Recipes Data Structure

_______________________________ RECIPE _______________________________

INGREDIENTS SECTION

100 gms, potato, sliced
50 gms, capsicum, finely chopped
50 gms, onions, chopped
100 ml, groundnut oil
10 gms, cumin, crushed
10 gms, turmeric
20 gms, chilly power
To taste, salt

COOKING INSTRUCTIONS

1. Add oil to pan and heat it for 3-4 minutes.
2. Add cumin and then add onion. Fry for 3-4 minutes
3. Add potato and capsicum. Fry for 8-10 minutes.
4. Add turmeric, cumin, and salt. Mix thoroughly.
5. Keep the mixture on low heat for another 5 minutes.

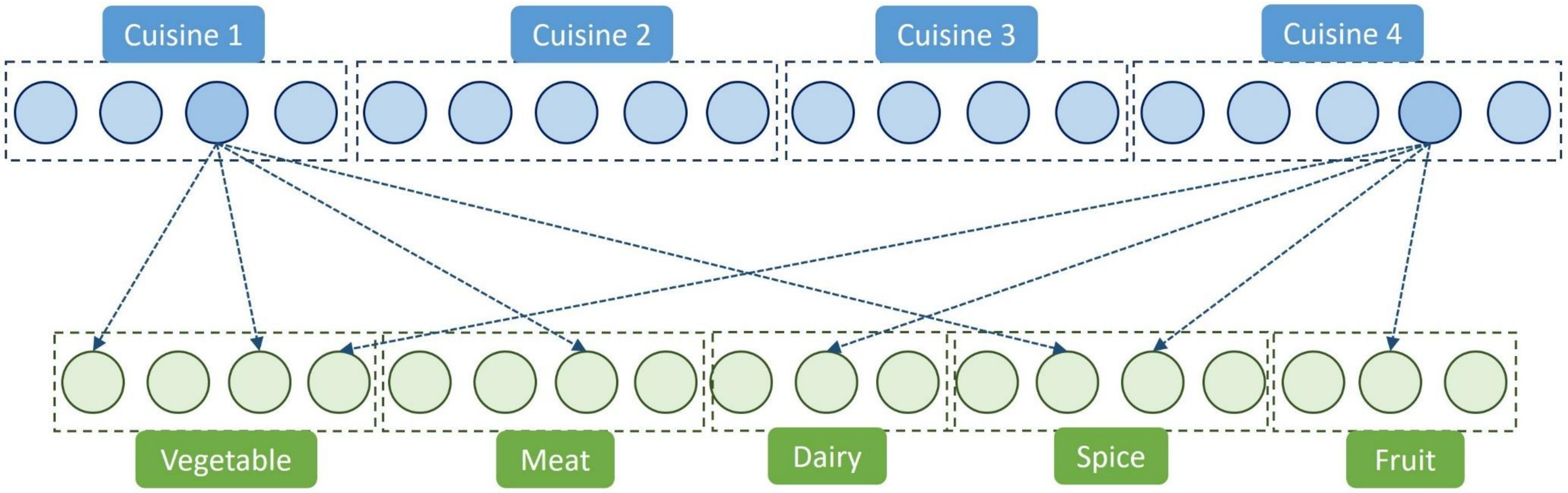
Recipes & Ingredients

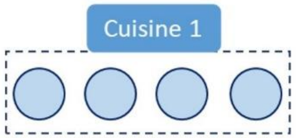
2543 Traditional Indian Recipes (TarlaDalal)

Regional cuisines: Bengali, Gujarati, Jain, Maharashtrian, Mughlai, Punjabi, Rajasthani, South Indian.

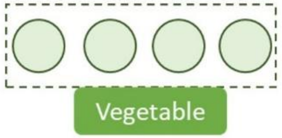
A Jain, NK Rakhi & G Bagler,* "Analysis of Food Pairing in Regional Cuisines of India", **PLoS ONE**, *10(10): e0139539*(2015).

Recipes Data





A ‘cuisine’ comprises of a set of recipes assessed to be of similar geo-cultural origin.



An ‘ingredient category’ represents a set of ingredients assessed to be of similar nature.

A recipe is defined as an unordered list of ingredients.

For illustration, the associations between recipe and its ingredients are shown here for two recipes.

Recipes Data Structure

Recipe-01 : Ingredient-01, Ingredient-02, Ingredient-15, Ingredient-19, Ingredient-06
Recipe-02 : Ingredient-06, Ingredient-12, Ingredient-08, Ingredient-15

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Recipe-100: Ingredient-06, Ingredient-11, Ingredient-15, Ingredient-13

Recipes Data Structure

Recipe-01 — Ingredient-01
Recipe-01 — Ingredient-02
Recipe-01 — Ingredient-15
Recipe-01 — Ingredient-19
Recipe-01 — Ingredient-06

Recipe-02 — Ingredient-06
Recipe-02 — Ingredient-12
Recipe-02 — Ingredient-08
Recipe-02 — Ingredient-15

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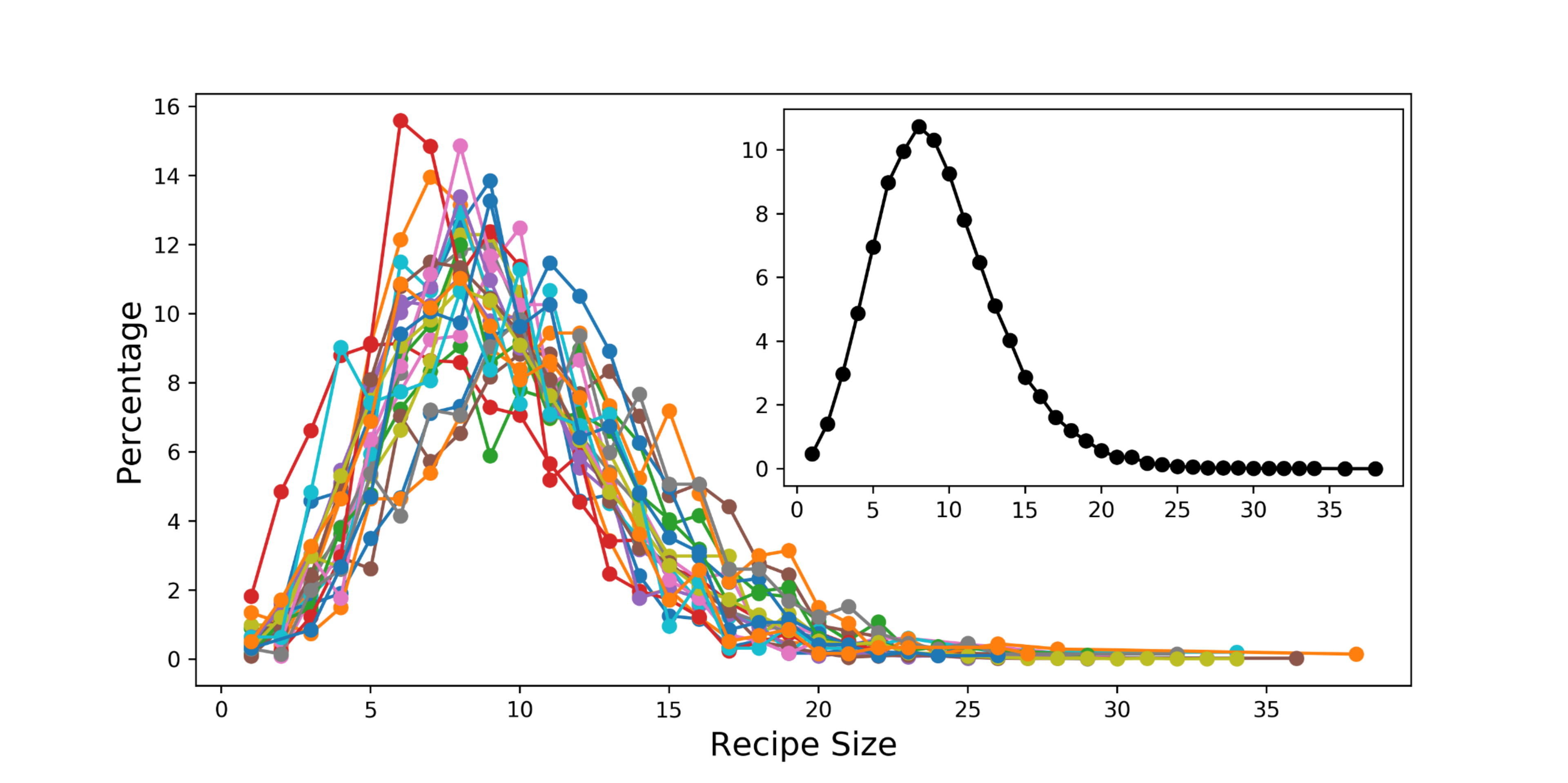
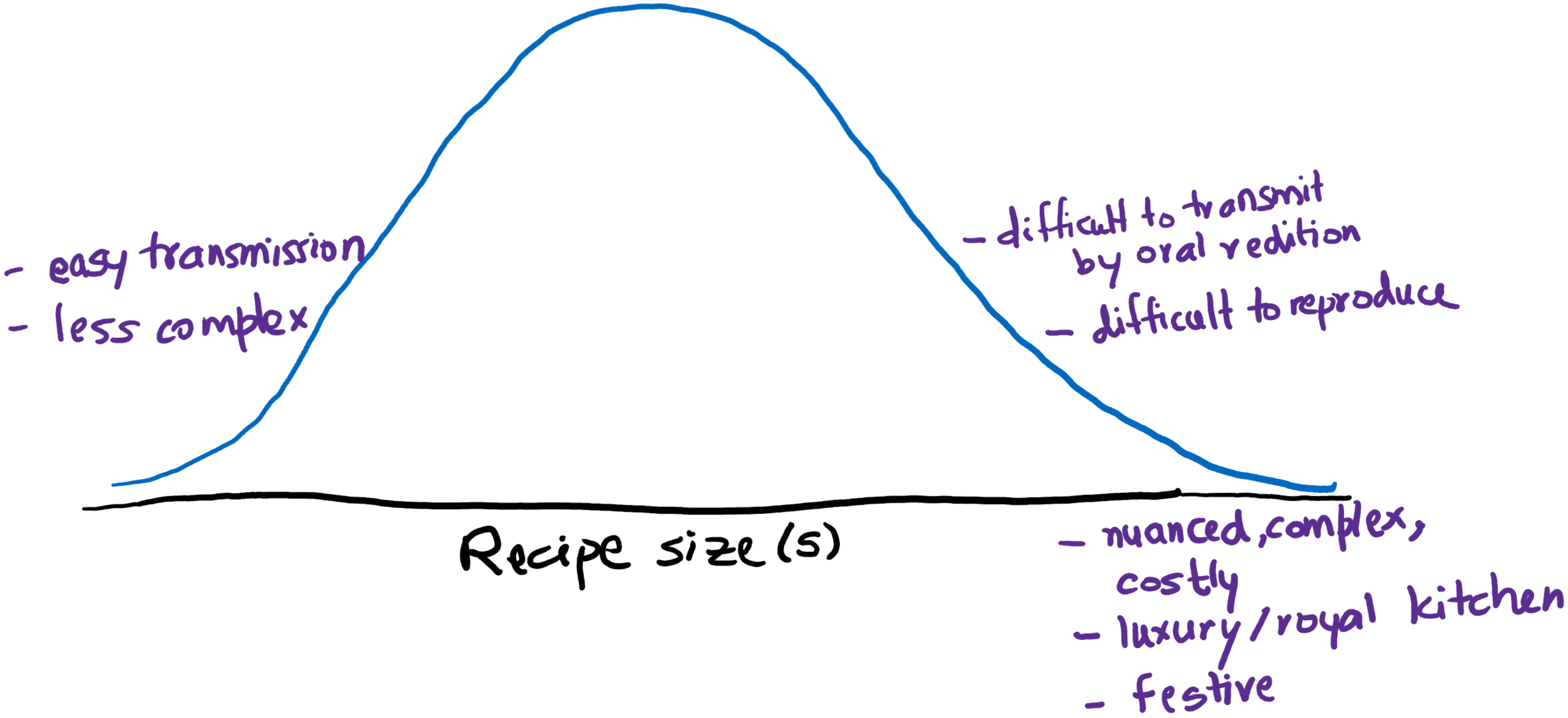
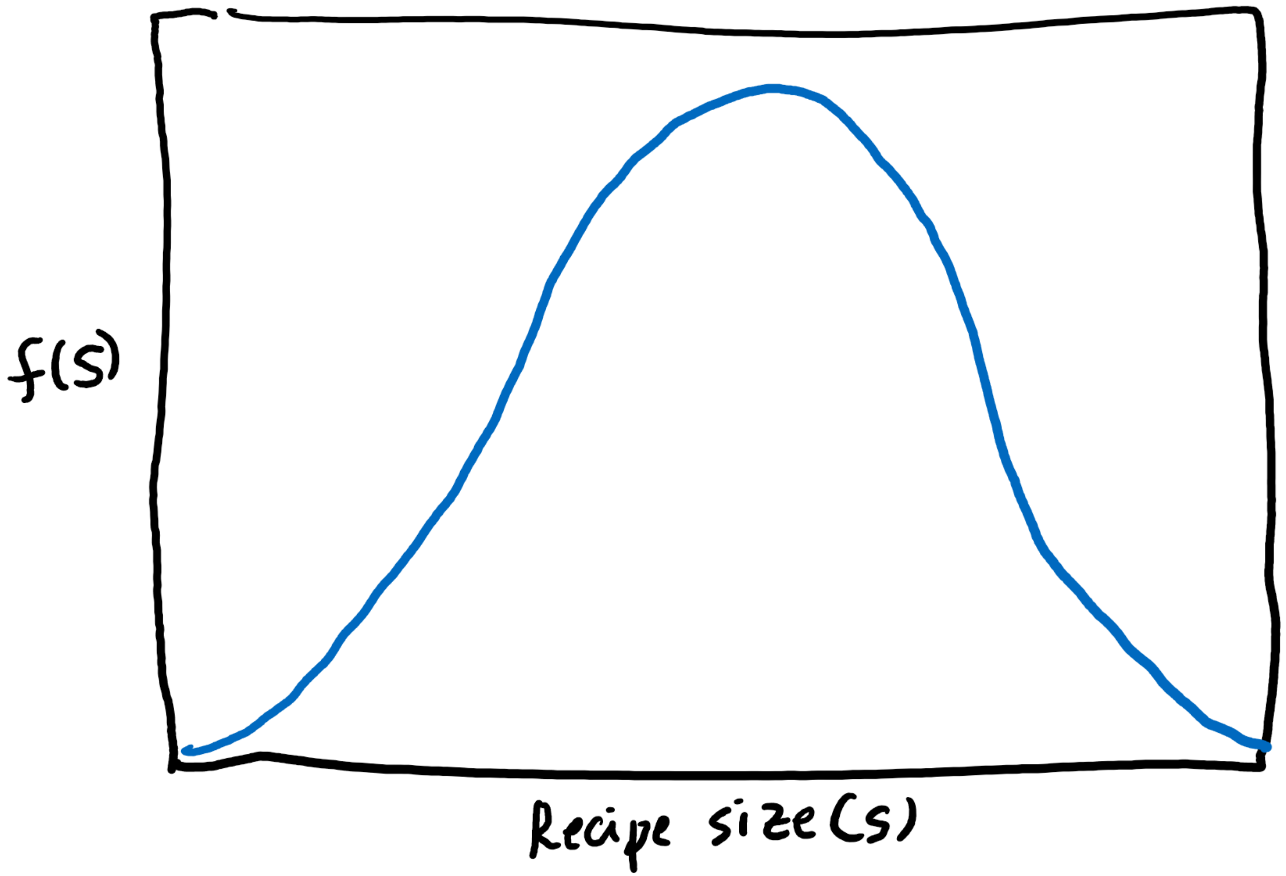
Recipe-100 — Ingredient-06
Recipe-100 — Ingredient-11
Recipe-100 — Ingredient-15
Recipe-100 — Ingredient-13

Recipes Data Statistics



The recipe size distribution of recipes is observed to follow a normal distribution.


- easy transmission
- less complex
- difficult to transmit by oral redition
- difficult to reproduce
Recipe size(s)
- nuanced, complex, costly
- luxury/royal kitchen
- festive

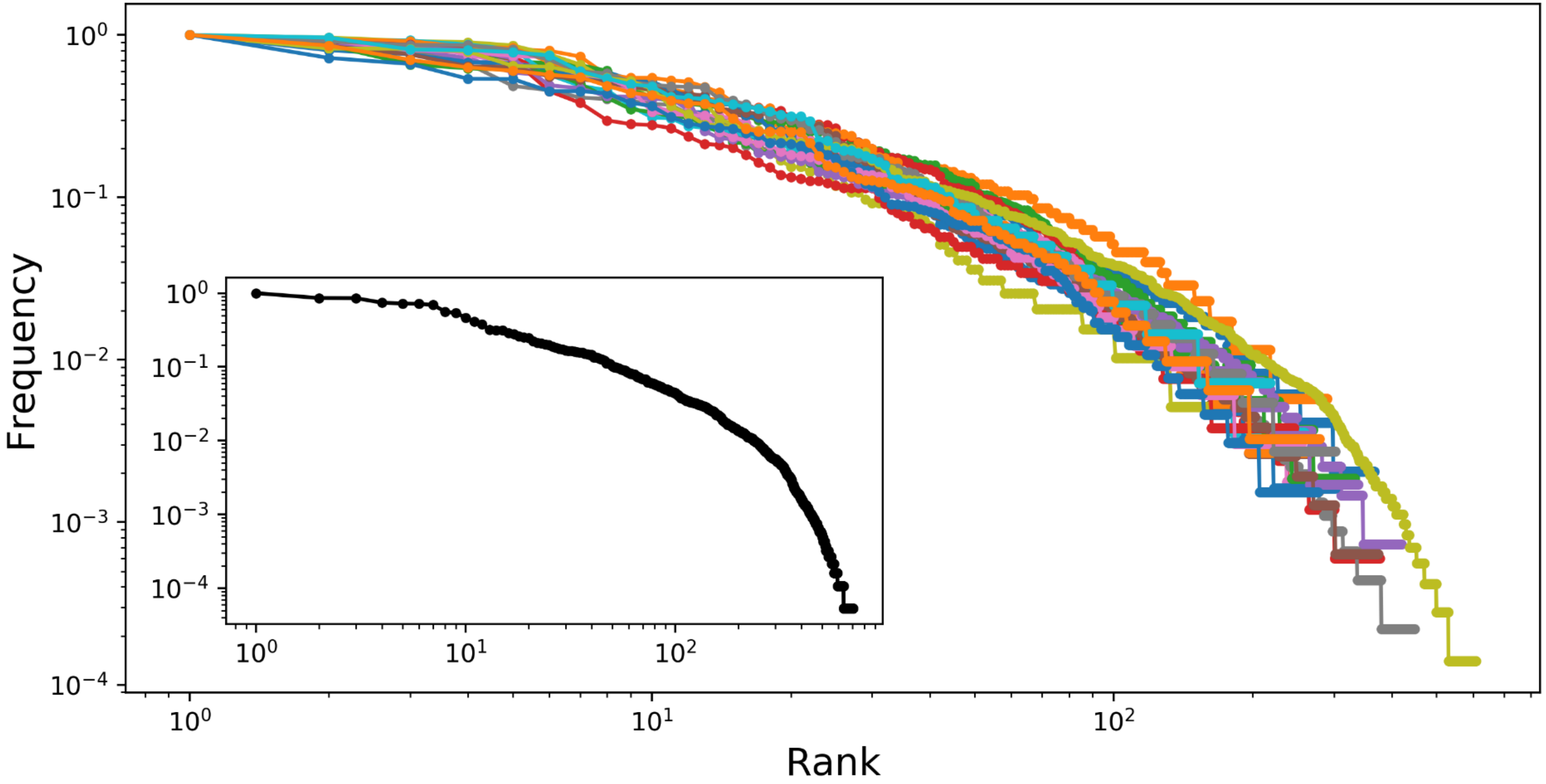


$s = 2, 3, 4, 5$ – Distribution

$N(s) = 0.1, 0.4, 0.4, 0.1$ – Normalized distn

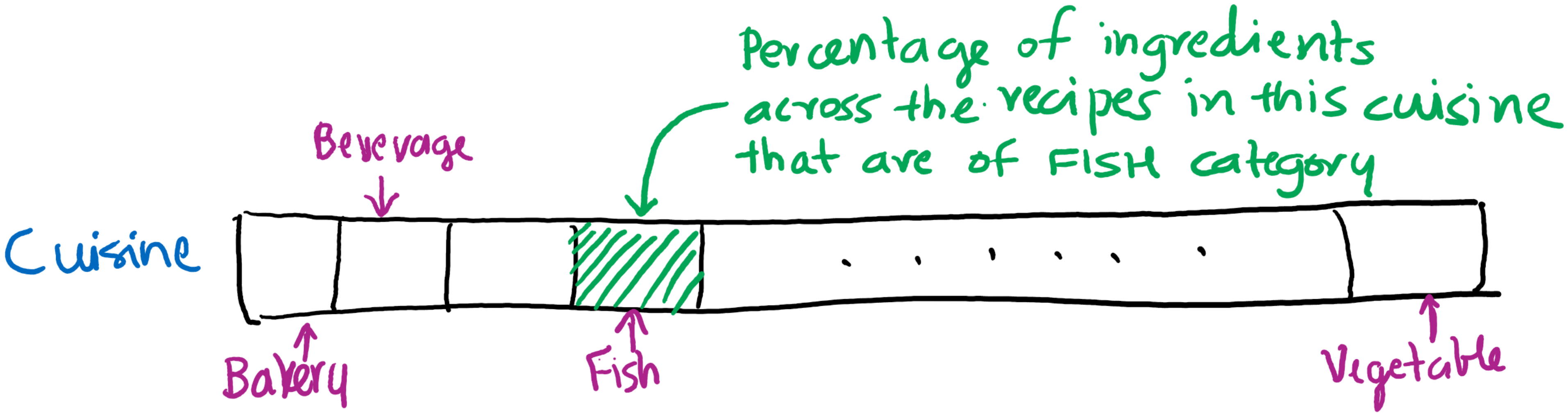
$N(\geq s) = 1, 0.9, 0.5, 0.1$ – Cumulative dist

Recipes Data Statistics

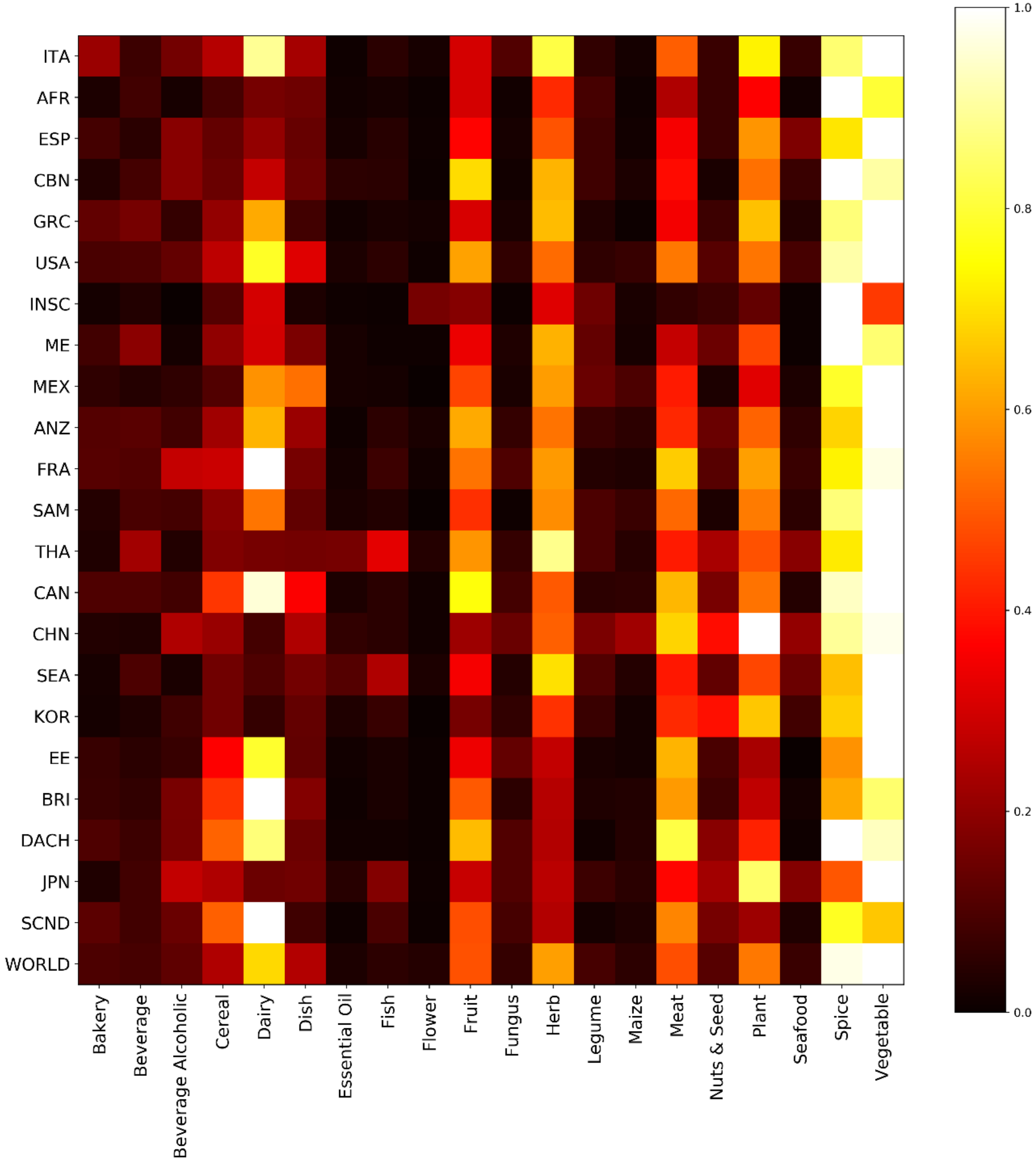


The nature of the Frequency-Rank statistics is observed to consistently present with a power law across the world cuisines.

Recipes Data Statistics



Recipes Data Statistics



Recipe Data Statistics

- Item set mining of cuisines
- Algorithms for Frequence Item Set Mining (FISM)
- https://data-mining.philippe-fournier-viger.com/introduction-high-utility-itemset-mining/

Ideas

- A mathematical/computational model to capture the evolution of recipes so as to capture the statistics of contemporary cuisines.
- A ‘recipe data structure’ that captures practically all quantifiable nuances of cooking.
- An app (web/mobile) for crowdsourcing recipes from lay users.
- What other kinds of known data mining algorithms could be used to analyze cuisines?
- Mining the bipartite graph ingredient-disease associations

Computational Gastronomy

Assignment 1

You may use Python and Jupiter Notebook to complete the assignments and documentation.

Notes: You are responsible for the backup of data and results, which will be used for evaluation.

Follow the rubric diligently while submitting. Name the files with the question numbers.

---

1. Complete the following analysis using the CulinaryDB data shared with you.
   (a) Scrape (using libraries such as BeautifulSoup) any **10,000 recipes**. **Submit the raw data.** **[5]**
   (b) Write a script to extract information about the 'name of the ingredients' from the ingredients section. **Store recipes in the form of a (Recipe ID)—(Ingredient Name) form**. **[10]**

   NOTE: You must not scrape/use data from RecipeDB

2. Analyze the data obtained for the following.
   (a) Find the number of unique ingredients. List them with their frequencies. **Submit the file.** **[2]**
   (b) Plot the recipe size distribution for these recipes and the average size of the recipes (s). Properly label the axes. **Submit the file.** **[3]**
   (c) Plot cumulative distribution of recipe size (label axes properly). **Submit the file.** **[5]**

3. For the data of recipes obtained in the above question (1):
   (a) Plot the frequency-rank distribution. Scale and label axes properly. **Submit the file.** **[5]**

4. **Compare** the nutritional profile of a 'boiled egg' versus that of a 'boiled rice and *daal*'. **[2]**

5. List **five** most uncommon food ingredients that you (or your parents or grandparents) know of. List their (a) Common/Vernacular/Local Name, (b) English Name (if available), (c) Seasonal Use (if known), and (d) Nutritional Values (if available). **[5]**

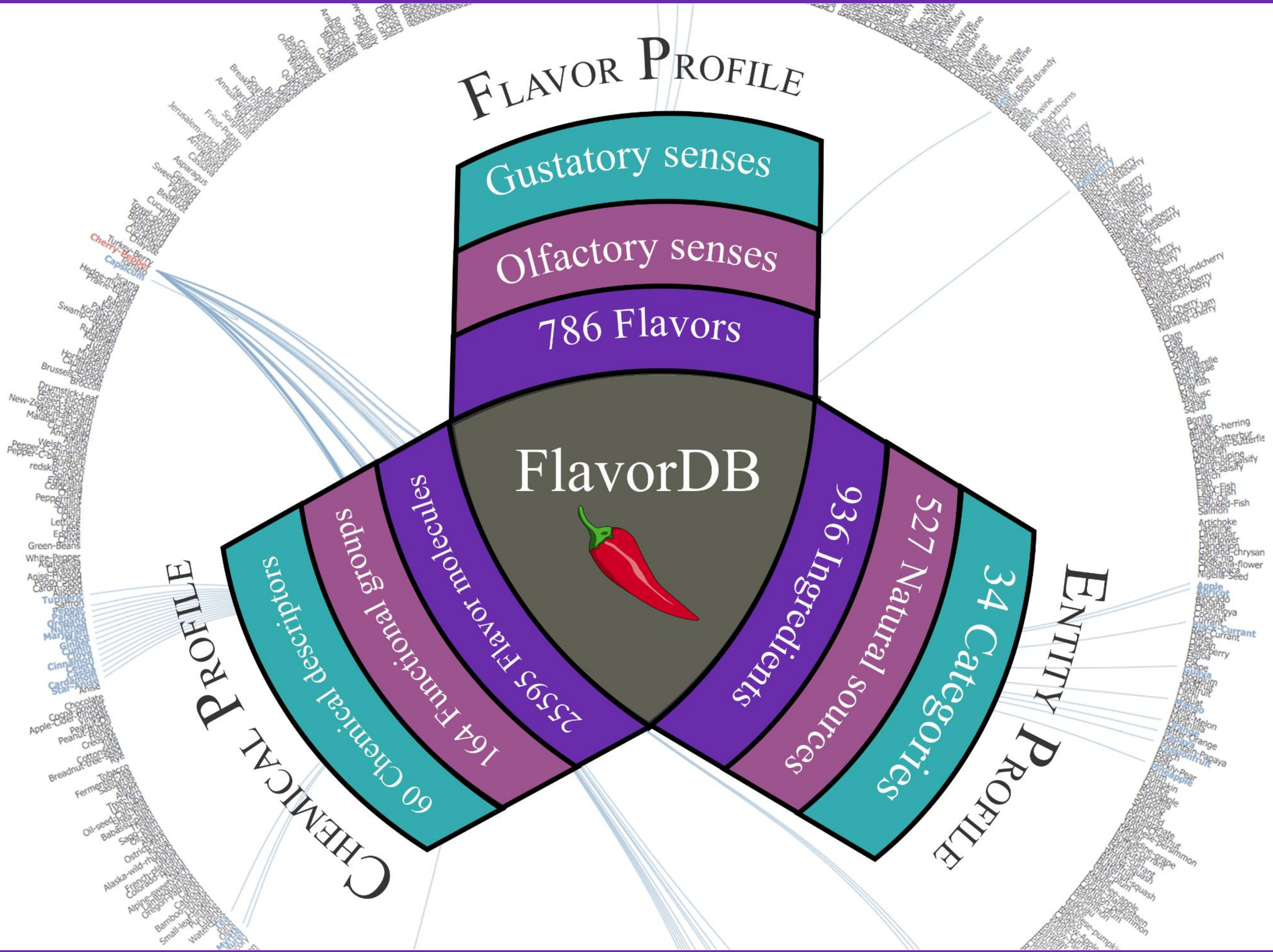
6. Consider the following statements and **provide scientific arguments** about them being a scientific truth or a myth. **[3]**

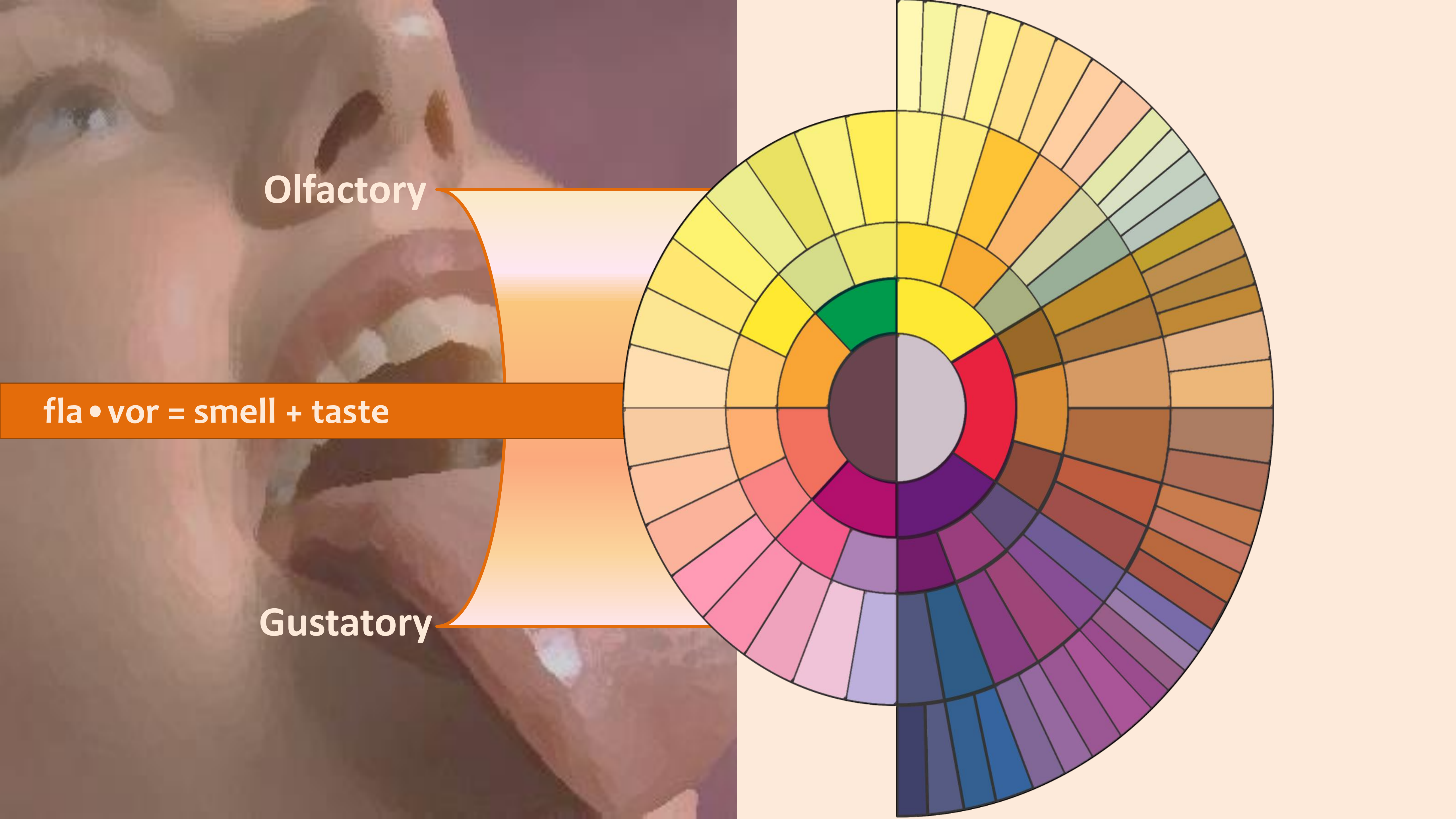
   (a) Cooking food in microwave destroys its 'nutritional value'.
   (b) Refrigerating food destroys its 'nutritional value'.
   (c) Genetic modifications in plans or animals are 'bad'.

7. **Write a brief (5-8 lines) summary** on the technique used for finding out the calorific content of food products. **[2]**

8. **List eight specific technologies/products, with 1-3 lines of description for each** that you envision could emerge from the application of the Computational Gastronomy paradigm. Be as specific/narrow as possible. **[8]**

Flavor Data Analytics

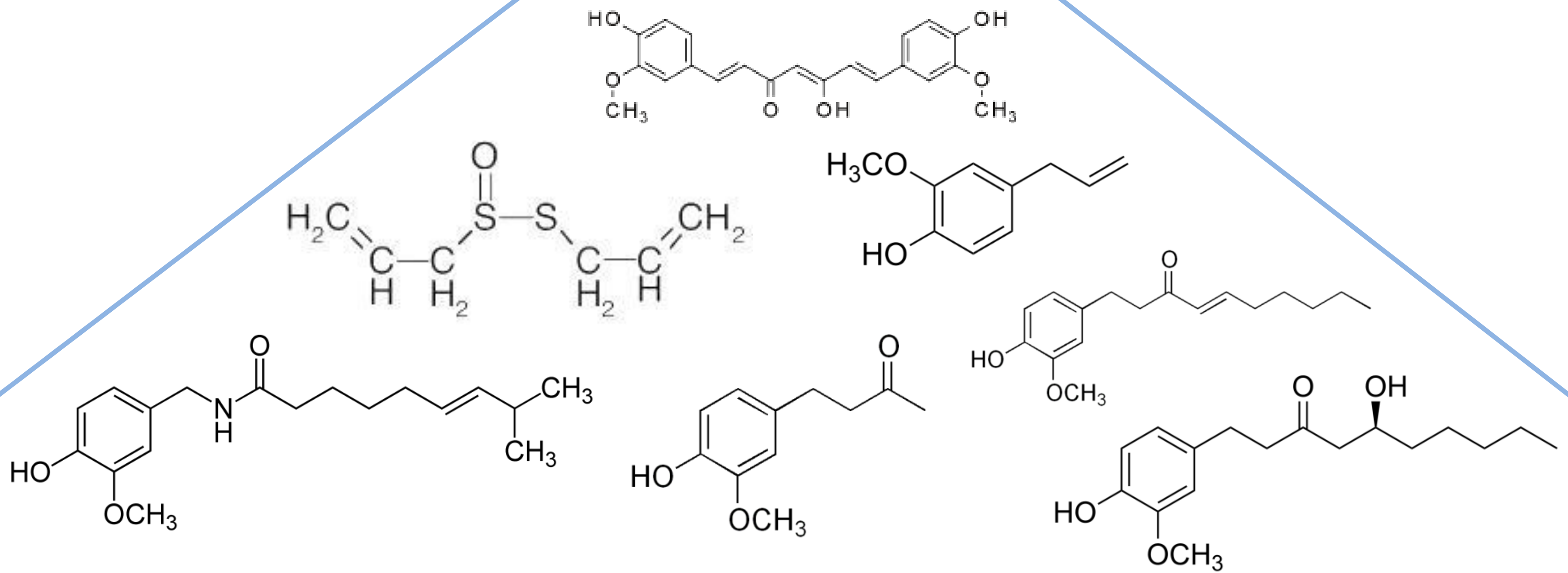



Olfactory
fla • vor = smell + taste
Gustatory

PubMed

PubChem

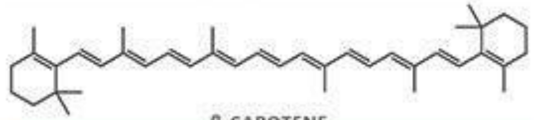
Fenaroli's Handbook



THE CHEMISTRY OF PUMPKINS

Halloween's approaching. Before you get out the pumpkin-carving kit, take a look at this spooktacular review of the chemicals behind the color, aroma, and taste of this seasonal squash.

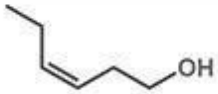
COLORATION



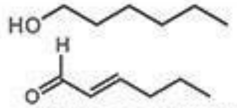
β-CAROTENE

A pumpkin's hue is due to carotenoid compounds such as β-carotene, the same compound that gives carrots their orange color. Other carotenoids include lutein, found in egg yolks, and zeaxanthin, found in corn.

AROMA

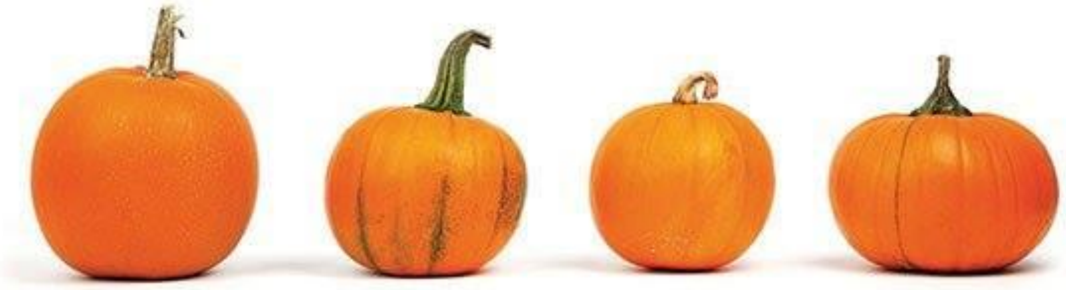


cis-3-HEXEN-1-OL

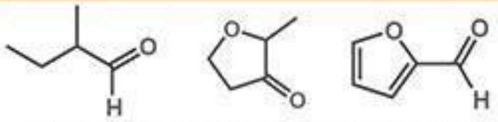


n-HEXANOL & 2-HEXENAL

When cut, pumpkins emit a vegetal aroma thanks to several compounds. The main aroma contributor is *cis*-3-hexen-1-ol, along with other six-carbon alcohols and aldehydes. Buttery-smelling diacetyl is also present.



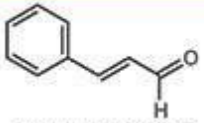
CANNED PUMPKIN



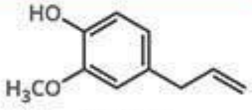
2-METHYLBUTANAL, COFFEE FURANONE & FURFURAL

Canned pumpkin emits almost none of the six-carbon odor compounds given off by a freshly carved pumpkin. Instead, its volatiles include burnt-smelling 2-methylbutanal, coffee furanone, and furfural.

PUMPKIN SPICE

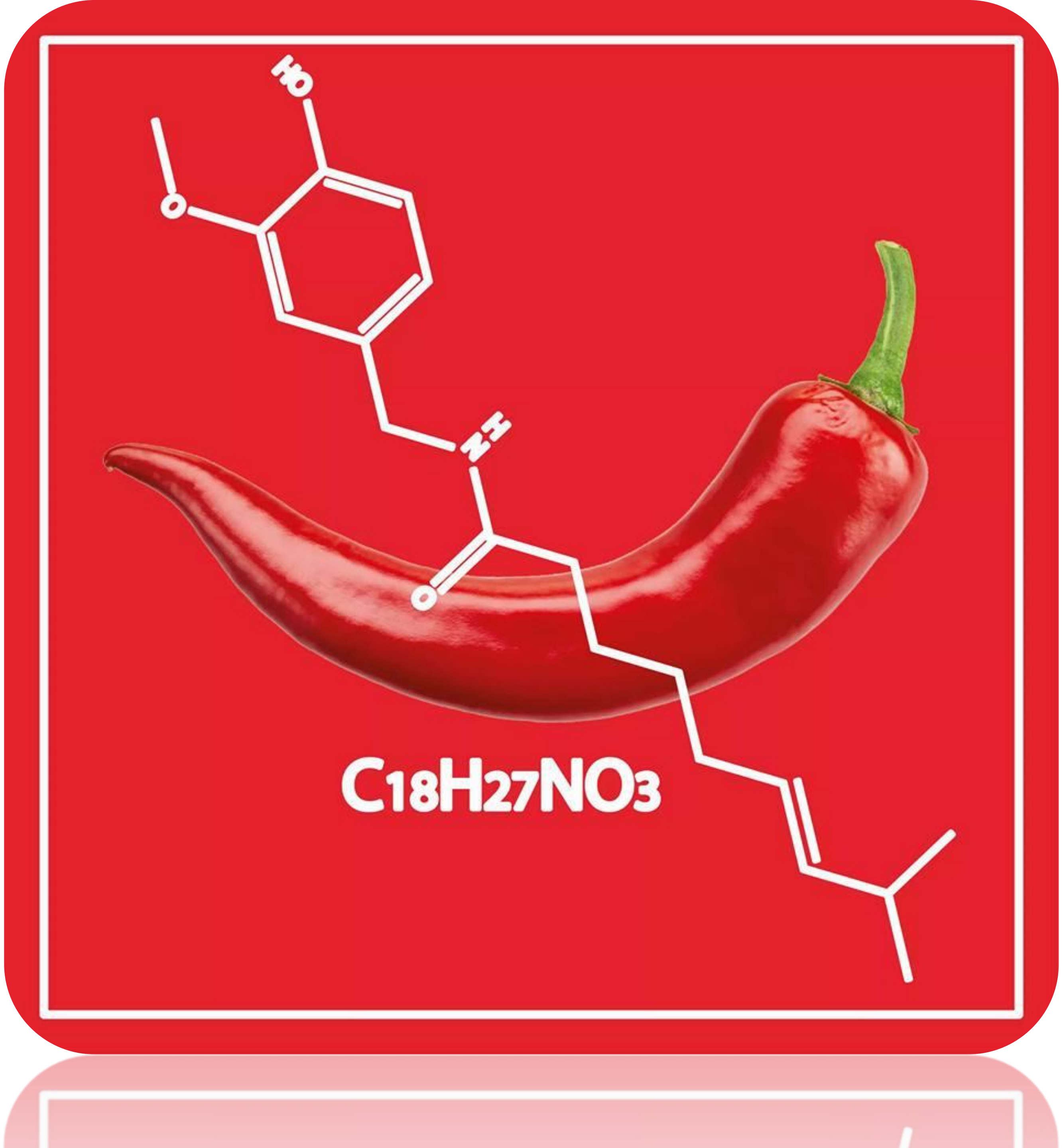


CINNAMALDEHYDE



EUGENOL

Pumpkin spice flavor has little to do with pumpkin and more to do with the spices added, including cinnamon (cinnamaldehyde), nutmeg, and clove (eugenol). Other compounds in the mix add caramelized notes.



HO
O
NH
O
C18H27NO3

FlavorDB: a database of flavor molecules

ABSTRACT

Flavor is an expression of olfactory and gustatory sensations experienced through a multitude of chemical processes triggered by molecules. Beyond their key role in defining taste and smell, flavor molecules also regulate metabolic processes with consequences to health. Such molecules present in natural sources have been an integral part of human history with limited success in attempts to create synthetic alternatives. Given their utility in various spheres of life such as food and fragrances, it is valuable to have a repository of flavor molecules, their natural sources, physicochemical properties, and sensory responses. FlavorDB (http://cosylab.iiitd.edu.in/flavordb) comprises of 25,595 flavor molecules representing an array of tastes and odors. Among these 2254 molecules are associated with 936 natural ingredients belonging to 34 categories. The dynamic, user-friendly interface of the resource facilitates exploration of flavor molecules for divergent applications: finding molecules matching a desired flavor or structure; exploring molecules of an ingredient; discovering novel food pairings; finding the molecular essence of food ingredients; associating chemical features with a flavor and more. Data-driven studies based on FlavorDB can pave the way for an improved understanding of flavor mechanisms.

FlavorDB

A resource to explore flavor molecules

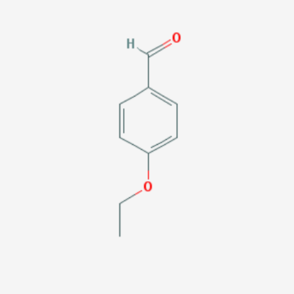
FlavorDB Summary

Flavor is an expression of olfactory and gustatory sensations experienced through a multitude of chemical processes triggered by molecules. Beyond their key role in defining taste and smell, flavor molecules also regulate metabolic processes with consequences to health. Such molecules present in natural sources have been an integral part of human history with limited success in attempts to create synthetic alternatives. Given their utility in various spheres of life such as food and fragrances, it is valuable to have a repository of flavor molecules, their natural sources, physicochemical properties, and sensory responses.

FlavorDB comprises of 25595 flavor molecules representing an array of tastes and odors. Among these 2254 molecules are associated with 936 natural ingredients belonging to 34 categories. The dynamic, user-friendly interface of the resource facilitates exploration of flavor molecules for divergent applications: finding molecules matching a desired flavor or structure; exploring molecules of an ingredient; discovering novel food pairings; finding the molecular essence of food ingredients; associating chemical features with a flavor and more. Data-driven studies based on FlavorDB can pave the way for an improved understanding of flavor mechanisms.

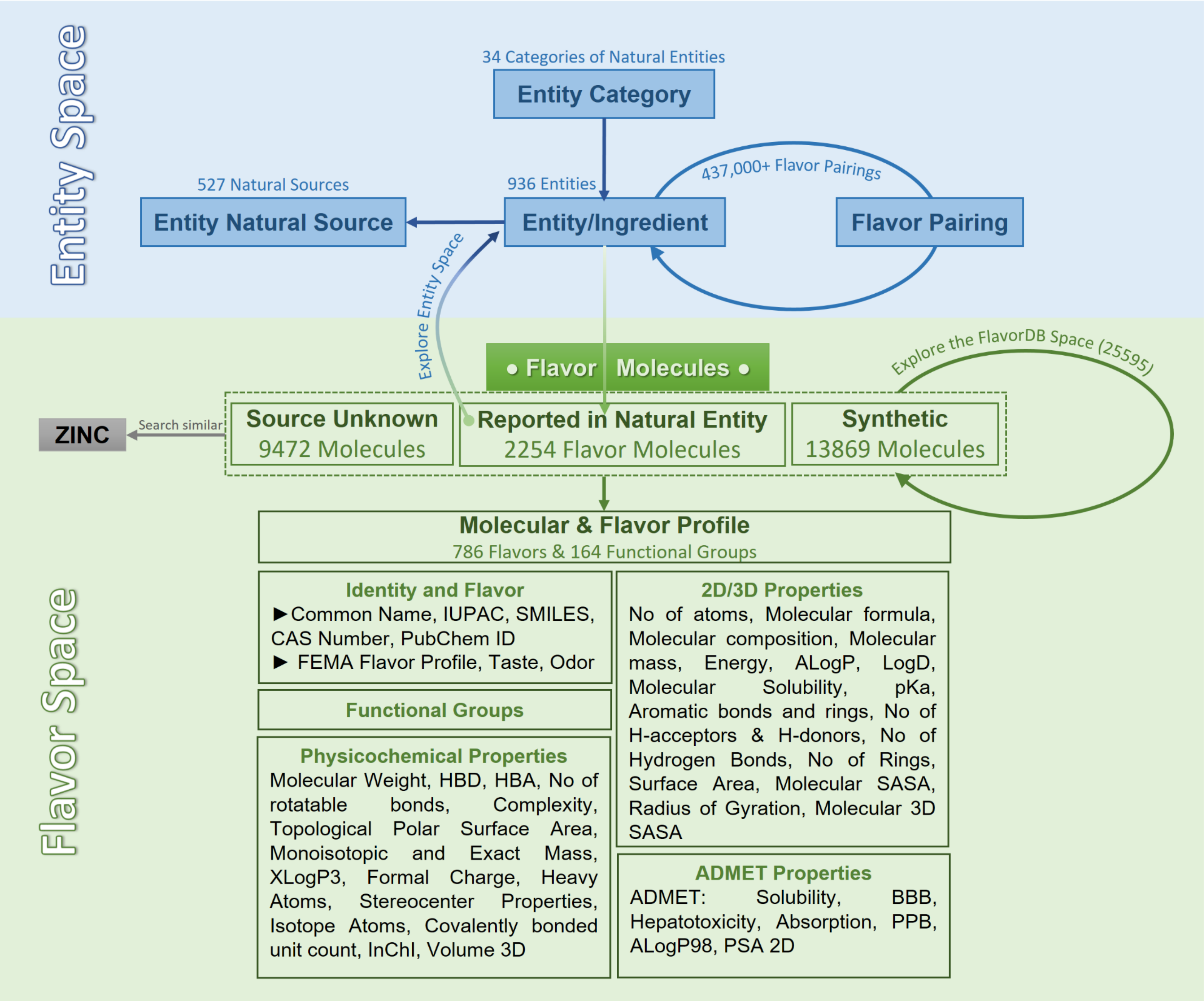
Neelansh Garg†, Apuroop Sethupathy†, Rudraksh Tuwani†, Rakhi NK†, Shubham Dokania†, Arvind Iyer†, Ayushi Gupta†, Shubhra Agrawal†, Navjot Singh†, Shubham Shukla†, Kriti Kathuria†, Rahul Badhwar, Rakesh Kanji, Anupam Jain, Avneet Kaur, Rashmi Nagpal, and Ganesh Bagler*, FlavorDB: A database of flavor molecules, Nucleic Acids Research, gkx957, (2017). †Equal contribution *Corresponding Author

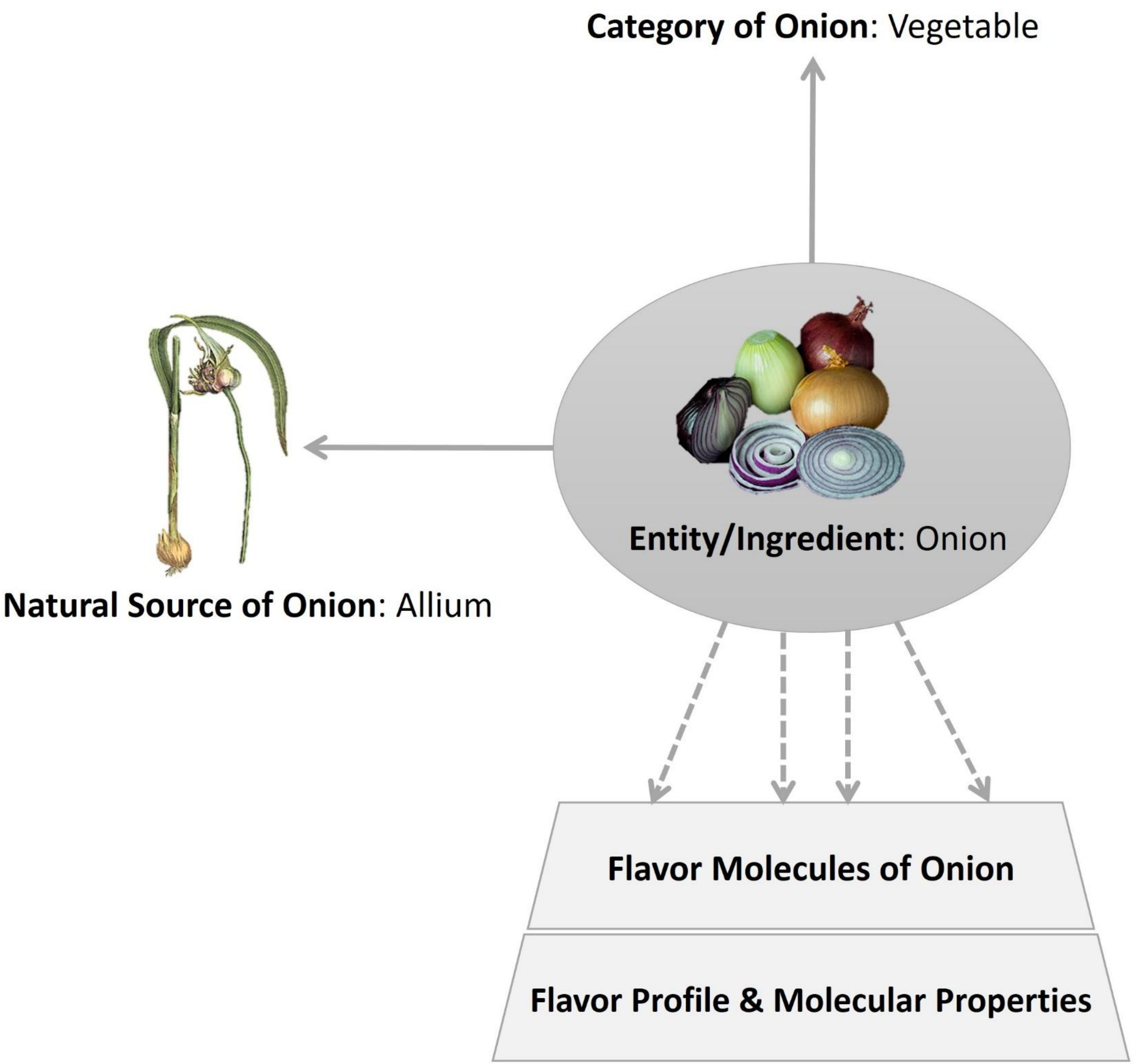
Molecule of the Day



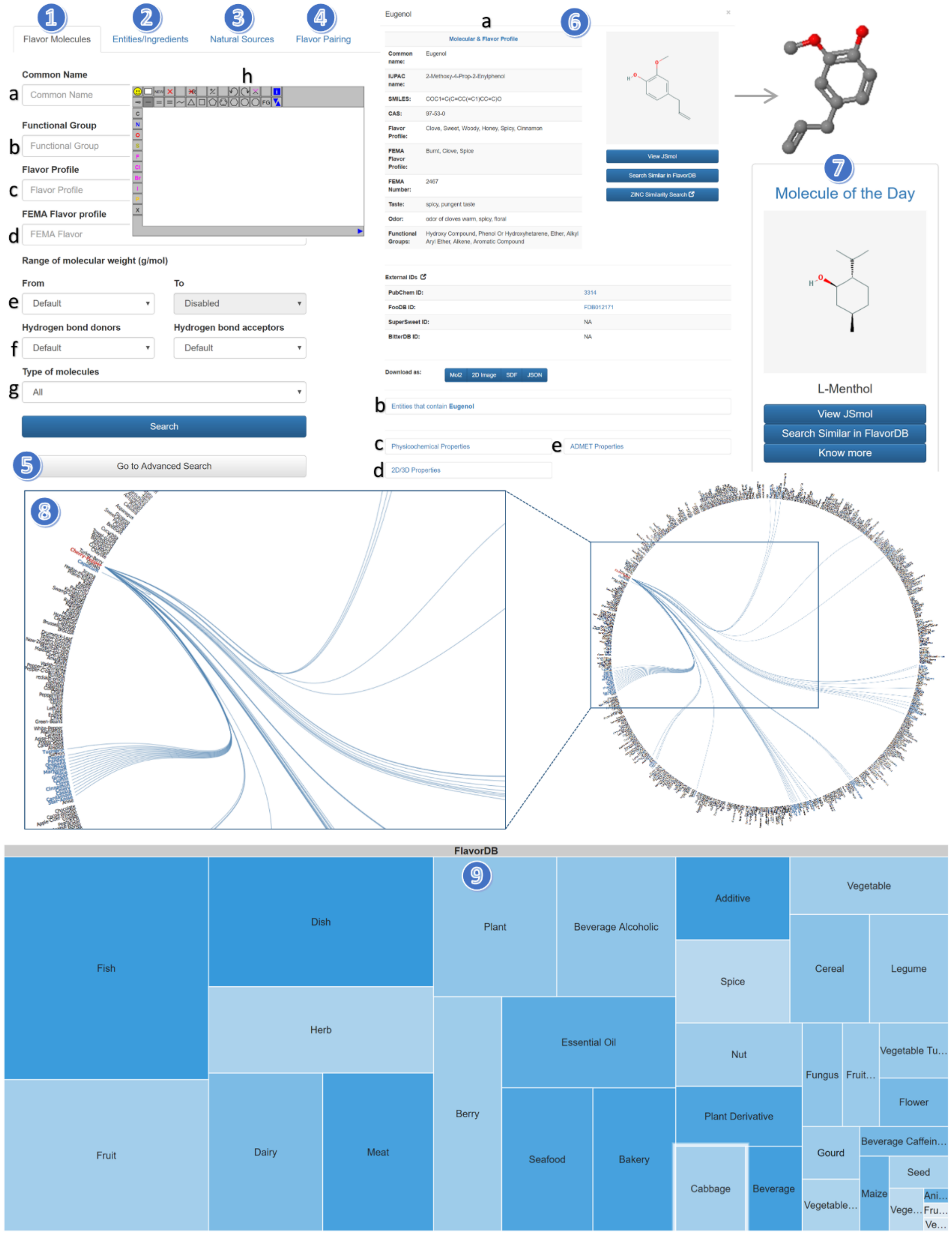
4-Ethoxybenzaldehyde

View JSmol
Search Similar in FlavorDB
Know more


Entity Space
34 Categories of Natural Entities
Entity Category
527 Natural Sources
Entity Natural Source
936 Entities
Entity/Ingredient
437,000+ Flavor Pairings
Flavor Pairing
Explore Entity Space
Flavor Space
● Flavor Molecules ●
Explore the FlavorDB Space (25595)
ZINC
Search similar
Source Unknown
9472 Molecules
Reported in Natural Entity
2254 Flavor Molecules
Synthetic
13869 Molecules
Molecular & Flavor Profile
786 Flavors & 164 Functional Groups
Identity and Flavor
► Common Name, IUPAC, SMILES, CAS Number, PubChem ID
► FEMA Flavor Profile, Taste, Odor
Functional Groups
Physicochemical Properties
Molecular Weight, HBD, HBA, No of rotatable bonds, Complexity, Topological Polar Surface Area, Monoisotopic and Exact Mass, XLogP3, Formal Charge, Heavy Atoms, Stereocenter Properties, Isotope Atoms, Covalently bonded unit count, InChI, Volume 3D
2D/3D Properties
No of atoms, Molecular formula, Molecular composition, Molecular mass, Energy, ALogP, LogD, Molecular Solubility, pKa, Aromatic bonds and rings, No of H-acceptors & H-donors, No of Hydrogen Bonds, No of Rings, Surface Area, Molecular SASA, Radius of Gyration, Molecular 3D SASA
ADMET Properties
ADMET: Solubility, BBB, Hepatotoxicity, Absorption, PPB, ALogP98, PSA 2D

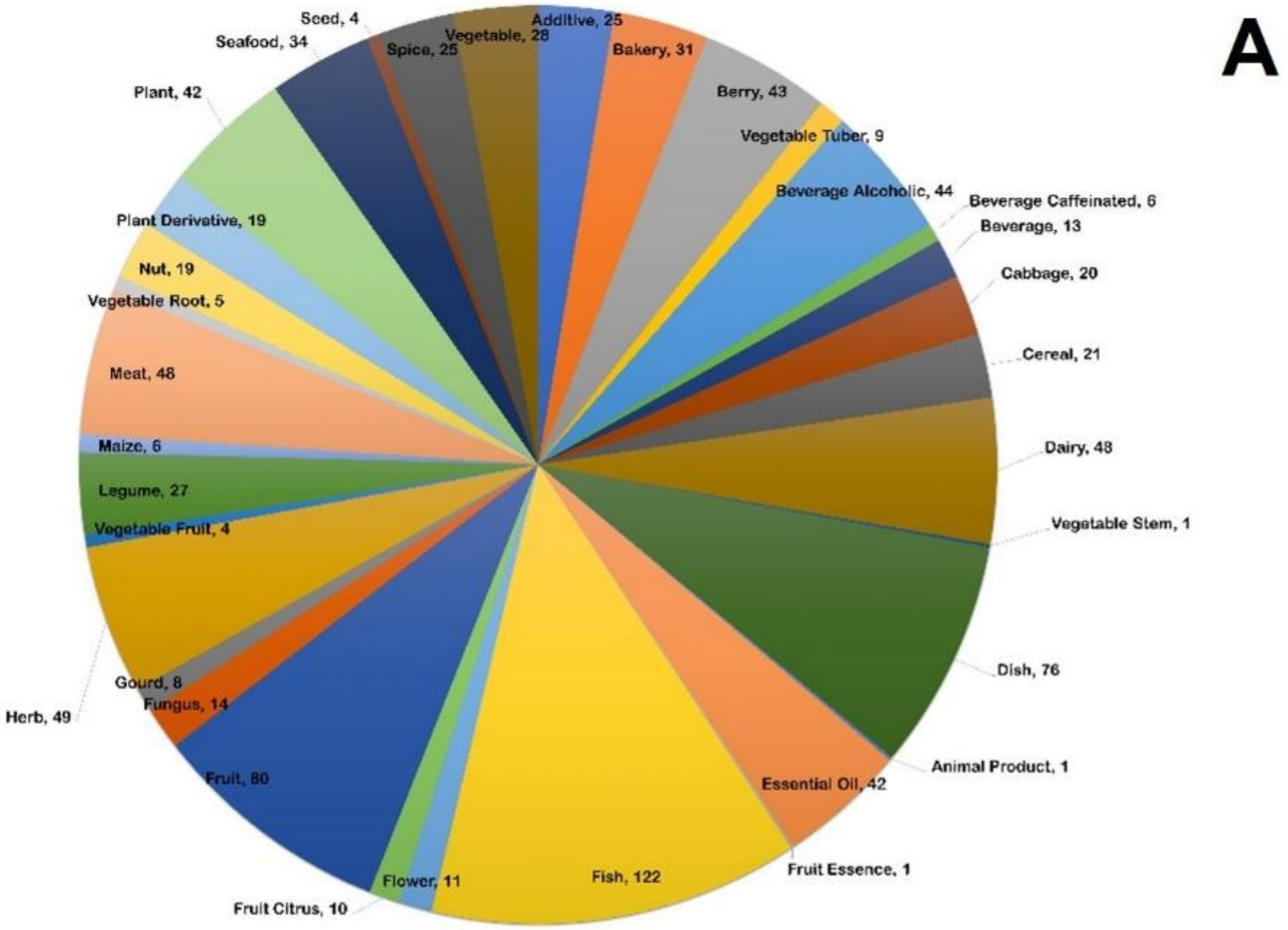


Category of Onion: Vegetable
Natural Source of Onion: Allium
Entity/Ingredient: Onion
Flavor Molecules of Onion
Flavor Profile & Molecular Properties

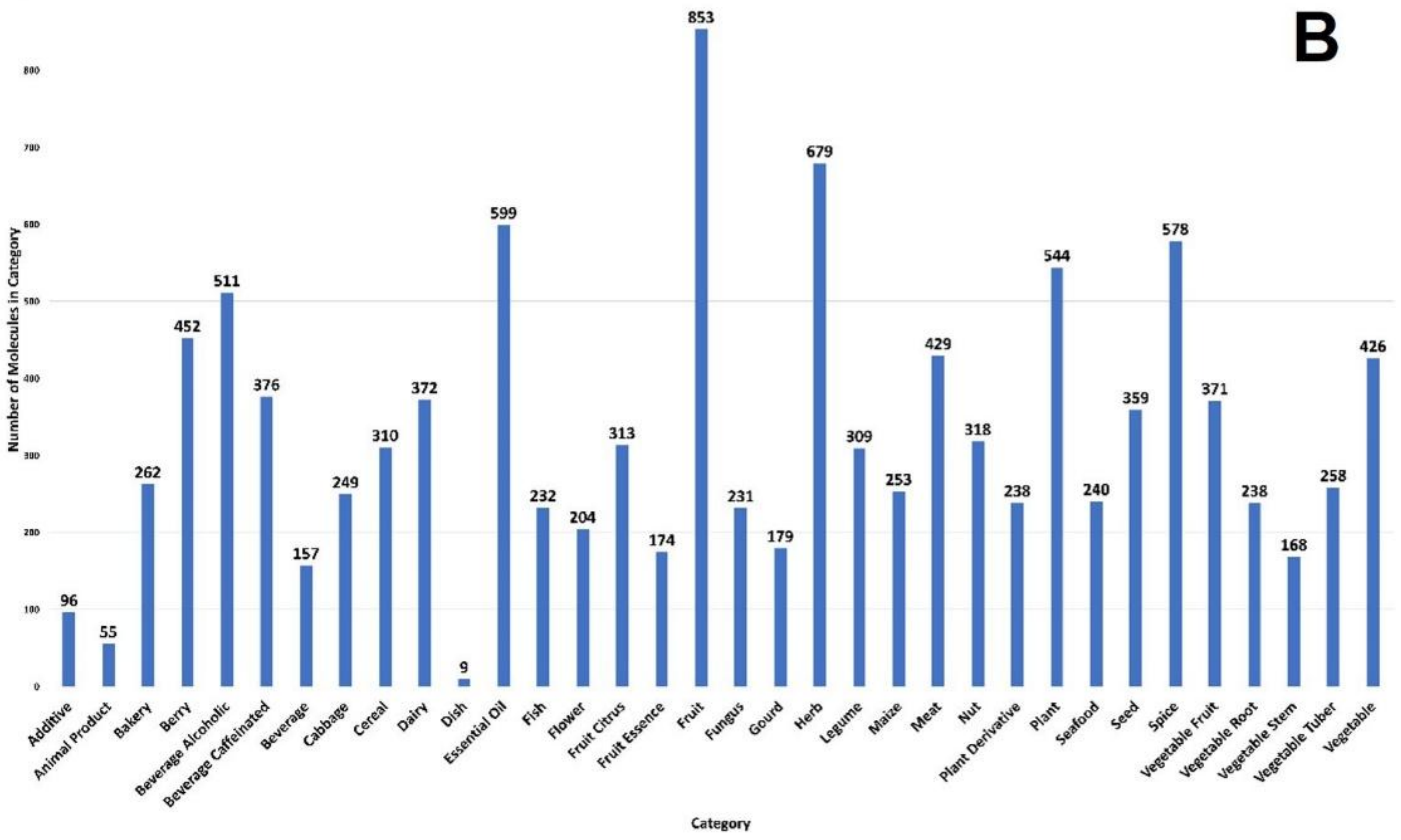


1
2
3
4
Flavor Molecules
Entities/Ingredients
Natural Sources
Flavor Pairing
Common Name
a
Common Name
h
Functional Group
b
Functional Group
Flavor Profile
c
Flavor Profile
FEMA Flavor profile
d
FEMA Flavor
Range of molecular weight (g/mol)
From
To
e
Default
Disabled
Hydrogen bond donors
Hydrogen bond acceptors
f
Default
Default
Type of molecules
g
All
Search
5
Go to Advanced Search
Eugenol
a
6
Molecular & Flavor Profile
View JSmol
Search Similar in FlavorDB
ZINC Similarity Search
External IDs
b
c
d
e
7
Molecule of the Day
L-Menthol
View JSmol
Search Similar in FlavorDB
Know more
8
FlavorDB
9
Fish
Dish
Plant
Beverage Alcoholic
Additive
Vegetable
Spice
Cereal
Legume
Herb
Essential Oil
Nut
Fungus
Fruit...
Vegetable Tu...
Berry
Flower
Plant Derivative
Fruit
Dairy
Meat
Seafood
Bakery
Gourd
Beverage Caffein...
Seed
Cabbage
Beverage
Maize
Vegetable...

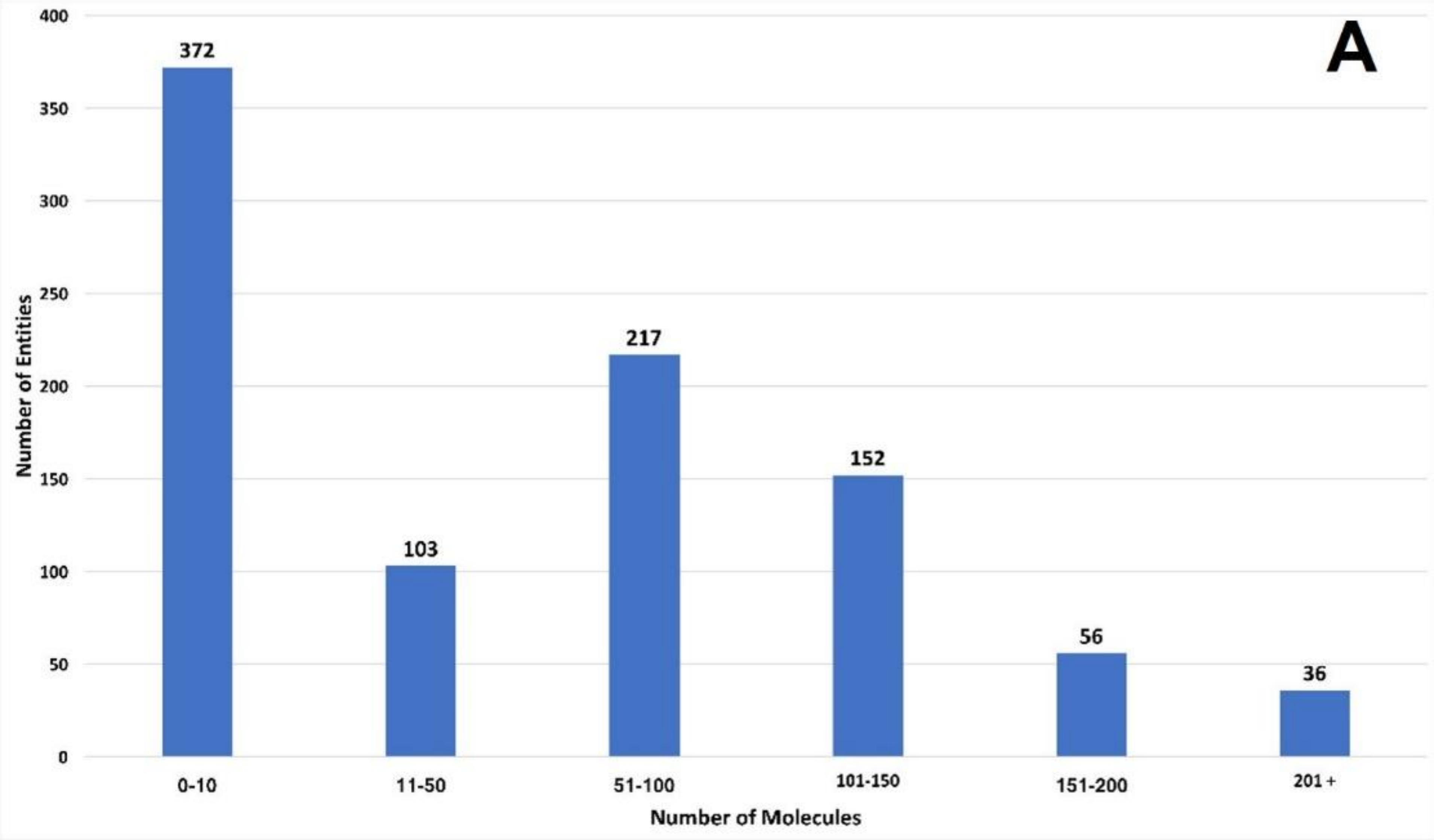
Number of natural ingredients per category



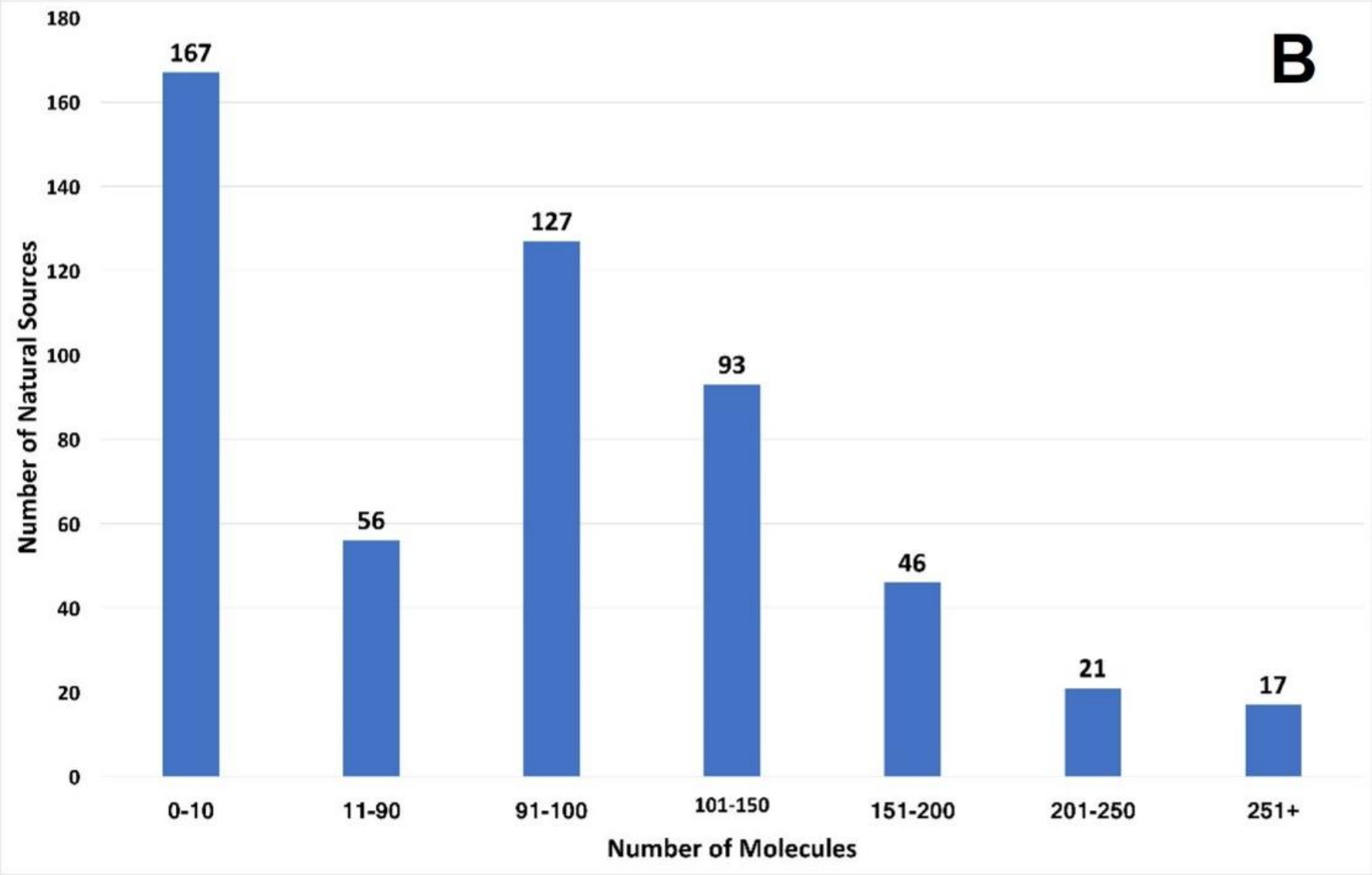
Number of unique molecules per category



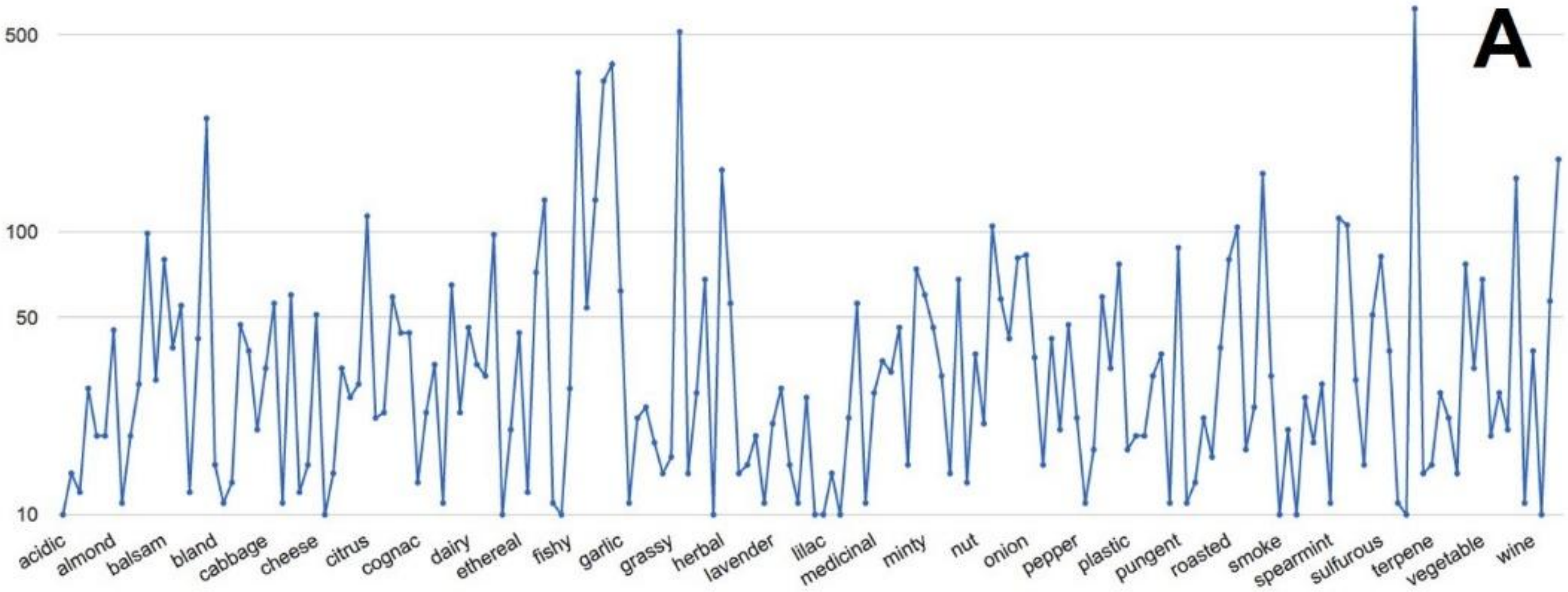
Number of unique molecules per entity



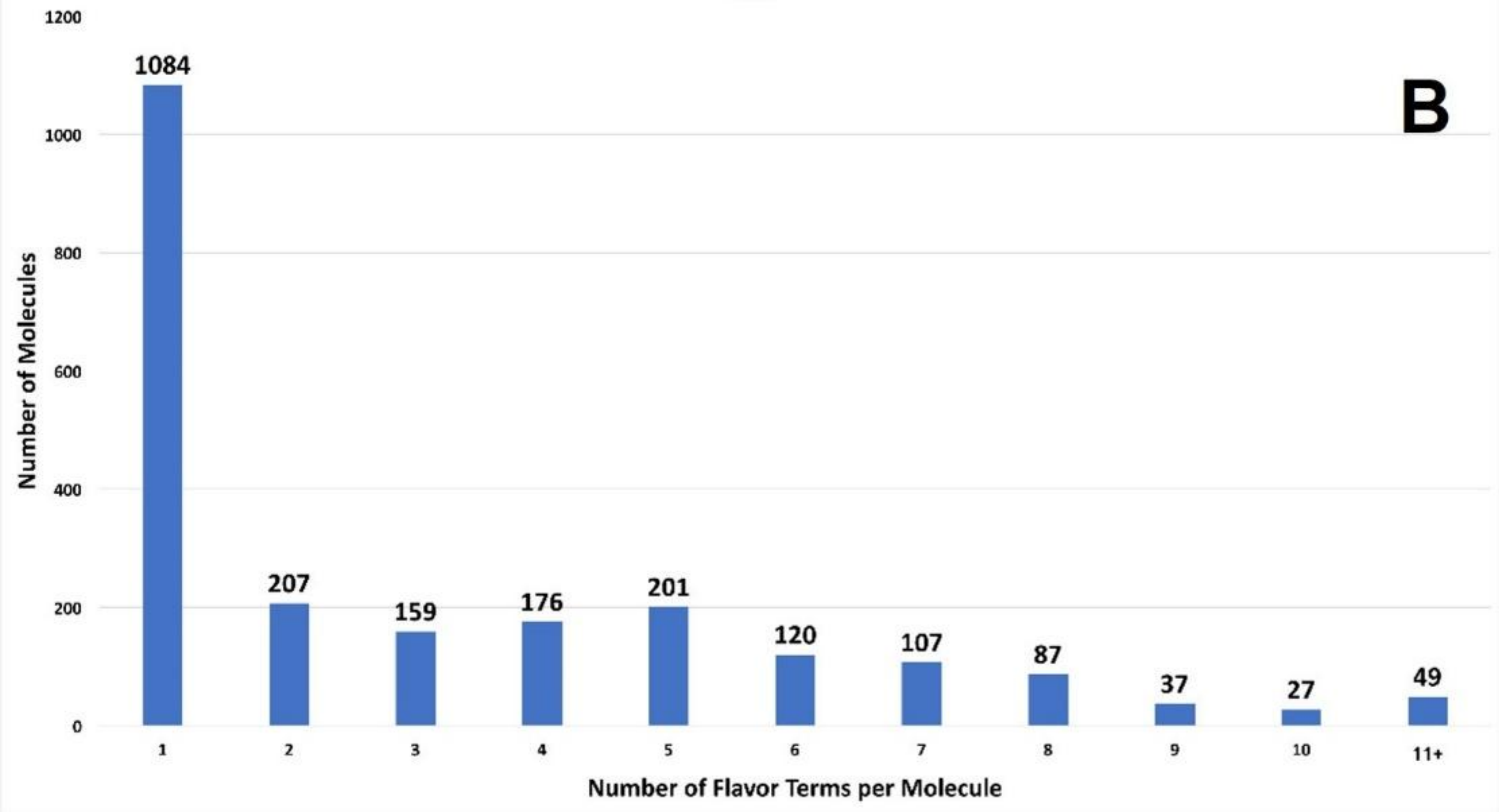
Number of unique molecules per Natural Source



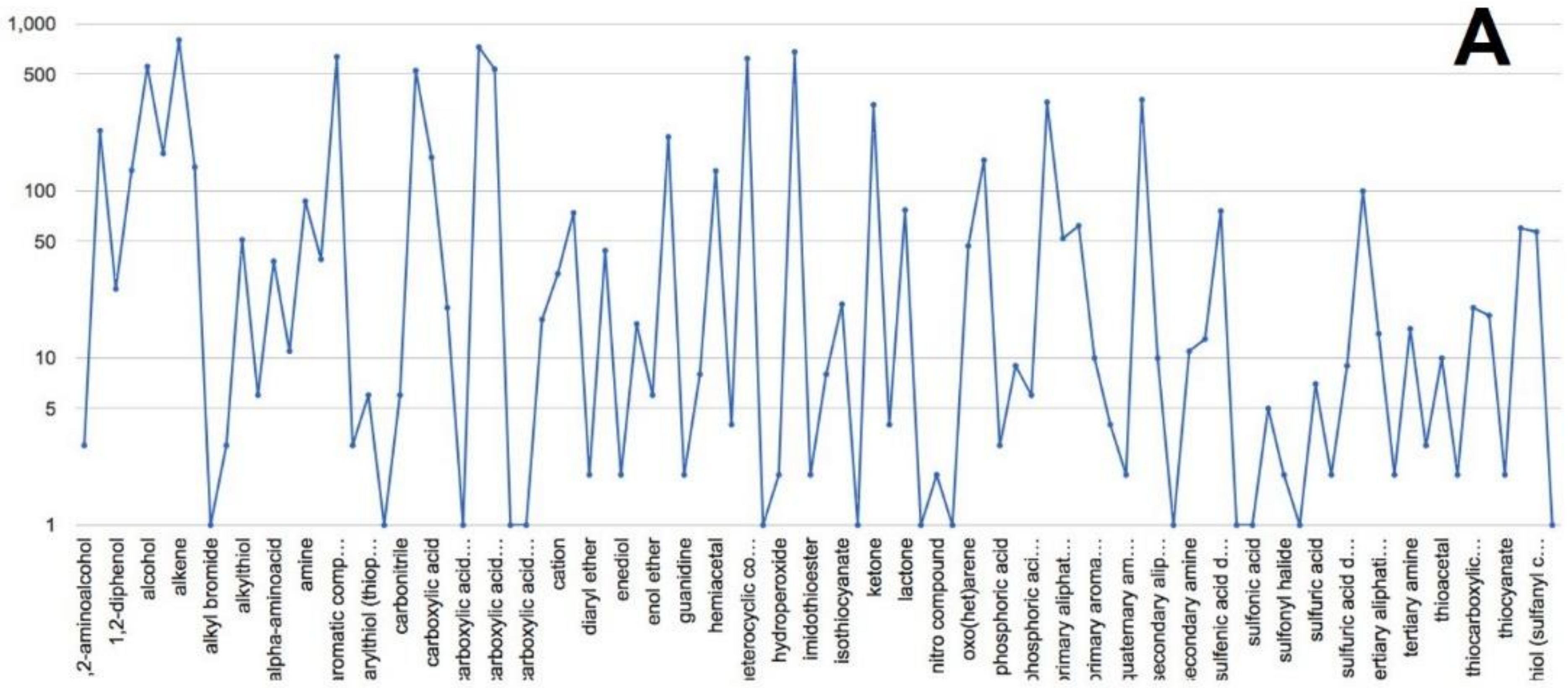
Number of molecules that have a specific flavor attribute



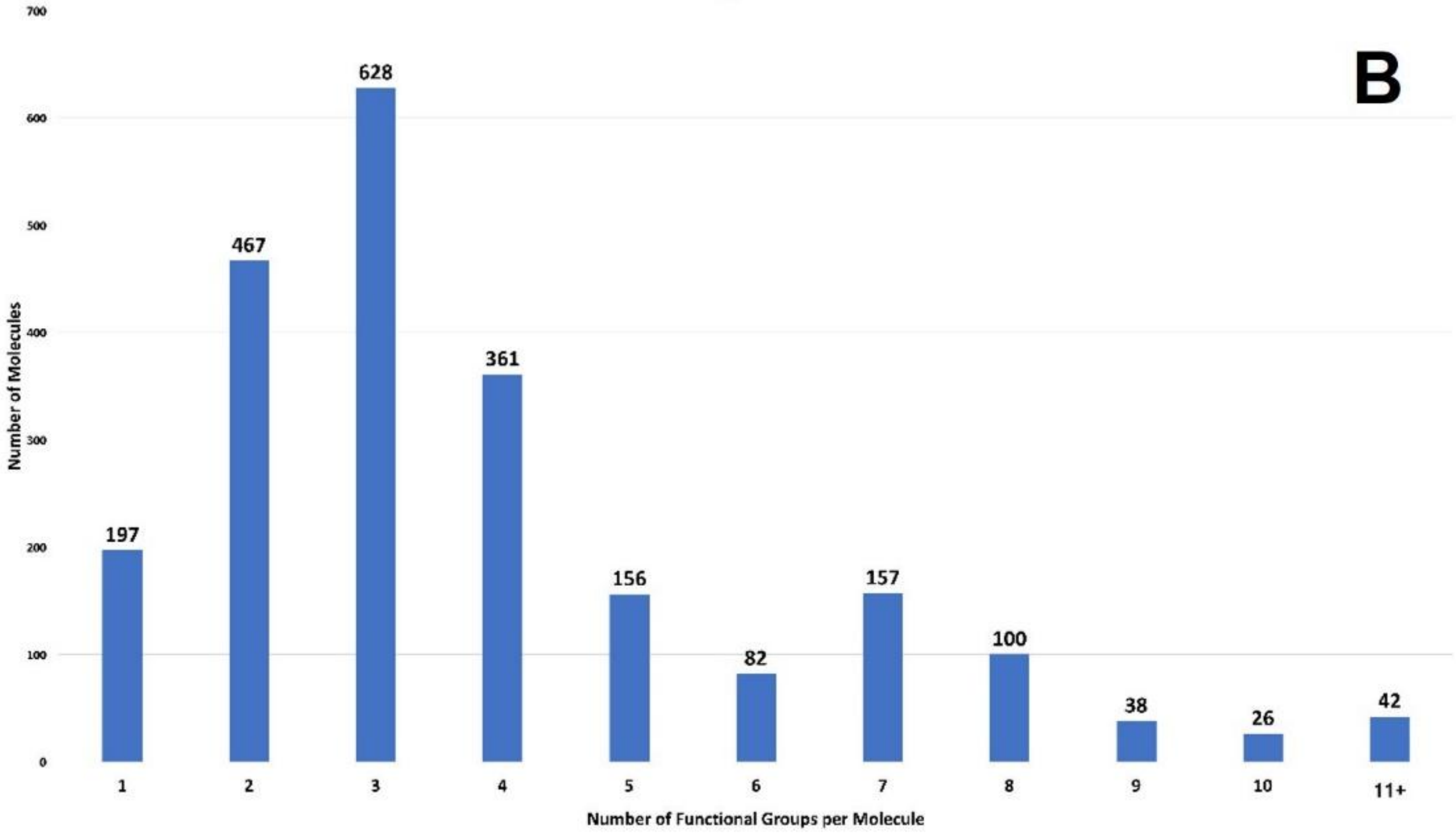
Number of flavor terms per molecules



Number of molecules associated to each functional group



Number of molecules having a specific ‘functional group’



Ideas

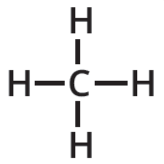
- **Improvised models of culinary evolution**.
  - What if the evolution happens by choosing ingredient pairs (as opposed to ingredients)?
  - What if the flavor plays a major role?

- FlavorDB/FlavorDB2 data analytics and visuals
- Chemical Elements (Fe/Ca/Zn etc.): Flavor-wise/Food-wise
- **Services**: A.Recipe.A.Day/An.Ingredient.A.Day *See: A.Word.A.Day*
- **Artificial Flavors**: Recreating natural flavors by combining and mixing flavor molecules. Data?
- **Fragrance/Perfumes**: The art of juxtaposing molecules. Data?
- A simple model of transformation of flavor molecules, when boiled/fried/roasted/etc.?

A BRIEF INTRODUCTION TO ORGANIC CHEMISTRY

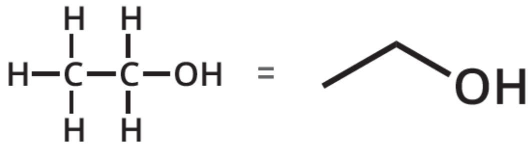
6	1	7	8	16	17
C	H	N	O	S	Cl
Carbon	Hydrogen	Nitrogen	Oxygen	Sulfur	Chlorine

Organic chemistry is the study of carbon-based compounds. Organic compounds usually contain primarily carbon and hydrogen, but we'll also see some containing the other elements shown here.



METHANE

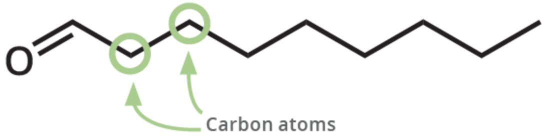
The chemical bonds in organic compounds are formed by the atoms sharing a pair of electrons with each other. Carbon can form four bonds to other atoms; oxygen usually forms two bonds, while hydrogen can only form one bond. Bonds are shown as lines; two lines between atoms indicates a double bond, or two shared pairs of electrons.



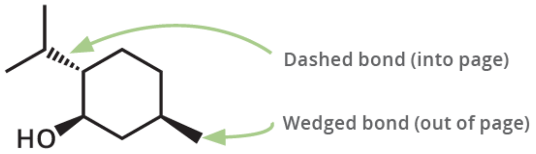
Displayed formula

Skeletal formula

Organic compounds can be drawn showing all their bonds and all their atoms, as on the left. However, for bigger molecules, this can end up looking pretty messy so we commonly use the skeletal formula to represent molecules.



The skeletal formulas show each carbon atom as a bend in the chain of the molecule. Hydrogen atoms attached to carbons aren't shown, to make the structure easier to interpret. Atoms other than carbon and hydrogen are shown.

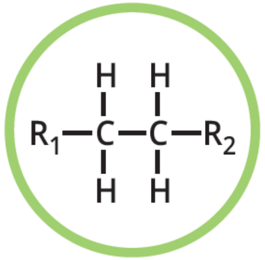


While chemical structures are shown in two dimensions on the page, obviously they are three dimensional in real life. In some cases, it is useful to indicate this in structures, so for this purpose we sometimes use dashed bonds, to show a bond going away from you and into the page, and wedged bonds, to show a bond coming toward you and off of the page.

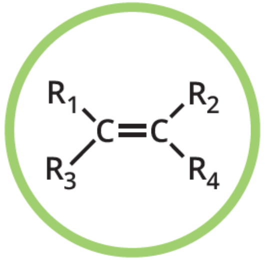
FUNCTIONAL GROUPS IN ORGANIC CHEMISTRY

Functional groups are groups of atoms in organic compounds that are responsible for the characteristic reactions and properties of those compounds. In many compounds in this book, you will see several of these groups in one molecule. The functional groups present in a molecule are usually reflected in its name, as indicated here.

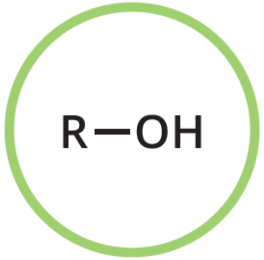
You may also see “R” used in some molecules—this represents a further part of the molecule that may be variable. If you see “X” used, it indicates a halogen atom (the halogens are the elements fluorine, chlorine, bromine and iodine). Some typical functional groups are shown here.



ALKANE
Naming: -ane
e.g., ethane

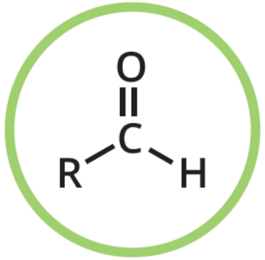


ALKENE
Naming: -ene
e.g., ethene

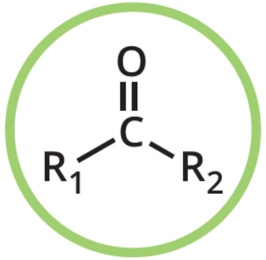


ALCOHOL
Naming: -ol
e.g., ethanol

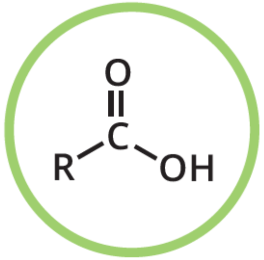
HALOALKANE
Naming: halo-
e.g., chloroethane



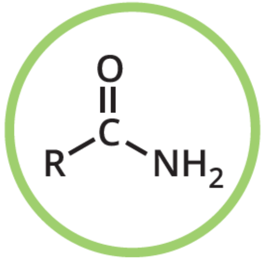
ALDEHYDE
Naming: -al
e.g., ethanal



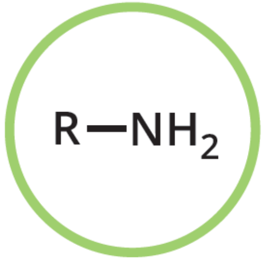
KETONE
Naming: -one
e.g., propanone



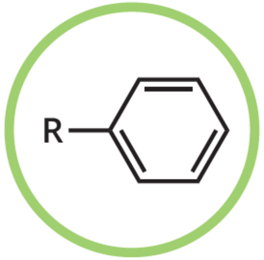
CARBOXYLIC ACID
Naming: -oic acid
e.g., ethanoic acid



AMIDE
Naming: -amide
e.g., ethanamide



AMINE
Naming: -amine
e.g., ethanamine



ARENE
Naming: -ylbenzene
e.g., ethylbenzene

WHY DOES SMOKING MEAT CHANGE ITS FLAVOR?

Smoking foods, be it ham, bacon, beef or fish, is a cooking method that dates back to a time before refrigeration, when the best way to preserve meats that would otherwise start to rot and spoil was to smoke them. Today, we smoke a variety of foods mainly for the enjoyment of the flavor, and there are a number of chemical compounds that contribute to this.

The process of smoking commonly involves exposing the food to smoke from burning wood. The compounds produced in the smoke are subject to a wide number of factors, such as the type of wood, the temperature and the amount of oxygen. Some compounds have been specifically highlighted as major contributors to the overall flavor and aroma of the meat. The compounds are generated by pyrolysis, which is the thermal decomposition of the organic compounds that make up the wood in the absence of an adequate supply of oxygen.

In general, a class of compounds called phenolic compounds are mostly credited with the specific flavors of smoked foods. One of these, guaiacol, is produced by the breakdown of lignin, a compound which makes up to a third of the dry mass of wood. It's largely responsible for the smoky *flavor* of smoked meats, and is also found in roasted coffee and whisky. It isn't responsible for the smoky *aroma* of smoked meat, however. Another compound, syringol, which is also produced from the pyrolysis of lignin, is the major compound which contributes to the smell of smoked food.

So next time you are enjoying a slice of chorizo, remember that a lot of chemical breakdown has taken place to make it so delicious.

THE MEAT SMOKING PROCESS

Before the meat is smoked, it is hung to allow its surface to dry and produce a pellicle. This is a coating of proteins on the surface that helps smoke adhere to the meat during the smoking process. In the absence of this coating, the meat may end up too dry from smoking. Food which is cold-smoked still needs to be cooked afterwards; hot-smoked food is usually edible after the process. Generally, smoke roasting is any process that roasts or bakes meat as well as smoking it.

68–86˚F

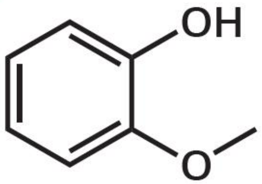
COLD SMOKING

126–176˚F

HOT SMOKING

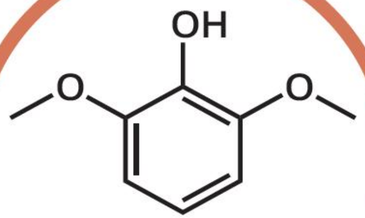
482˚F+

SMOKE ROASTING



GUAIACOL

largely responsible for smoky flavor



SYRINGOL

largely responsible for smoky aroma

WHY DOES ASPARAGUS MAKE YOUR PEE SMELL?

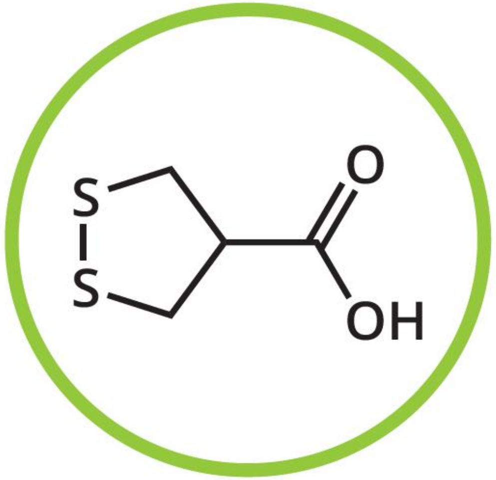
If you've ever eaten asparagus, you may have noticed that, soon after ingestion, it imparts a strange, somewhat unpleasant scent to your urine. But then again, you may not have noticed anything at all—and there's a scientific explanation for that too.

The chemicals that cause the effect are all suspected to stem from just one chemical compound: asparagusic acid (which is found naturally only in asparagus—hence its name). It has been pinpointed as the probable source of several organic compounds that have been shown to affect the odor of urine.

When we eat asparagus, the asparagusic acid molecules contained within the vegetable are broken down by digestion into a number of sulfur-containing organic compounds. In studies, a technique known as gas chromatography-mass spectrometry was used to analyze the "headspace" of urine produced after consumption of asparagus. The headspace is the gas space immediately above the liquid surface, which is occupied by light, volatile compounds in the liquid, and analysis of this is useful in identifying odor-causing compounds. The analysis of the post-asparagus urine showed the presence of several compounds that were not present, or present in negligible amounts, in normal urine. The primary compounds present, in quantities a thousand times greater than in normal urine, were methanethiol and dimethyl sulfide. The compounds dimethyl sulfoxide and dimethyl sulfone were also present and likely modified the aroma to give it a "sweet" edge.

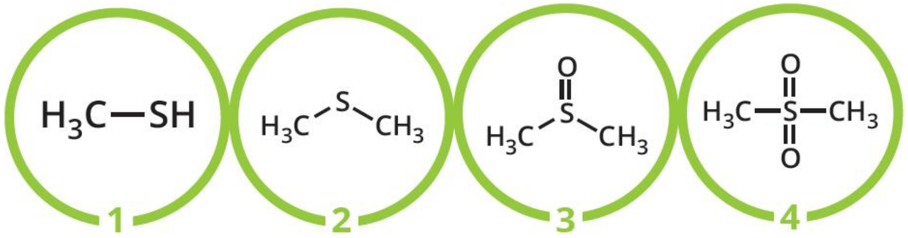
The human nose is very sensitive to thiol compounds—a concentration as low as a few parts per billion is enough for us to be able to detect them. To give you an idea of how bad thiol compounds can smell, they're also found in skunk spray. So, the increase in concentration of these compounds in urine after eating asparagus goes a long way toward explaining why the effect is so potent. The odor is detectable remarkably quickly after eating asparagus, within 15 to 30 minutes.

Interestingly, the ability to smell the aroma of "asparagus pee" is not universal. Research has shown that a proportion of people are unable to detect the change in smell, with one study finding 2 out of 31 people were unable to detect a difference in odor after eating asparagus. It was initially thought that everyone produced the odor, but only some could smell it; however, it has since been suggested, after a range of research, that not all people exhibit the effect after eating asparagus, with another study placing the figure of people who do produce "asparagus pee" at 43 percent.



ASPARAGUSIC ACID
(FOUND ONLY IN ASPARAGUS)

ASPARAGUSIC ACID BREAKDOWN PRODUCTS



1. METHANETHIOL
2. DIMETHYL SULFIDE
3. DIMETHYL SULFOXIDE
4. DIMETHYL SULFONE

ASPARAGUSIC ACID
↓
SULFUR-CONTAINING COMPOUNDS
↓
UNPLEASANT AROMA

CAN CARROTS HELP YOU SEE IN THE DARK?

Carrots can help improve your night vision is a commonly accepted claim, and one that's probably responsible for plenty of reluctant children's consumption of the vegetable at their parent's request. Whether there's any truth to this claim can be determined by examining the chemical products present, and what happens to them in our bodies.

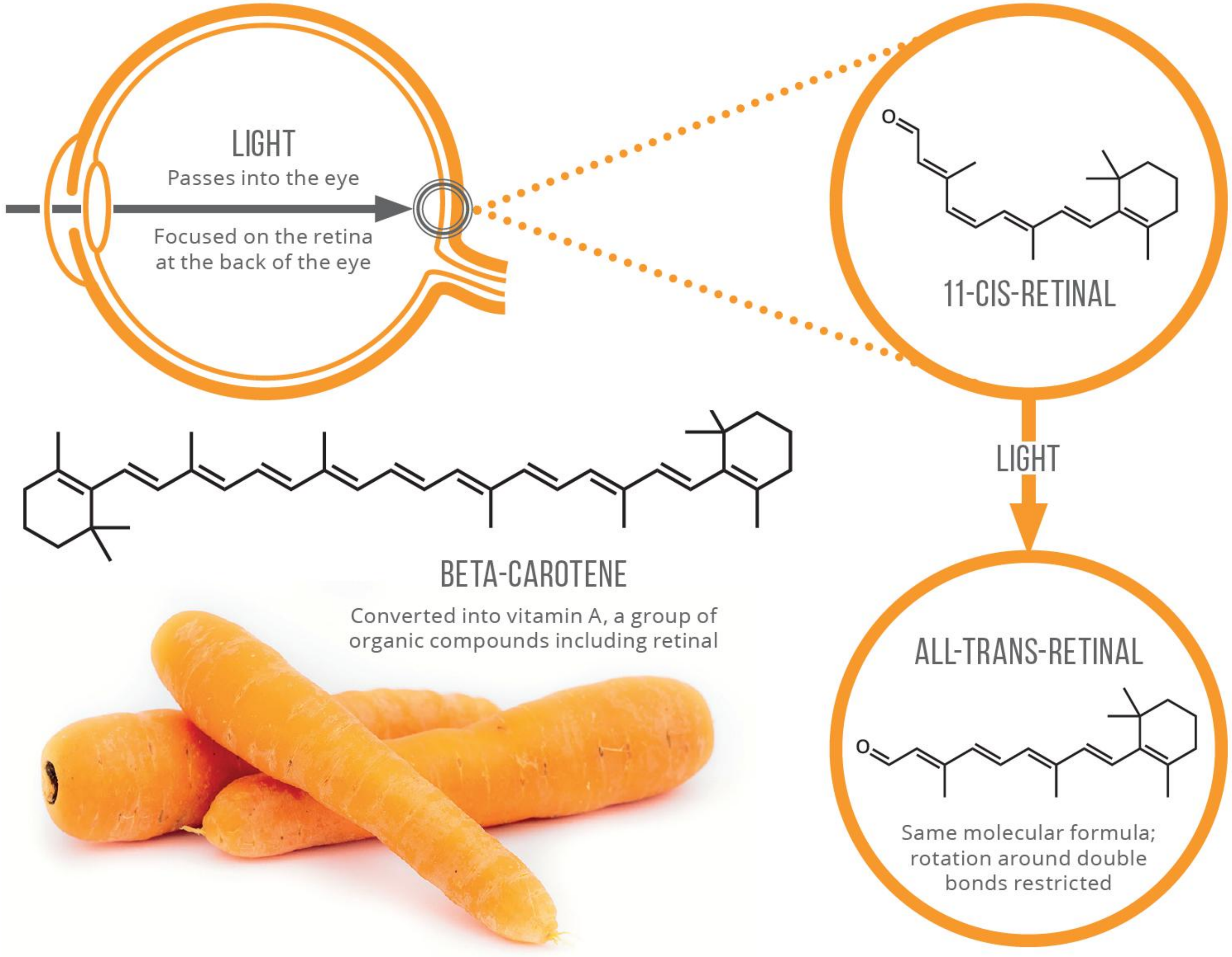
The orange color of carrots comes from a chemical they are particularly rich in, beta-carotene. It causes an orange coloration as the bonds in the molecules can absorb specific wavelengths of visible light, resulting in only certain wavelengths being reflected. When ingested, beta-carotene is converted into vitamin A in the liver.

Vitamin A is actually a small group of compounds with very similar chemical structures. They include retinal, the compound that forms the chemical basis for vision in humans and animals. It binds to proteins in the retina of the eye, and also strongly absorbs visible light. The absorption of a photon of light then causes the retinal molecule to convert from one isomer, or form of the compound, to another. When it does this, it can no longer fit into the protein binding site, and effectively shakes itself free. These movements are converted to electrical impulses in the nerve cells in the membrane to which the protein is attached, and these electrical impulses then travel to our brain, via the optic nerve, to be interpreted.

On the surface, then, the claim that carrots can help your vision would seem to have some pretty solid scientific grounding. Retinal is essential for vision, and the beta-carotene in carrots offers a compound from which our body can produce the retinal our eyes require. However, eating carrots will only improve your eyesight if you are vitamin A deficient. This is because the liver simply stores any excess beta-carotene until it's needed, and only a comparatively small amount of vitamin A is needed for vision. A carrot a day actually provides all the beta-carotene your body requires.

It turns out that the idea that carrots can improve your eyesight has its roots in a bit of British propaganda from World War II. After successfully using a new radar system to locate and shoot down German bombers, the British forces came up with the entirely false campaign stating that their pilots were eating carrots to improve their night vision in order to hide the existence of the radar system from the Germans. This campaign of disinformation was so successful that it took root and persists today.

There is one effect that excessive consumption of carrots can have. Eating too many can cause carotene levels in the body to build up to the extent that your skin can develop a yellowy-orange hue. There's even a medical term for this condition: carotenemia.


LIGHT
Passes into the eye
Focused on the retina
at the back of the eye
O
11-CIS-RETINAL
LIGHT
BETA-CAROTENE
Converted into vitamin A, a group of
organic compounds including retinal
ALL-TRANS-RETINAL
O
Same molecular formula;
rotation around double
bonds restricted

WHY ARE RAW KIDNEY BEANS POISONOUS?

Kidney beans are an essential ingredient in a good chili con carne. However, they also have a more sinister side, in that, unless they are cooked, they harbor a potent toxin that can lead to illness, or even death in extreme cases. Luckily, there are measures taken to ensure that the canned kidney beans bought in supermarkets are already safe for consumption, but this toxicity is still a very real risk with raw kidney beans.

The toxin responsible for the potentially poisonous nature of kidney beans is actually a protein, called phytohemagglutinin, often abbreviated to PHA. This protein is present in the beans because it helps protect them against pests and pathogens. In humans, however, PHA can cause duplication of cells (mitosis), affect cell membranes, and cause red blood cells to clump together.

PHA is actually found in many other types of beans, although in much lower concentrations than in red and white kidney beans. Its presence is usually measured in hemagglutinating units, hau. Raw, red kidney beans can contain up to 70,000 hau; by comparison, uncooked fava beans have only 5–10 percent of this amount.

Eating as few as four or five raw red kidney beans can be enough to initiate symptoms of poisoning, which include nausea, vomiting and diarrhea. Eating a large enough number could potentially be deadly, though recorded cases are rare. In most cases of poisoning, unless a large number of beans have been ingested, hospital treatment is not required and the symptoms subside after several hours.

Why is it, then, that we have nothing to fear from the canned kidney beans available in supermarkets? The reason is that these beans are specifically prepared in order to minimize the concentration of the toxin before they make it to the shelves. They will be soaked for a period of several hours and then boiled for thirty minutes. The heat breaks down the toxin, and makes the kidney beans safe to eat; compared to the high levels beforehand, cooked kidney beans only contain about 200–400 hau of PHA. Some of the instances of kidney bean poisoning have come from people using raw kidney beans and cooking them in a slow cooker, which doesn’t reach a high enough temperature to break down PHA. In fact, it can increase the concentration of the protein, so it’s important to ensure that, if you do cook with raw kidney beans, they are cooked through thoroughly.

HEMAGGLUTINATION UNITS (HAU)

70,000	200–400
UNCOOKED	COOKED

The protein, phytohemagglutinin, is responsible for the poisonous nature of raw kidney beans.

Canned kidney beans are safe to eat from the can, as they are specially treated before packaging:

SOAKED FOR SEVERAL HOURS & **BOILED** FOR THIRTY MINUTES.

HEMAGGLUTINATING UNIT CONTENT OF OTHER BEAN VARIETIES

CANNELLINI BEANS	FAVA BEANS
~30%	~5–10%

Percentages are for raw beans, compared to hemagglutinating units in raw kidney beans.

4–5 RAW KIDNEY BEANS

This quantity of raw beans is enough to induce the symptoms of poisoning within 3 hours, which include:

- NAUSEA
- VOMITING
- DIARRHEA
- ABDOMINAL PAIN

WHY DO ONIONS MAKE YOU CRY?

There are very few people who haven't been reduced to tears while chopping onions. Interestingly, however, the chemical compounds that cause this effect aren't present at all in an unchopped onion—so where do they come from?

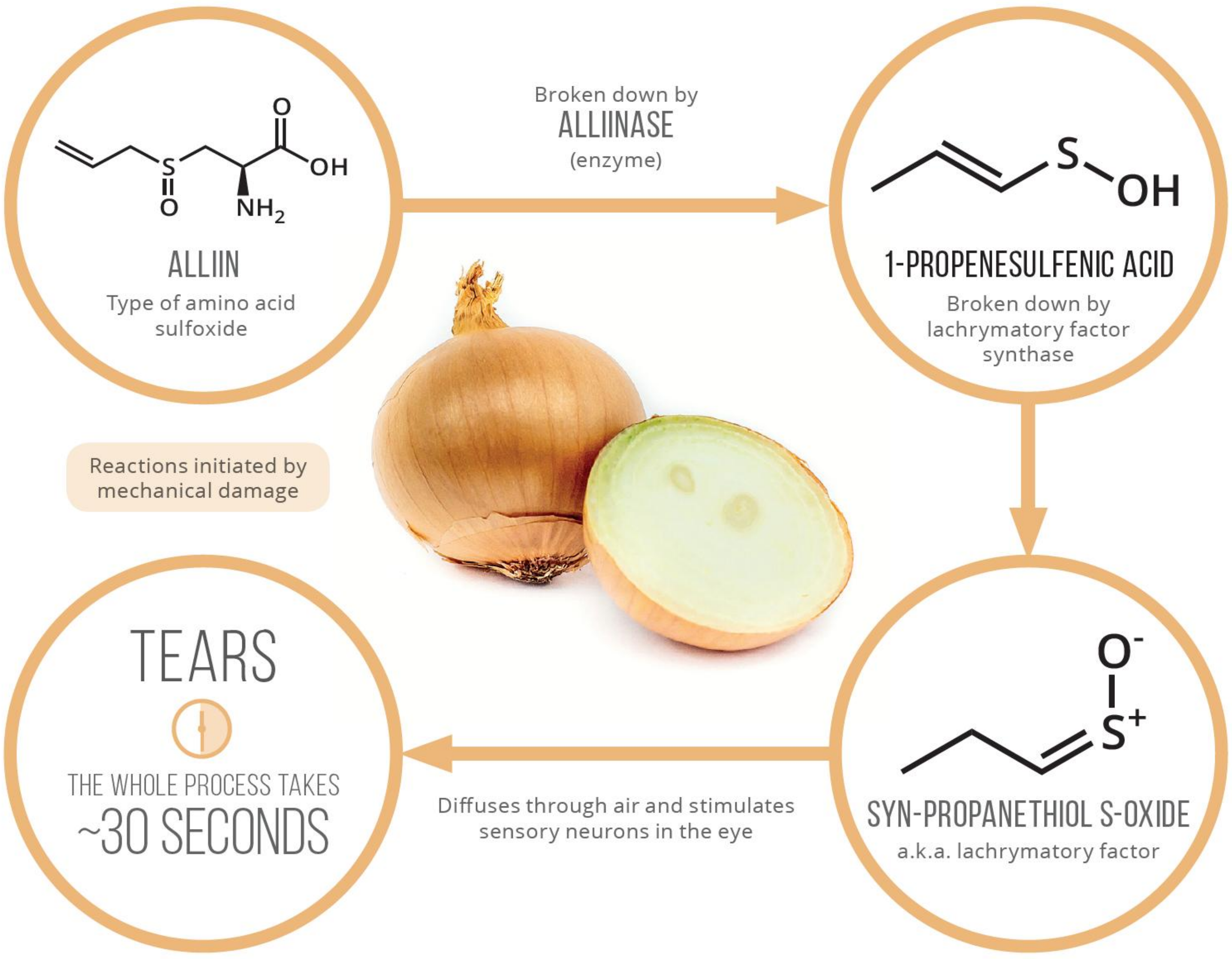
Onions are composed of many different chemicals, including a class of compounds called amino acid sulfoxides. When onions are sliced, the mechanical damage to the onion cells causes the release of a class of enzymes called alliinases from the cells of the onion. These enzymes can break down amino acid sulfoxides into another class of compounds, known as sulfenic acids.

One particular sulfenic acid that can be produced by this process is 1-propenesulfenic acid. This compound can be rapidly converted by another enzyme, called lachrymatory factor synthase, to give the compound syn-propanethial-S-oxide, and it's this compound that gives onions their tear-inducing abilities. Production of this gaseous chemical peaks around 30 seconds after mechanical damage to the onion takes place.

Syn-propanethial-S-oxide causes the production of tears because it can diffuse through the air to your eyes, where it can then stimulate sensory neurons, leading to stinging. The crying response to this is a result of your eye trying to flush the irritant out by producing tears from the tear glands.

There are numerous theories as to how this reaction to chopping onions can be prevented. Personally, I've found the effect dramatically decreases when wearing contact lenses; this is because the lenses sit in front of the cornea, the area which has the highest density of nerve endings in your eye, therefore preventing the chemical coming into contact with them. However, this isn't an option for those who don't wear contact lenses, so what other options are available?

Aside from wearing goggles while chopping onions (fine if you're not averse to looking slightly ridiculous in the comfort of your own home), another suggestion involves putting onions in the fridge, or even the freezer, for 15 minutes prior to chopping. Though this might sound a little odd, scientifically it makes sense: the reactions leading to the production of syn-propanethial-S-oxide will take place more slowly at a lower temperature, and so you can get the onion chopped and into the pan before it can seek its revenge.


Broken down by
ALLIINASE
(enzyme)
ALLIIN
Type of amino acid sulfoxide
1-PROPENESULFENIC ACID
Broken down by lachrymatory factor synthase
Reactions initiated by mechanical damage
SYN-PROPANETHIOL S-OXIDE
a.k.a. lachrymatory factor
Diffuses through air and stimulates sensory neurons in the eye
TEARS
THE WHOLE PROCESS TAKES
~30 SECONDS

WHY CAN NUTMEG ACT AS A HALLUCINOGEN?

When you think of hallucinogens, you probably wouldn't expect to find one lurking, unbeknownst to you, on your kitchen spice rack. However, the hallucinogenic properties of nutmeg have been known for some time—historical records as far back as the sixteenth and seventeenth centuries comment on its narcotic effects. So, what are the chemical compounds that cause this?

Several compounds have been implicated in the hallucinogenic effect of nutmeg, the main one being myristicin, which accounts for approximately 1.3 percent of raw nutmeg. It has been suggested in research that the effects of nutmeg could be due to the breakdown of myristicin in the liver into MMDA, a drug of the amphetamine class and known psychedelic. However, while this transformation has been observed in the livers of rats, there has been no evidence of such a transformation occurring in humans.

Interestingly, when a significant amount of pure myristicin was given to a group of subjects (twice the amount present in 20 grams of nutmeg), while six out of ten showed some effects, they were much milder than expected in comparison to the effects of nutmeg. This suggests that the presence of other compounds in nutmeg must also be important in inducing the full "nutmeg effect." Compounds that are suspected of contributing to the effect are elemicin and safrole.

Before you reach for an experimental spoonful of nutmeg, it's worth noting the effects it can induce. 1–2 milligrams of nutmeg per kilogram (2.2 pounds) of body weight can induce effects in the central nervous system (myristicin inhibits nerve impulses responsible for involuntary movement of muscles in certain systems in the body, such as the gastrointestinal tract and lungs), and anecdotal records state a tablespoon is enough to bring on other effects including nausea, vomiting, flushing, elevated heart rate, euphoria, hallucinations and dry mouth; not a particularly cheery band of side effects.

It doesn't really get much better—as well as some of the effects being less than pleasant, they can last for several days, with some reporting symptoms such as vision, balance and concentration problems lasting for over a week. In all, it's probably best that the nutmeg stays confined to your kitchen spice rack.

1 TABLESPOON

is enough to induce unpleasant symptoms

SYMPTOMS

NAUSEA

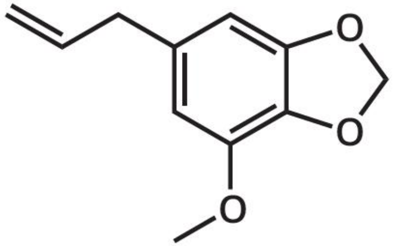
HALLUCINATIONS

RAISED HEART RATE

Other reported effects of nutmeg ingestion include vomiting, euphoria, flushing and a dry mouth.

DURATION EFFECTS PERSIST FOR 24–36 HOURS AFTER INGESTION

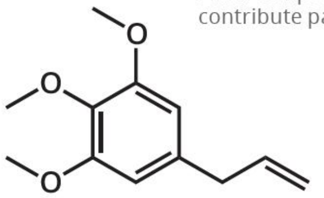
Anecdotal evidence suggest that after-effects of excessive nutmeg ingestion can, in some cases, be felt up to a week after ingestion.



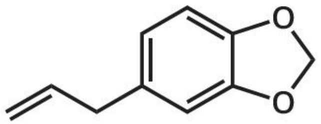
MYRISTICIN

main hallucinogenic compound present in nutmeg

Other compounds in nutmeg are also thought to contribute partially to the hallucinogenic effect



ELEMICIN



SAFROLE

WHY DO LEMONS HELP PREVENT SCURVY?

Lemons contain a number of acids; the major acidic compound, citric acid, likely needs no introduction, and even has its own E number (E330). There are, though, a couple of other acids found in a lemon's chemical structure that make important contributions. One of them is the reason why lemons are recommended as a way of warding off a specific disease, scurvy.

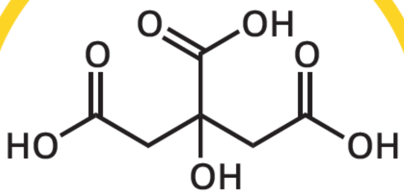
Citric acid is the main contributor to the lemon's sour taste. Malic acid is present in around 5 percent of the concentration of citric acid. It, too, has its own E number (E296), and is also found in apples and cherries, where it is responsible for aspects of their flavor.

Another acid present in lemons, and one with which citric acid is occasionally confused, is ascorbic acid, or vitamin C. The vitamin C levels in a lemon, at around 50 milligrams per 100 grams, are on par with those of an orange, and significantly higher than those in a lime (~29mg/100g). This last fact in particular is one that the British Navy discovered a little too late, much to their detriment in the early 1900s.

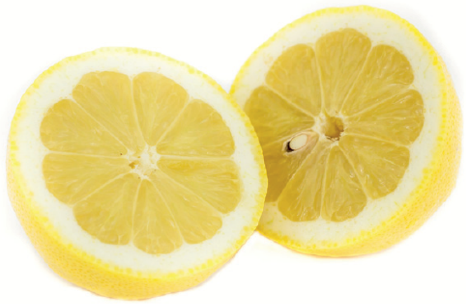
Vitamin C is required by the body to produce collagen, the main protein of connective tissues in animals. Scurvy is a disease caused by a lack of vitamin C, the symptoms of which include spots, bleeding gums, loss of teeth, jaundice, fatigue, joint pain, fever and eventual death. The disease was a major problem for seafarers, who would spend months at sea, and without a supply of fresh citrus fruit to supplement their vitamin C levels often succumbed to scurvy. By the mid-1700s, physicians had, however, discovered that citrus fruits were an effective cure for the disease, and in the late 1700s all Royal Navy ships were required to serve lemon juice in rations.

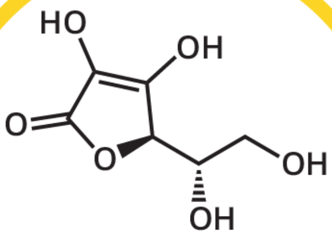
Despite this recommendation, a lack of awareness of vitamin C, and the differing vitamin C content of lemons and limes, meant scurvy again became an issue in the early 1900s. The Royal Navy began to start using lime juice instead of lemon, as they could source these from within the British colonies. They did so under the assumption that the acidity of lemons was what warded off scurvy, and as limes were more acidic it followed that they would be equally effective. This had occasionally dire consequences, with several Arctic expeditions succumbing to scurvy due to the failure of lime juice to provide enough vitamin C.

The confusion this caused was not fully resolved until the eventual isolation and discovery of vitamin C by the Hungarian Albert Szent-Györgyi in 1932. Vitamin C was actually named after its scurvy-preventing abilities—the name, “ascorbic acid,” comes from “antiscorbutic,” a term used to refer to substances preventing scurvy.



CITRIC ACID
Found in all citrus fruits





ASCORBIC ACID
a.k.a. vitamin C, antiscorbutic

SCURVY THE SYMPTOMS
After 3 months of vitamin C shortage

- FATIGUE
- JOINT PAIN
- RED-BLUE SPOTS
- BLEEDING GUMS
- SHORTNESS OF BREATH
- JAUNDICE

A TIMELINE OF SCURVY BETWEEN 1500–1800, IT'S ESTIMATED SCURVY KILLED 2 MILLION SAILORS

1500 (BC)	1499	1520	1747–62	1795	1932
First known written record of scurvy	Vasco da Gama loses 116 of a crew of 170, many to scurvy	Ferdinand Magellan loses 208 of a crew of 230, mainly to scurvy	James Lind trials show lemon juice prevents scurvy	British Navy makes use of lemon juice mandatory	Vitamin C linked with scurvy prevention

DO BANANAS HELP OTHER FRUIT RIPEN QUICKER?

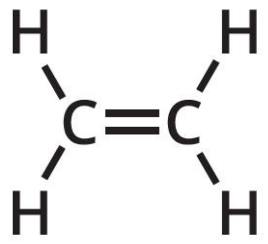
Bananas are grown in 107 countries, and although at one time they may have been considered exotic, they're now one of the most popular fruits worldwide. Picked green from the trees, they slowly ripen to a yellow color—but common advice is not to keep them in the fridge, otherwise their skin turns brown, or even black. This is due to the enzymatic browning reactions of the type we discussed when considering avocados. Leading on from that, a tactic commonly suggested when wanting to ripen avocados quicker is to put them in a plastic bag with a banana.

This may seem like a bit of an odd suggestion, but by doing this you're actually taking advantage of a particular chemical produced by bananas. The chemical in question is ethene, a deceptively simple-looking compound which functions as a ripening hormone in fruits. It works by "switching off" particular genes in the fruit when it is produced, which eventually leads to other genes, responsible for making enzymes which help the ripening process, being "switched on." The ethene produced by bananas can quite easily stimulate this process in other fruits, too, hence the plastic bag suggestion.

This is a process that we use to our advantage. If bananas were picked when already yellow, they'd most likely be brown and beginning to rot by the time they reach our supermarket shelves. Therefore, they are picked from plantations when they are still green and unripe, and transported in this condition. To ensure that they don't over-ripen in transit, other chemical gases can be used to slow the ripening process. This is usually accomplished by the use of 1-methylcyclopropene, which is capable of blocking the effects of ethene on the fruit, slowing its ripening.

Once the fruits have been shipped, they're probably still not ripe. In these cases, artificial ripening can be used. Taking advantage of the effect of ethene on accelerating the ripening process, the fruit can be gassed with ethene, and over the course of a day or two will approach full ripeness.

Ethene has one other strange effect—it can also affect some flowering plants, so leaving a banana in the proximity of a flowering plant could make the blooms appear slightly quicker.



ETHENE

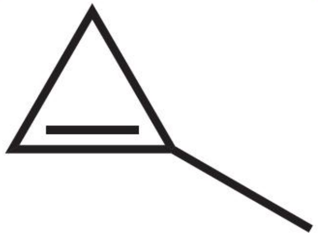
ripening hormone

THE ENZYMES INVOLVED IN FRUIT RIPENING

PECTINASE
Breaks down plant cell walls—softening the fruit's flesh.

AMYLASE
Breaks down carbohydrates, forming the sugars that make fruit taste sweet.

HYDROLASE
Breaks down chlorophyll, causing the change in coloration associated with ripening.



1-METHYLCYCLOPROPENE

inhibits ethene's action

The Underlying Chemistry

- Why Does Smoking **Meat** Change Its Flavor? [flavor]
- Why Does **Asparagus** Make Your Pee Smell? [aroma]
- Can **Carrots** Help You See in the Dark? [color]
- Why Are **Raw Kidney Beans** Poisonous? [poison]
- Why do **onions** make you cry? [sensation]
- Why Can **Nutmeg** Act as a Hallucinogen? [mind]
- Why Do **Lemons** Help Prevent Scurvy? [health]
- Do **Bananas** Help Other Fruit Ripen Quicker? [transformation]