text is overlaid in the center of the image.

**Scents of flowers, of leaves  
of same plant  
are often different....**

Western Spicebush  
*Calycanthus occidentalis*



Western Spicebush  
*Calycanthus occidentalis*

**Smells of blossoms, of leaves  
have different functions**



Western azalea  
*Rhododendron occidentale*

A close-up photograph of a branch from a California bay tree. The branch is covered with numerous bright green, lanceolate leaves that have a smooth, waxy texture. In the center of the branch, there is a cluster of small, bright yellow flowers. Some of the flowers are in full bloom, while others are still in bud form, appearing as small, rounded, purple-tinged structures. The background is a dense thicket of similar foliage, creating a lush green environment. The lighting is bright and natural, highlighting the vibrant colors of the leaves and flowers.

# Smells of Leaves

California bay tree  
*Umbellularia californica*

# Human sense of smell

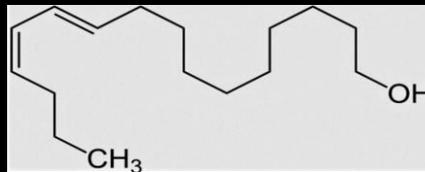


is affected by a person's age, sex, individual differences.

Humans have a broad range of sensitivity.

Humans are specially sensitive towards sulfurous smells. (Cooking gas...)

# Human sense of smell compared .....



Bombykol  $C_{16}H_{30}O$   
pheromone



Silk moth (*Bombyx mori*)

# CalACS Earth Day Booth at John Muir Ntl. Historic Park

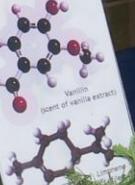


## Scents from Plants

Build molecular models of some common compounds

Which are organic compounds?

## Nice Scents!



## Plant Smells

Try to identify each plant smell



# ACS

Chemistry for Life™

