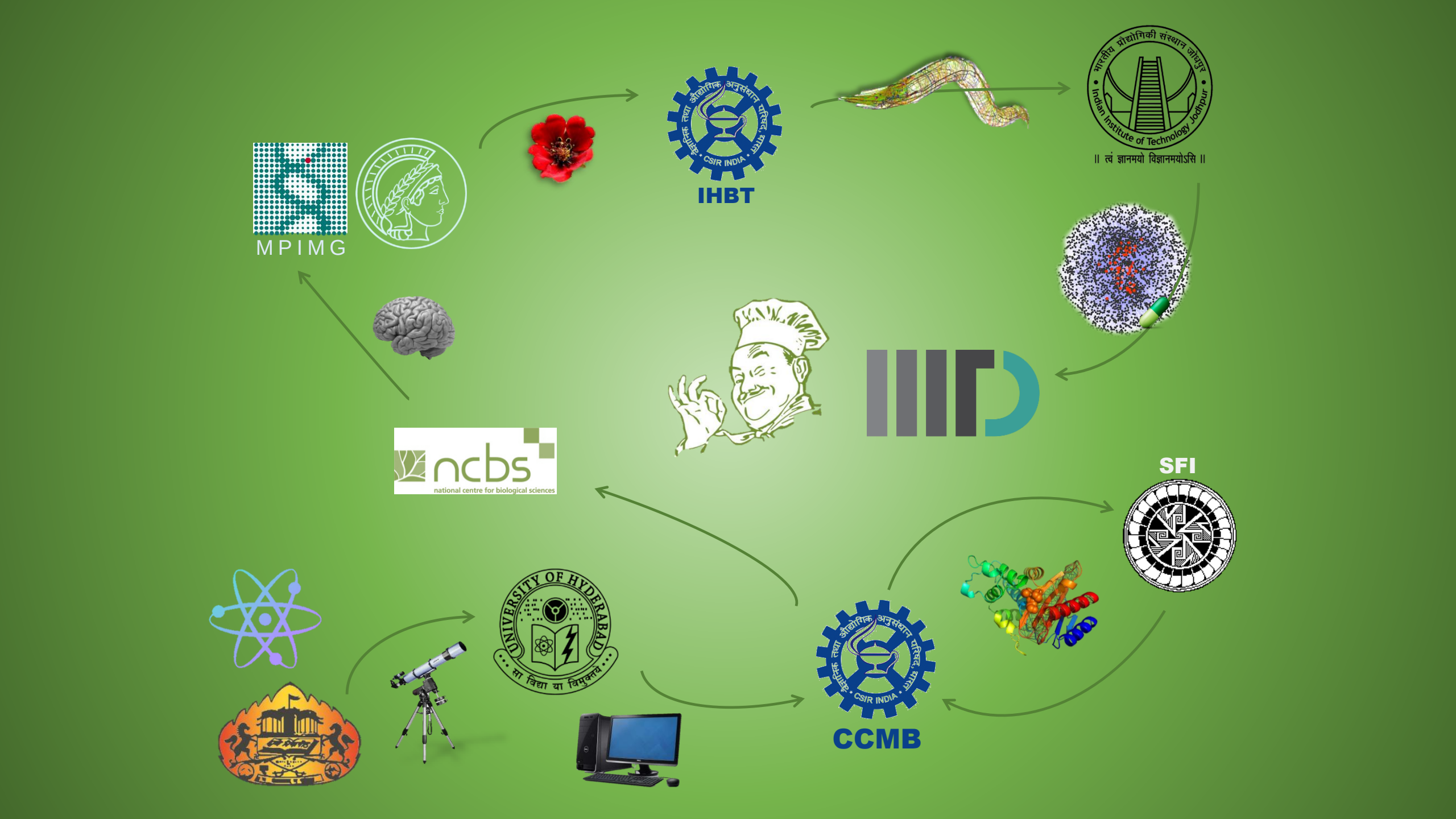
Computational Gastronomy

Infosys Centre for
Artificial Intelligence

GANESH BAGLER

A Data-driven Science of Food, Flavors, Nutrition, Health & Sustainability

Computational Gastronomy = Food + Data Science + Artificial Intelligence


MPIMG
IHBT
Indian Institute of Technology Jodhpur
॥ त्वं ज्ञानमयो विज्ञानमयोऽसि ॥
ncbs
national centre for biological sciences
SFI
UNIVERSITY OF HYDERABAD
CCMB

From astronomy to gastronomy

Why food?

Cooking is alchemy

Being Human

Being Human

'Catching Fire—How cooking made us human' by Richard Wrangham

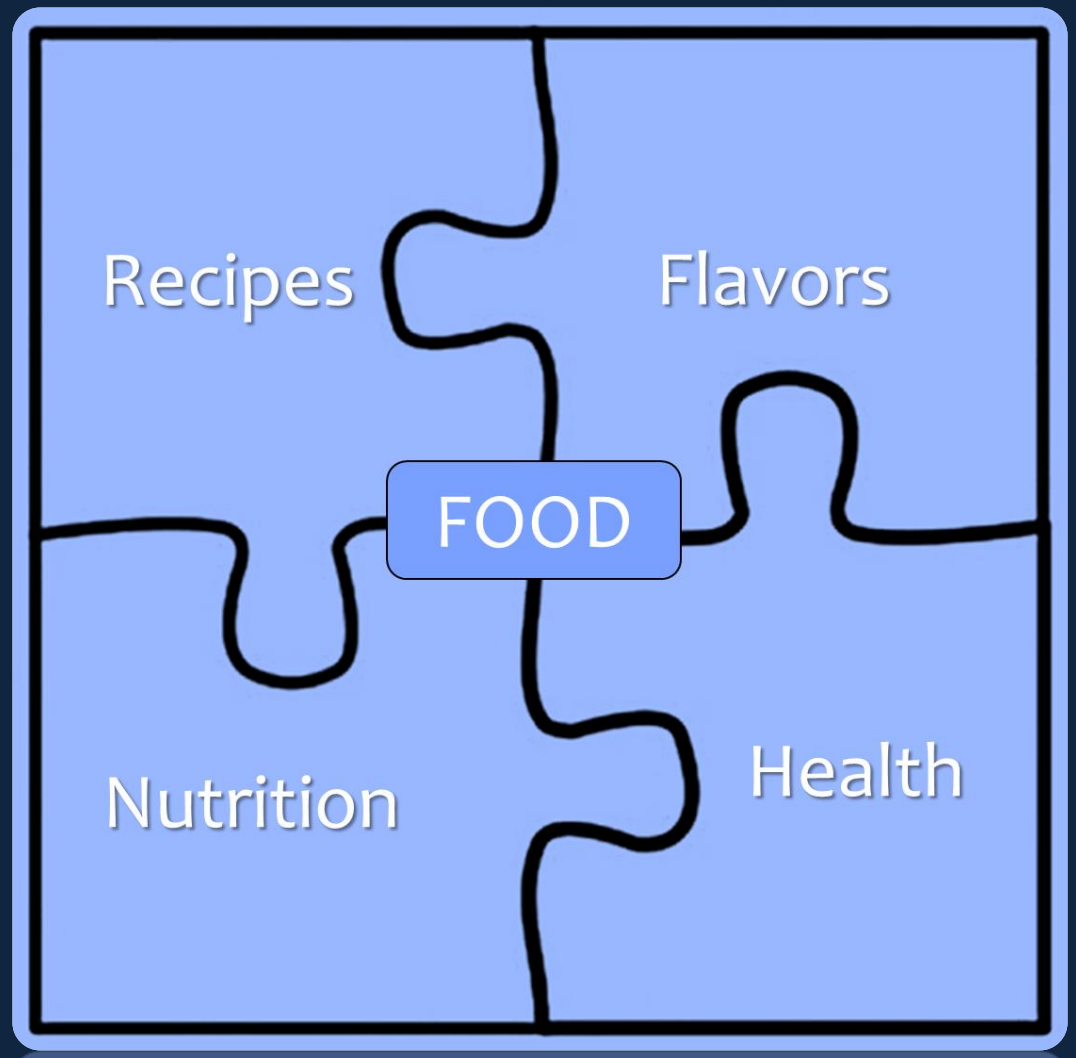
Feeding 10 Billion


Innovation [noun]
make changes in something established,
especially by introducing new methods, ideas, or products.
The Enquirer, Vraja Kishor's Blog

DATA

Making Food Computable

MAKING FOOD COMPUTABLE


Recipes
Flavors
FOOD
Nutrition
Health

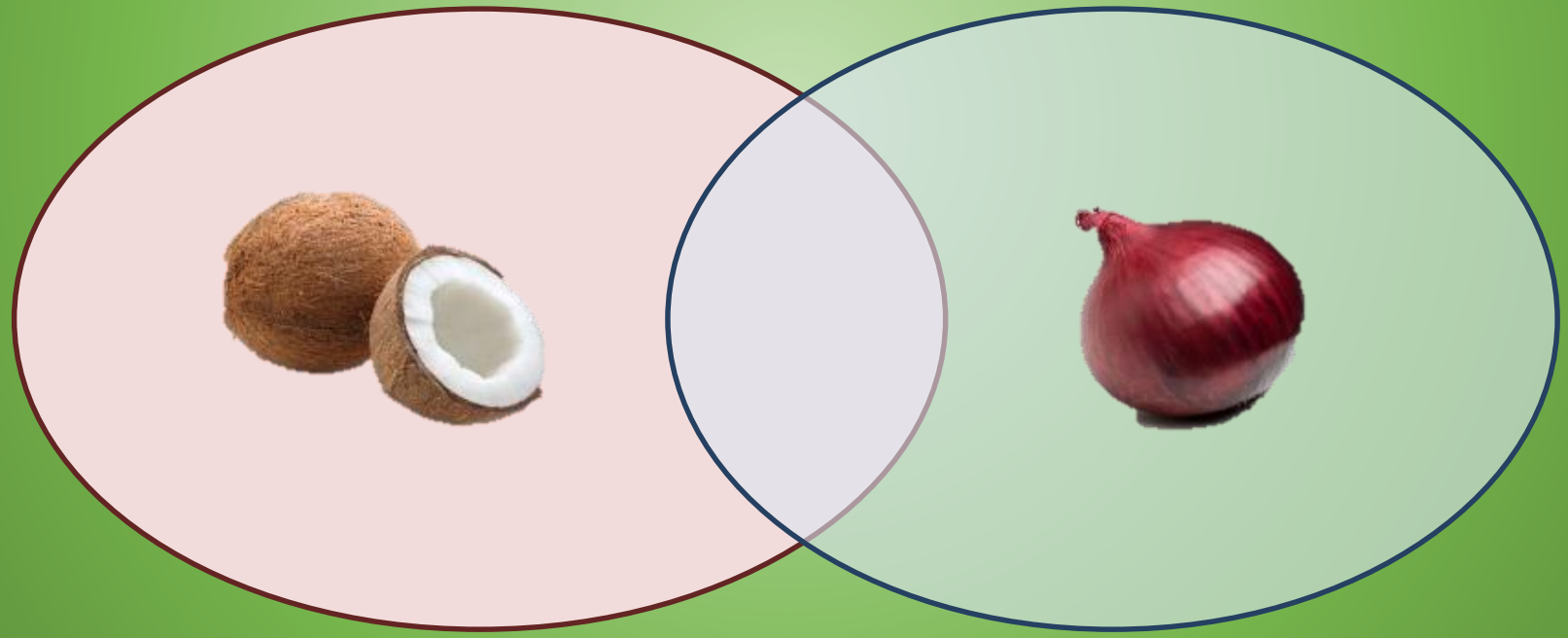

TEDx IISERPune
x = independently organized TED event
Making Food Computable
TEDx IISERPune

Why do we eat what we eat?

Why do we combine ingredients
in our recipes the way we do?

Food Pairing Hypothesis

Ingredients that **taste similar** tend to be **used together** in traditional recipes



Ahn *et. al*, "Flavor network and the principles of food pairing", Scientific Reports (2011).
A Jain, NK Rakhi, G Bagler*, "Spices form the basis of food pairing in Indian cuisine", **arXiv**:1502.03815 (2015).

India—A potpourri of cultures with a rich and diverse culinary heritage

- Diverse
- Culture-rich
- Wellbeing-centric

Ganesh Bagler*, ‘The digital way forward for the Indian Cuisine’ (2019).

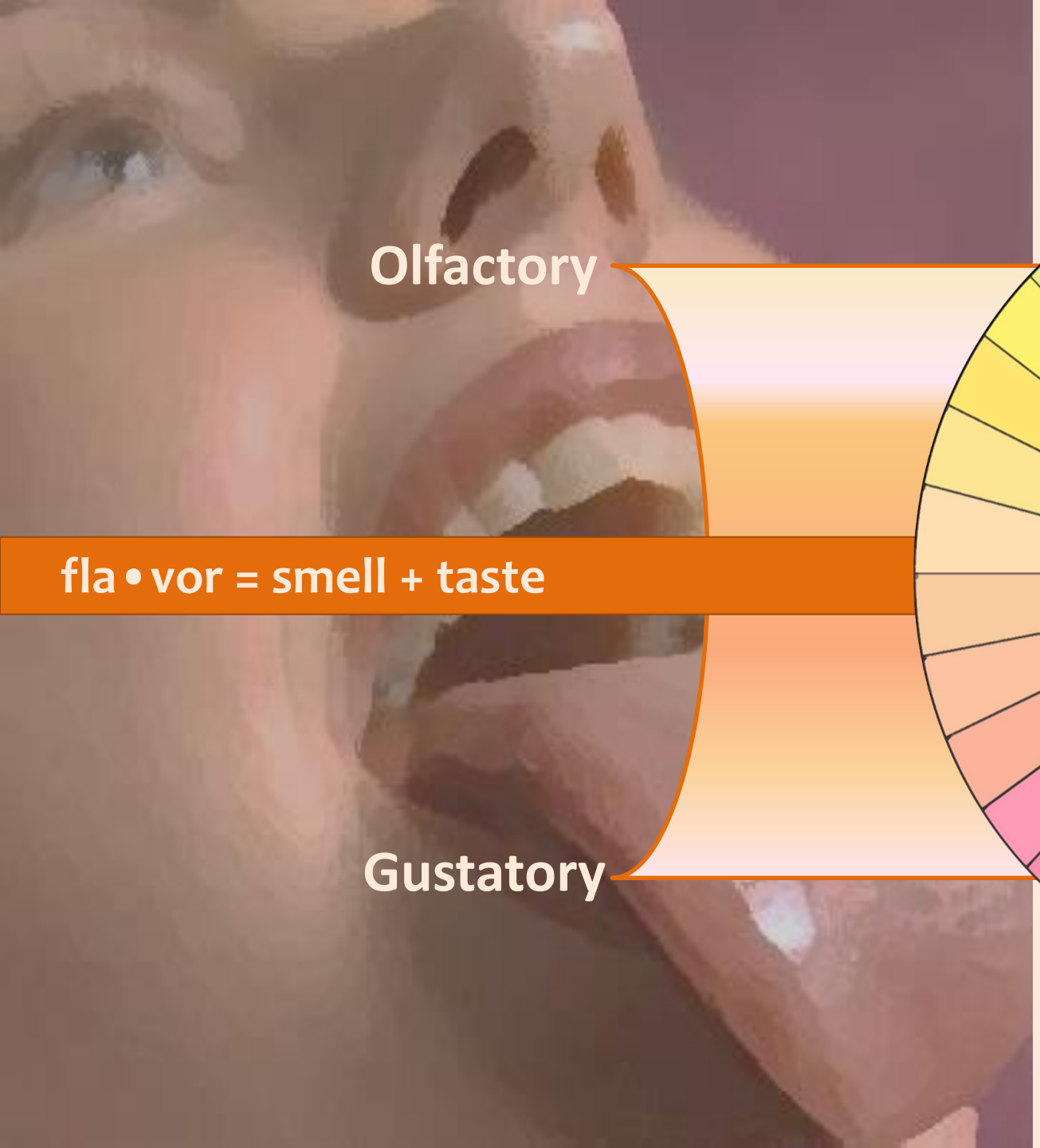
Data is the New Oil

Recipes & Ingredients

2543 Traditional Indian Recipes (TarlaDalal)

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

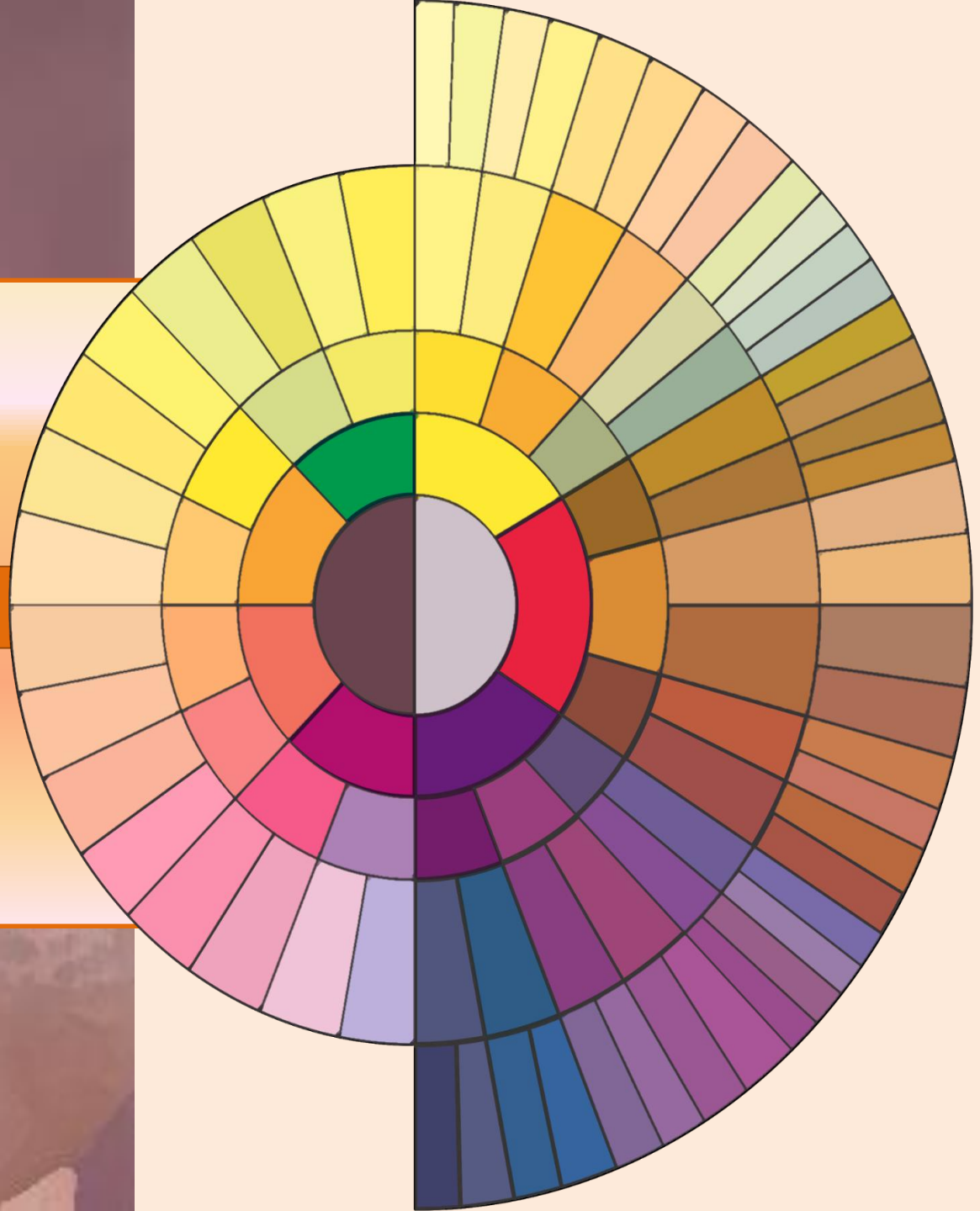
A Jain, NK Rakhi & G Bagler,* “Analysis of Food Pairing in Regional Cuisines of India”, **PLoS ONE** (2015).



Olfactory

fla • vor = smell + taste

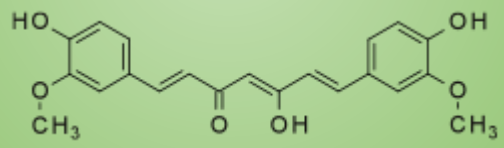
Gustatory

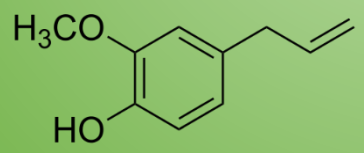


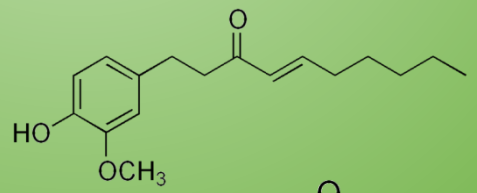
PubMed

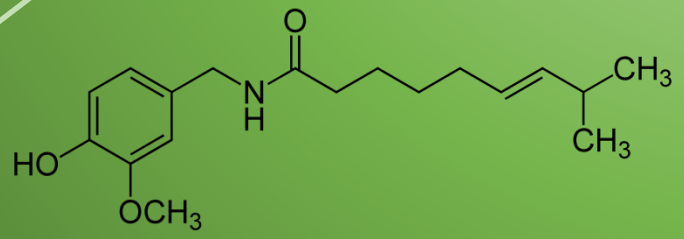
PubChem

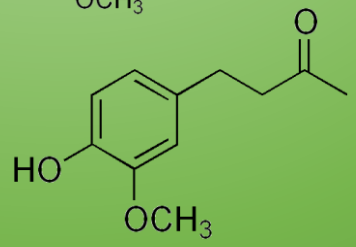
Fenaroli's Handbook

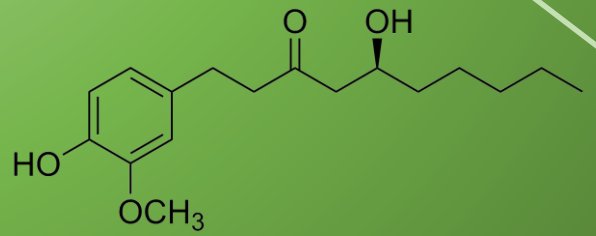






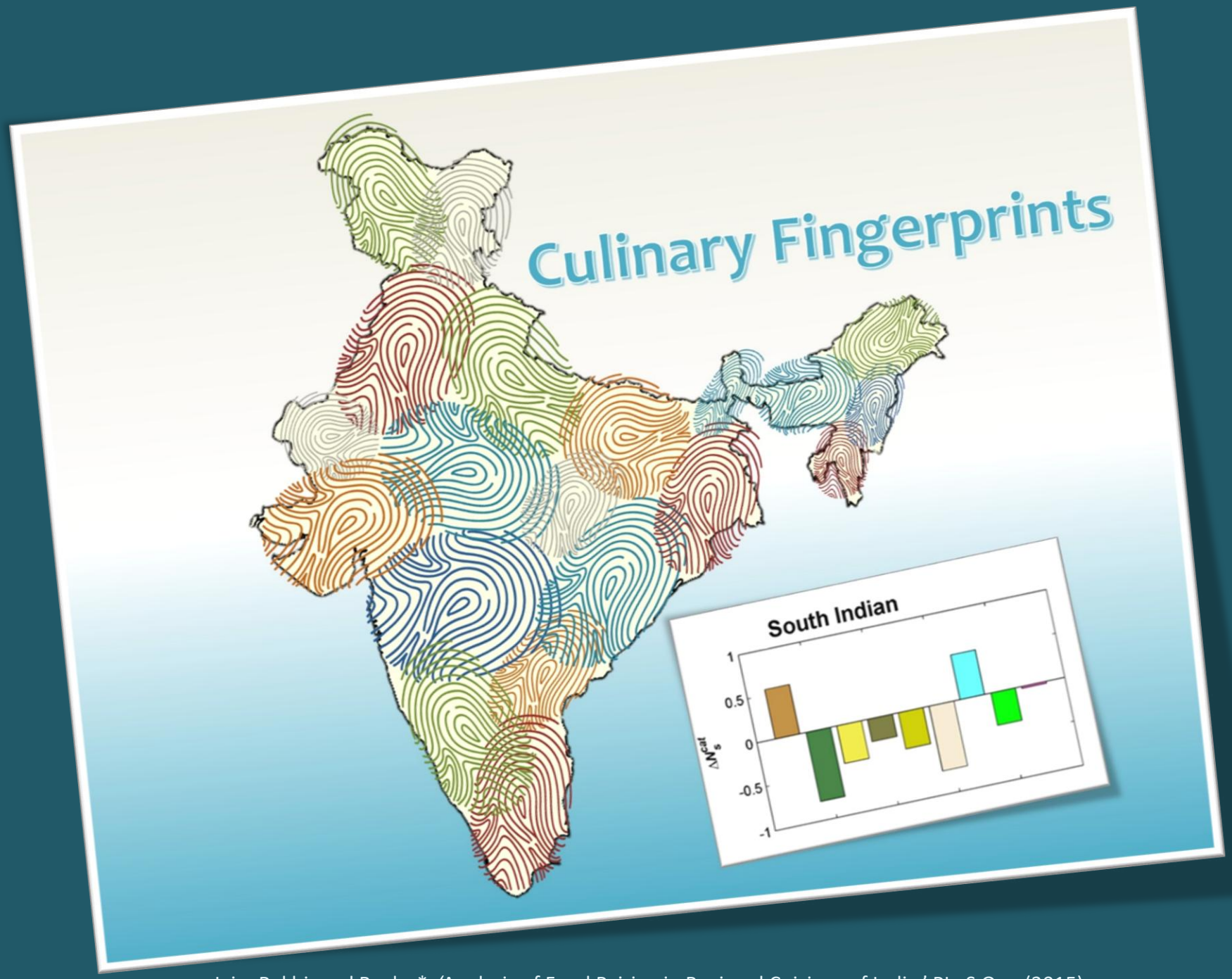






Food Pairing

Jain, Rakhi, and Bagler*, ‘Analysis of Food Pairing in Regional Cuisines of India,’ PLoS One (2015)



Jain, Rakhi, and Bagler*, ‘Analysis of Food Pairing in Regional Cuisines of India,’ PLoS One (2015)

A View from **Emerging Technology from the arXiv**

Best of 2015: Data Mining Indian Recipes Reveals New Food Pairing

By studying the network of links between Indian recipes, **computer scientists have discovered that the presence of certain spices makes a meal** much less likely to contain Ingredients with flavors in common.

MIT Technology Review

Best of 2015
MIT Technology Review

Jain, Rakhi and Bagler*, arXiv (2015) | Jain, Rakhi and Bagler*, PLoS One (2015)


Recipes
Flavors
Sustainability
Nutrition
Health

PLEASURE

Flavor

PUBLIC HEALTH

Nutrition

Health

FOOD

Recipes

CULTURE

Carbon Footprints

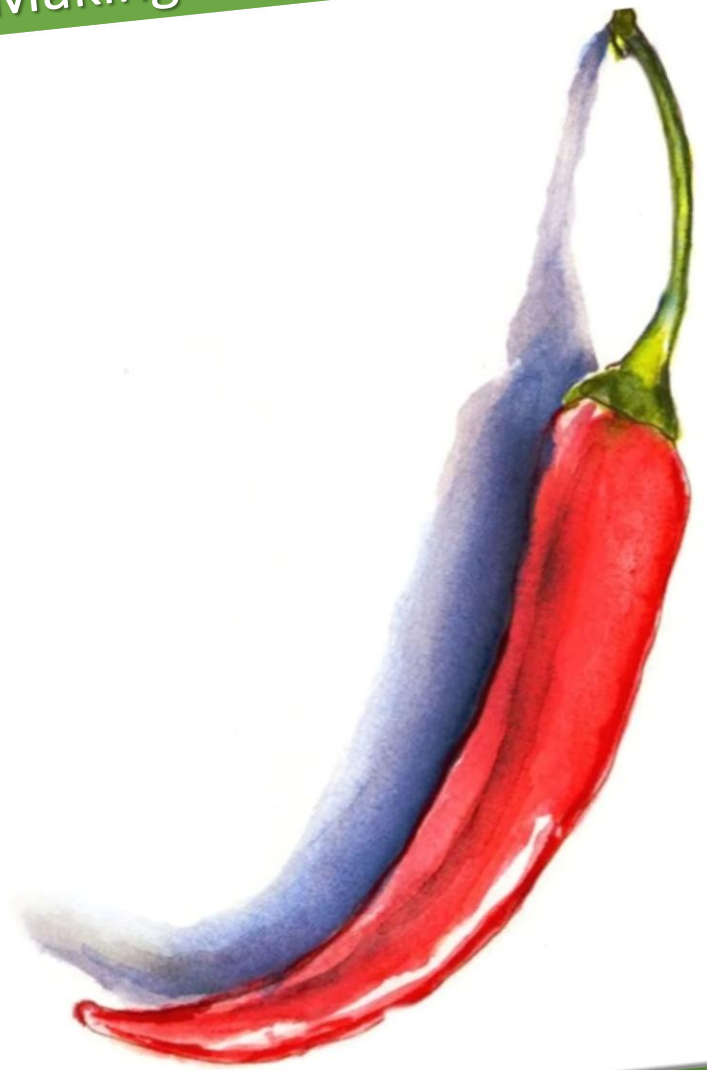
SUSTAINABILITY

INDIVIDUAL

COMMUNITY

CIVILIZATION

Making Food Computable



RecipeDB

A structured repository of Recipes from across the globe

FlavorDB

A repository of flavor molecules found in food ingredients

SpiceRx

A platform for exploring the health impacts of culinary herbs and spices

DietRx

A platform for exploring the health impacts of dietary ingredients

SustainableFoodDB

A repository of carbon footprints of recipes

Ratatouille

Generate novel recipes with Artificial Intelligence

BitterSweet

A webserver for predicting BitterSweet taste molecules

SweetPred

State of the art ML algorithms to predict sweetness

WhatDish

A real-time dish detection app for diet management

Ayurveda Informatics

A computable database of Ayurveda

https://cosylab.iiitd.edu.in

Complex Systems Laboratory, IIIT-Delhi

The Ground Zero of Computational Gastronomy

Making Food Computable

https://cosylab.iiitd.edu.in

Culinary Fingerprints of the World Cuisines

Singh and Bagler*, IEEE International Conference on Data Engineering, DÉCOR, Paris (2018)

COMPUTATIONAL GASTRONOMY

THE TIMES OF INDIA, NEW DELHI
FRIDAY, MARCH 17, 2023

The food business is using ingredients' data and algorithms to understand how to create unique recipes, how to ensure sustainable food

CONSUMING PASSION: Data and delicious food

USING DATA TO PREDICT THE NEXT BIG FOOD ITEM

Ingredients in an Indian recipe are different from an American recipe. Capturing this difference by digging through the data of recipes, ingredients, and flavour molecules and showing it in a statistical pattern was unusual till we did it. Our research became popular because nobody had looked at the uniqueness of Indian recipes in a quantifiable manner.

Ganesh Bagler | PROFESSOR, INDRAPRASTHA INSTITUTE OF INFORMATION TECHNOLOGY DELHI

Predicting the next big food item or food group is a big part of using data. We look at items that people are posting, blogging, and new flavours that are being launched, to predict the next thing. This year, people are high on millets. Lentils, fermented food and plant-based proteins from lentils and mushrooms will be big after millets.

Akshay Malhotra | CHEF ENTREPRENEUR, AND PARTNER, TAGTASTE

I use (Ganesh) Bagler's work (in computational gastronomy) to combine foreign ingredients for Indian dishes. A miso marinated chicken tikka is awesome and it was possible because of the common flavours of miso with Indian spices

Parvinder Singh Bali | CORPORATE CHEF, OBEROI CENTRE OF LEARNING AND DEVELOPMENT

THE TIMES OF INDIA

DECODING FLAVOURS

▶ A pioneer of computational gastronomy in India, Dr Ganesh Bagler is helping chefs reinvent dishes, writes **Tania Bhattacharya**

Computational gastronomy expert Ganesh Bagler Photos: Ganesh Bagler, Tejwana Hiranjakom; Food Forward India

Garima Arora, above, of Restaurant Gaa, is using Bagler's research to experiment with flavours, top. Centre, her strawberry, caviar and hor wor (Thai lemon verbena) oil dish

If you are a foodie and love experimenting with flavours, how does a shrimp and egg salad sound for lunch? Or a tender juicy steak, just out of the oven, topped with a dollop of cheese – cheddar or Camembert, to be precise. And did you know that mushrooms go smashingly well with nearly every common fruit, from apples to apricots and even coconut?

These food pairings may sound unappealing or at least unusual to most people, but Dr Ganesh Bagler of the Indraprastha Institute of Information Technology, New Delhi, says otherwise – and he has the data and research to show for it. The computational gastronomy expert has taken the food and drink industry by storm with his ground-breaking work on flavour molecules and its corresponding database, FlavorDB. His laboratory has also developed DietRx, an archive of nearly 2,000 foods, their chemical and genetic compositions, and their effect on health, which can enable culinary and drug interventions. (Ayurvedic diets are a prime example of the belief in healing via appropriate foods.)

"The power of data and food together is magic," says Bagler. Already, chefs such as Garima Arora of Restaurant Gaa in Bangkok, are using Bagler's research to fuel their own food experiments. "What I find amazing about Bagler's research is that his approach actually enables us to know exactly what makes up a cuisine – the things that make Indian cuisine Indian," Arora, who is the first Indian woman with a Michelin star to her name, tells *The Nationa*l.

"Once we have that knowledge, we can truly get to the main taste of a cuisine, which [illegible]

flavours and ingredients we don't need."

Bagler's work is also critical to Arora's Food Forward India, a non-profit initiative that aims to broaden the narrative around Indian food. "It fits into the framework by being a forward-thinking initiative, one that serves the purpose of codifying a cuisine, and identifying, quantitatively, its identity," says project manager Matylda Greelak.

Bagler, who is now considered the pioneer of computational gastronomy in India, credits curiosity for his success. Having studied various subjects from graduation through to postdoctoral studies – quantum mechanics, computer science, computational biology, computational genetics – Bagler returned to India in 2010 following a stint at Berlin's Max Planck Institute for Molecular Genetics. He joined the CSIR-Institute of Himalayan Bioresource Technology at Palampur as a researcher, and worked on medicinal plants in the western Himalayas, and on diseases such as cancer and asthma. But it was not enough. "I like to explain things; I'm a teacher," he says. This led him to the prestigious Indian Institute of Technology Jodhpur and finally IIIT-Delhi.

Bagler's foray into gastronomy happened when he came across a 2011 paper that took off from British chef Heston Blumenthal's food-pairing hypothesis: foods that share flavour molecules will taste [illegible] do not. For example, chocolate and blue cheese taste great together because they share 73 flavours (Blumenthal's interest was piqued when he paired white chocolate and caviar, and hit the right notes). This led to companies such as Foodpairing, which present thousands of combinations of ingredients for chefs to experiment with.

"Historically speaking, dishes have evolved over millennia from single-ingredient meals to complex ones," says Bagler. "Cooking techniques and creative expression aside, why are some ingredients used together and others not?" This was one of the critical questions that led Bagler to expand his research. "Food science has been around, but it explored foods or how to enhance sensory enjoyment. Now, people are looking at food from a data perspective."

What Bagler did differently was focus on Indian food, which he found is different from other cuisines because of the spices. Breaking down a collection of the late, celebrated Indian chef Tarla Dalal's recipes, Bagler realised that spices form the basis of food-pairing in Indian cuisine. Having divided various foods – vegetables, dairy, lentils, meats, etc – he saw that mixing up items across all other sections did not cause too much of a shift in flavour, but when the spices were shuffled, the taste changed entirely. For example, you could replace spinach [illegible] paneer and there would not be much change in the dish, but if you replaced turmeric with cinnamon, the very essence of the preparation alters. "Spices are the molecular fulcrum of Indian food," says Bagler.

In 2015, Bagler and his team of researchers sent this study to international science journals, which upheaded it to an open server where it was picked up by *MIT Tech Review*. This changed Bagler's life. "I only understood the academic value of this work, not its futuristic value," he says. "It took me a year to understand that this had led to the creation of a new field of study, and now, over the past five years, I've been developing the foundations of this area."

From 2,543 of Dalal's recipes, Bagler's database has expanded exponentially. Not only is the data free to access on various websites and apps, but the information is also provided in excruciating detail, from the scientific names of elements to a comprehensive flavour network, possible pairings and health benefits. Bagler is also due to launch RecipeDB at a conference postponed amid the Covid-19 crisis – where a massive collection of structured recipes will be available for everyone from chefs and cooking enthusiasts, to restaurateurs, multinationals and scientific organisations to use freely.

"People know food technology, but they do not know about flavour technology," says Deepika Nadimintri, a flavourist at [illegible] flavours for the dairy, confectionery and drinks industries. "Bagler's database is an all-in-one resource, where we can identify everything from flavour molecules to physical and chemical properties, and experiment easily," she says.

While Bagler consults for institutions such as the Indian Institute of Hotel Management and Symbiosis School of Culinary Arts, as well as a range of multinationals, chefs also swear by his research, which has "significantly reduced time spent on developing new dishes", says Akshay Malhotra, a chef, food consultant and former student of the Culinary Institute of America.

"FlavorDB will help us to understand the science behind Indian food, and it is only the [illegible] intelligence will influence the food industry," he says.

This aspect is also key to Bagler's future experiments. "Can we encode the intelligence of a chef into a computer, or can a computer fool a chef into thinking a recipe is real?" says Malhotra.

Can human creativity, which is at the heart of cooking, be reproduced using AI? It remains to be seen. For now, Malhotra's observations pertain to FlavorDB complementing chefs' instincts about pairing ingredients. As celebrity chefs Manjit Gill and Akshraj Jodha describe Bagler's work, he is successfully quantifying the knowledge that, until now, was only intuitively available to a cook – and everyone from chefs and diners to scientists [illegible]

AI and Food Innovations | Paris

LSTC Golden Jubilee Celebrations

Computational Gastronomy

The Future of Food

Ganesh Bagler

New culinary experiences The technique helps in coming up with innovative flavour pairings. (Below) Ganesh Bagler. SPECIAL ARRANGEMENT

Data-driven delicacies

Ganesh Baglar of Indraprastha Institute of Information Technology in Delhi aims to revolutionise our approach to food with data-driven Computational Gastronomy

Ananyaa Desikan
ananyaa.d@thehindu.co.in

Ganesh Baglar from Indraprastha Institute of Information Technology, Delhi has a new lens to look at gastronomy, which he believes can change the way we approach food.

"Why do we eat what we eat? or Why do we pair ingredients the way we do? These are the questions we started with to get to where we are now. Computational Gastronomy is a data-driven way of looking at food to create new culinary experiences. We get into the ingredients at a molecular level to find answers," he says.

Along with his team of researchers and developers, Ganesh has put together 10 repositories and applications based on this approach. Data has been compiled from one lakh eighteen thousand recipes from 26 world regions and 74 countries.

Understanding food

This methodology is used to study the evolution of cuisines and is also believed to be helpful in coming up with innovative flavour pairings.

"When we try to understand how contemporary Indian food came into being, it is similar to learning about the evolution of language. We place the data available to us in a multi-dimensional space and study similarities and dissimilarities with other global cuisines," he claims.

While this methodology helps understand the evolution of Indian cuisine, chefs who use this approach in their business believe that this also contributes to the evolution.

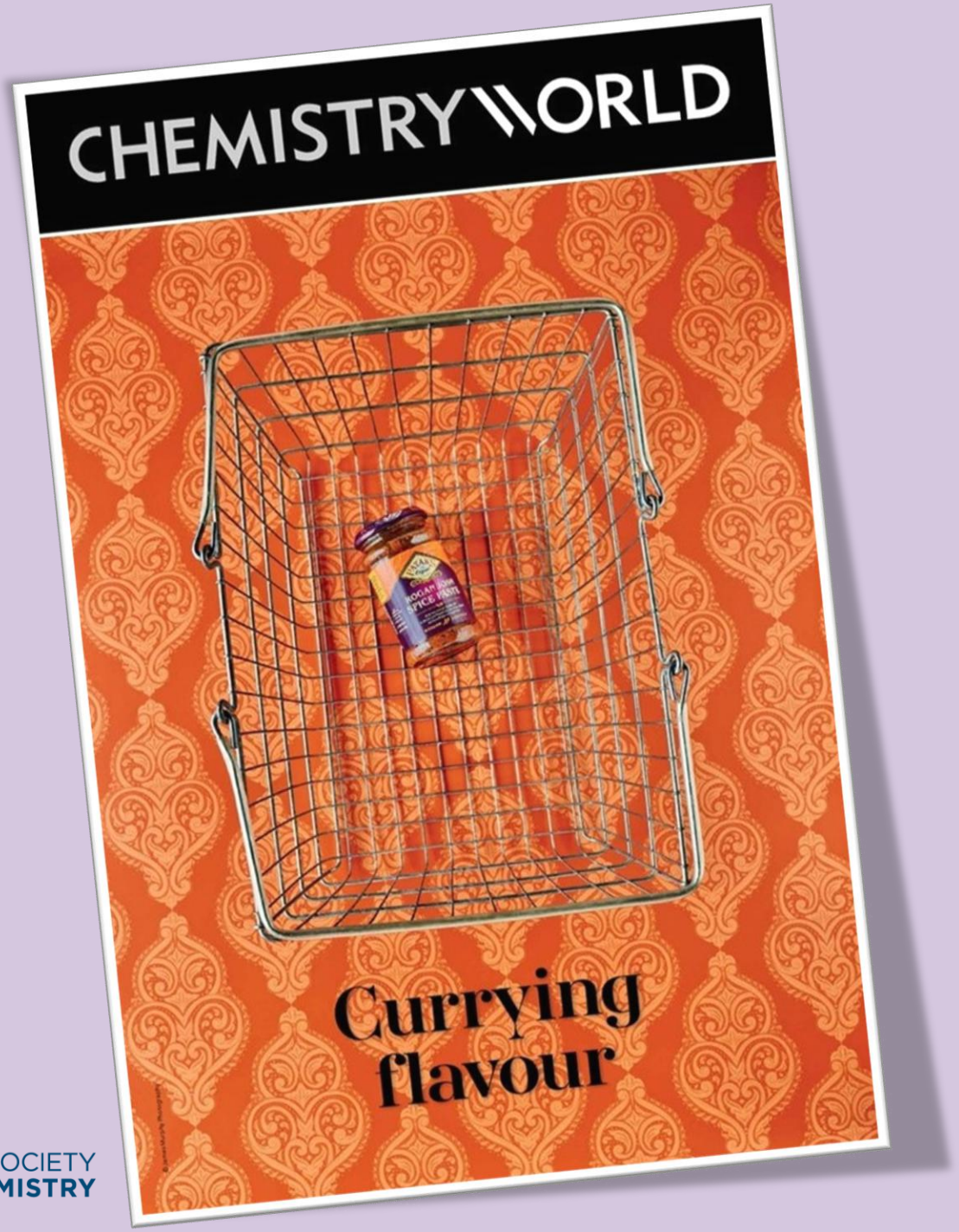
Garima Arora, the first female-Indian chef to win a Michelin star for her restaurant Gaa in Bangkok, says Bagler scientifically explains Indian food, adding "This is immensely helpful to chefs chasing new flavours and dishes. The data he has collected helps in coming up with new ingredient combinations that work. This can revolutionise Indian food."

In the FlavourDB repository, there are 25,595 flavour molecules that contribute to the taste or odour of an ingredient. By browsing through the extensive flavour network graphic or visual search option, one can look for flavour pairings based on the molecules the ingredients share. For instance, fenugreek shares more than 100 flavour molecules with ingredients like tea, soybean, papaya, guava and even cocoa.

"Our SustainableFoodDB repository gives the carbon footprint of each recipe, ingredient and also provides alternative ingredients," he says.

While going through the enormous amounts of data can be overwhelming, Ganesh informs us that there are applications like Ratatouille that can generate recipes based on the ingredients available. Ganesh says that when he deconstructs cuisines into recipes and ingredients to molecules, he feels like Dennis The Menace who pulls his toys apart. But he believes, "It is not just the data but algorithms that we have that can make a difference in the future of food."

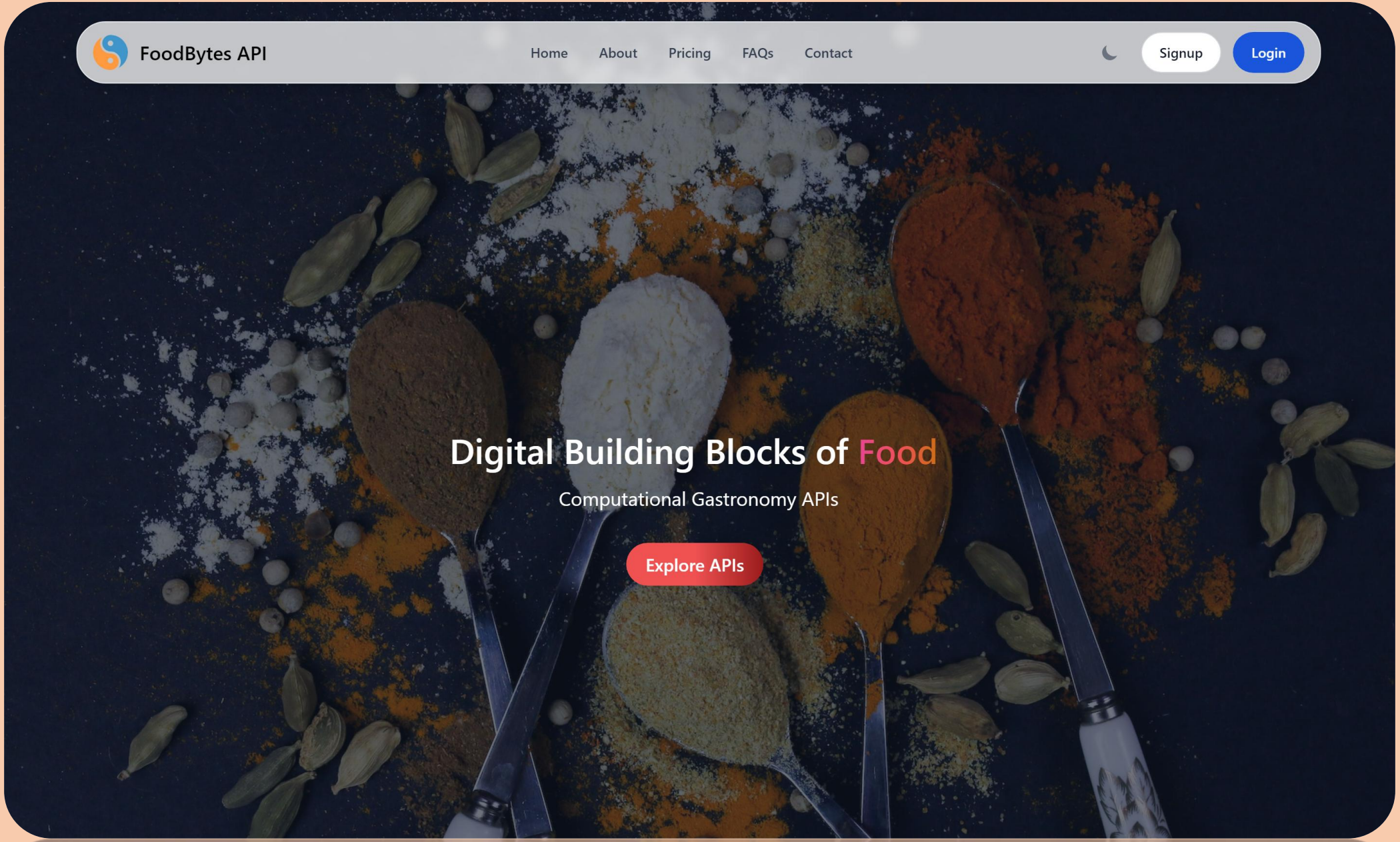
The Hindu (26 October 2023)



ROYAL SOCIETY OF CHEMISTRY

> The intersection of food science, data and computation is one of the most exciting frontiers, and your work is right in this sweet spot.

Sam Arbesman
Scientist in Residence, Lux Capital



Foodoscope Technologies Private Limited

Center for Sustainable Food

DIGITALLY DELICIOUS

The adventure of making food computable

GANESH BAGLER

India Science Book Fellowship 2024

Course Structure

This course introduces the emerging science of Computational Gastronomy, a blend of food, data science, and computational techniques.

The following are the specific objectives that the course aims to fulfill:

(a) Introduction to **the science of food**;

(b) Exposition to **culinary data**;

(c) Analysis and visualization of culinary data (statistical analysis, text mining, natural language processing, machine learning);

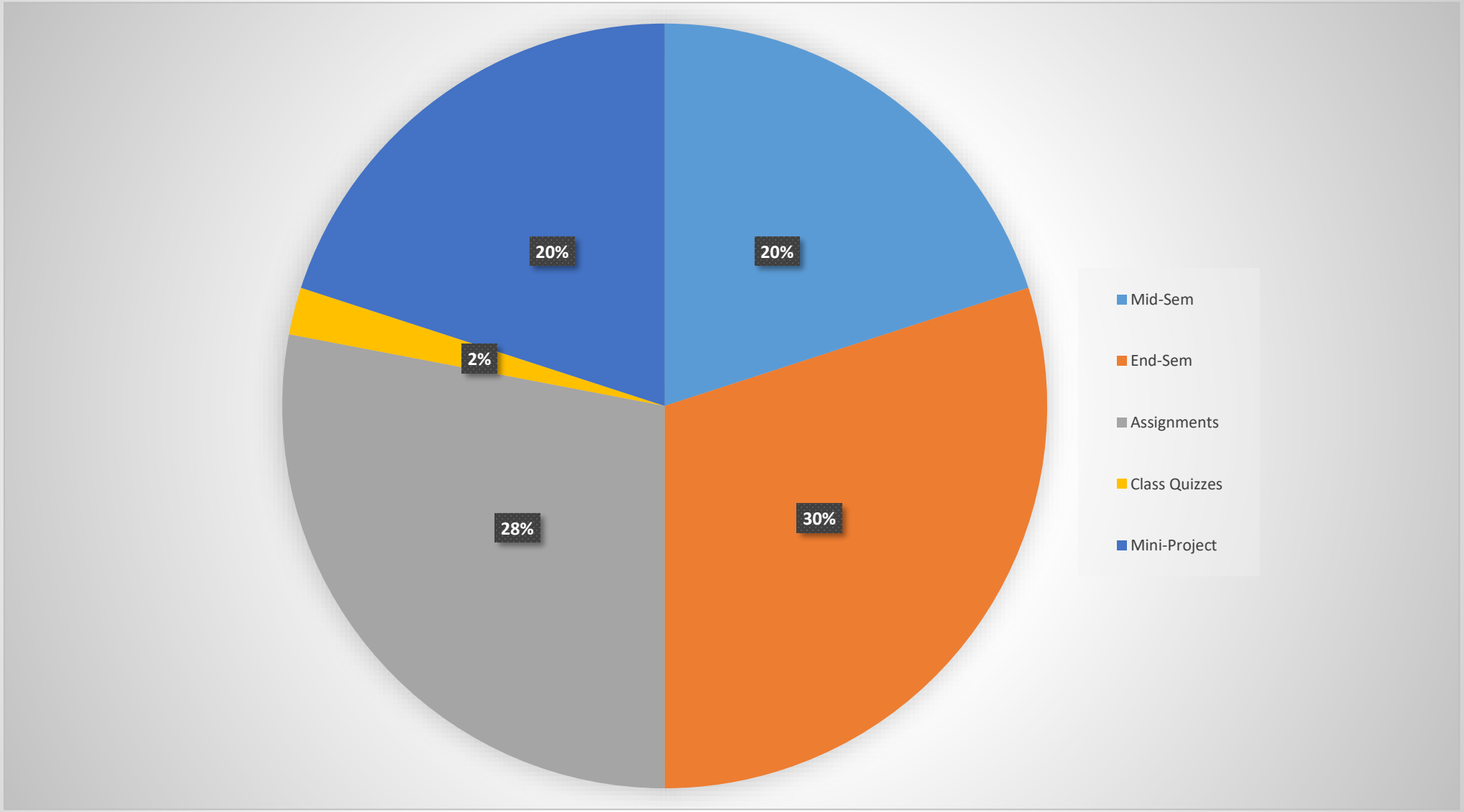
(d) Exposure to **challenges and opportunities**.

Post Conditions

- Students are able to **explain** the basic tenets of the science of food and the scope for data-driven analysis.
- Students are able to **explain, analyze, and interpret** major aspects of **culinary data**.
- Students are able to **design classification and prediction models** from culinary data.

Desirable Pre-requisites: A good command of programming (Python) and data analysis. Exposure to statistical analysis, data visualization, machine learning, and natural language processing.

Percentage Division of Evaluation Criteria



FAQs

- What are **class quizzes**?

→ Simple MCQs through Google Forms, based on the content being discussed in the class. **Weightage: 2%**

- What will be the nature and logistics of **mini-projects**?

→ **Teams of 1-3 students working on projects for at least 3 weeks** touching on aspects of data scraping & organization, data analysis, visualization, ML models (classification, regression), design of Android apps, web apps, technology leverage (blockchain, NFTs, NLP, NER, Ontology, Computer Vision, etc.), Kaggle challenge design, external API utilization, browser plugins, game design, library design, instrumentation/Arduino, social science questions, design challenges, exploratory research, and entrepreneurship.

Evaluation: Based on project-specific deliverables. **Weightage: 20%**

Opportunities: Hackathon, project-and-poster presentations in the Symposium, interactions with potential employers from industry, government & policymakers.

- What will be the structure of **the mid-sem and end-sem exams**?

→ A combination of **a small number of MCQs with partial negative marks** (correct: +1, wrong: -¼) and **short-answer questions**. **Weightage: Mid-Sem (20%) & End-Sem (30%)**

- What will be the nature and logistics of **assignments**?

→ **Teams of 1-2 students working on three assignments (2 best of 3)** involving experiential work & coding-based questions involving data collection, analysis, visualization, and problem-solving. **Weightage: 28%**

- Is **attendance** mandatory? Are there **points for attendance**?

→ NO!!

Week	Lecture Topic	COs Met	Assignment/Exercise
1 & 2	**Introduction to the science of food**: History of food, Cultural influences, Impact of Technology, Role of data science. Cooking-- the craft and magic: Session by a practicing chef highlighting the need for scientific understanding of food. Role of Computational Gastronomy in achieving data-driven food innovations.	CO1	6 hours (Reading Material)
3 & 4	**Culinary Data Analysis [Recipes]**: Recipes data structure, Data compilation and curation, Visualization and analysis, The structure of world cuisines, Ingredient popularity and uniqueness.	CO2	5+2 hours (Reading Material + Exercises + **Assignment-1**)
5 & 6	**Culinary Data Analysis [Flavors]**: Flavors data structure, Data compilation and curation, Visualization and analysis, Molecular composition of ingredients, Sensory attributes of taste and odor.	CO2	5+2 hours (Reading Material + Exercises)
7 & 8	**Culinary Data Analysis [Food Pairing]**: Food pairing, Hypothesis testing, Culinary fingerprints, Comparative analysis of world cuisines, Data visualization.	CO2	5+2 hours (Reading Material + Exercises)
9	Culinary Data Analysis [Health-Nutrition]: Nutritional data analysis, Health impacts of food, Food-disease associations, Data analysis and visualization.	CO2	3+2 hours (Reading Material + Exercises + **Assignment-2**)
10 & 11	**Modeling and Prediction [Cuisine]**: Cuisine classification, Features selection, Implementation of machine learning models, Comparison with the state of the art, Identity of a cuisine, Transforming a recipe from one cuisine to another.	CO3	5+2 hours (Reading Material + Exercises)
12 & 13	**Modeling and Prediction [Flavor and Fragrance]**: Prediction of taste and odor; Features selection, Implementation of machine learning models, Comparison with the state of the art.	CO3	5+2 hours (Exercises + **Mini Project**)
14	**Opportunities and Challenges**: Challenges for building the foundations of a data-driven culinary science; Scope for compilation of culinary data from textbooks, scientific literature, traditional knowledge sources, web-based sources (Twitter, Culinary forums, Reviews, Restaurant menus, Food service aggregators, FMCG data repositories, etc.); Opportunities in food-tech industry; Entrepreneurship; Policy making; Food security; Public Health, and Sustainable Development.	CO1, CO2, CO3	3 hours + **Mini Project Presentations**

Lectures & Office Hours

When: Tuesdays and Fridays, 11am—12:30pm

Where: C02 (Old Academic Block, Ground Floor)

Office Hours:
Tuesdays (9—10am & 12:30—1:30pm) &
Fridays (9—10am & 12:30—1:30pm).
A305 (R&D Block)

Computational Gastronomy

Infosys Centre for Artificial Intelligence

GANESH BAGLER

A Data-driven Science of Food

Computational Gastronomy is a data science that blends food, data, and computation for data-driven food innovations.

Impact of Technology on Food

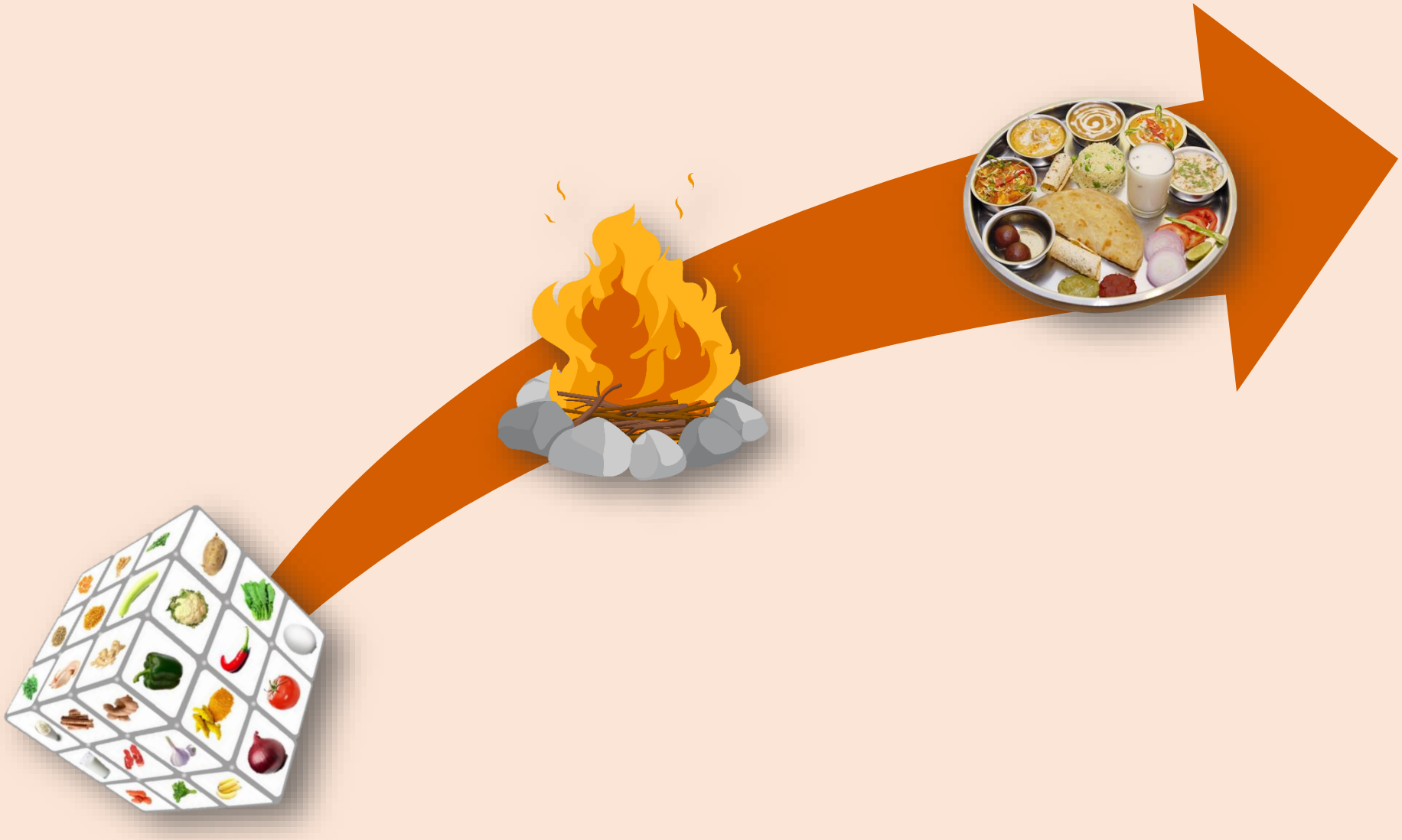
Scientific American, June 2015

Ganesh Bagler
Center for Computational Biology, IIIT-Delhi, New Delhi.

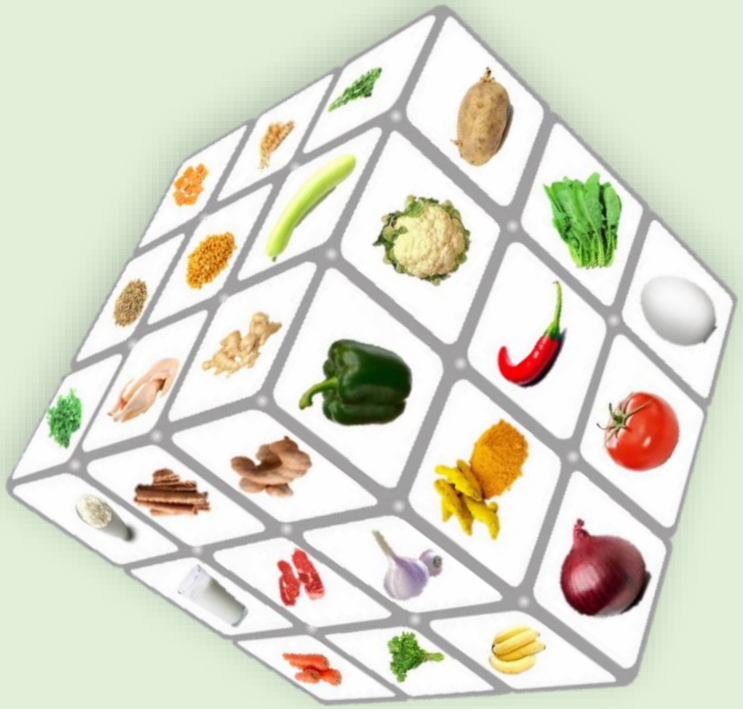
- What is food?
- What is technology?

- What are the ways in which food touches are lives?

Food is magic!

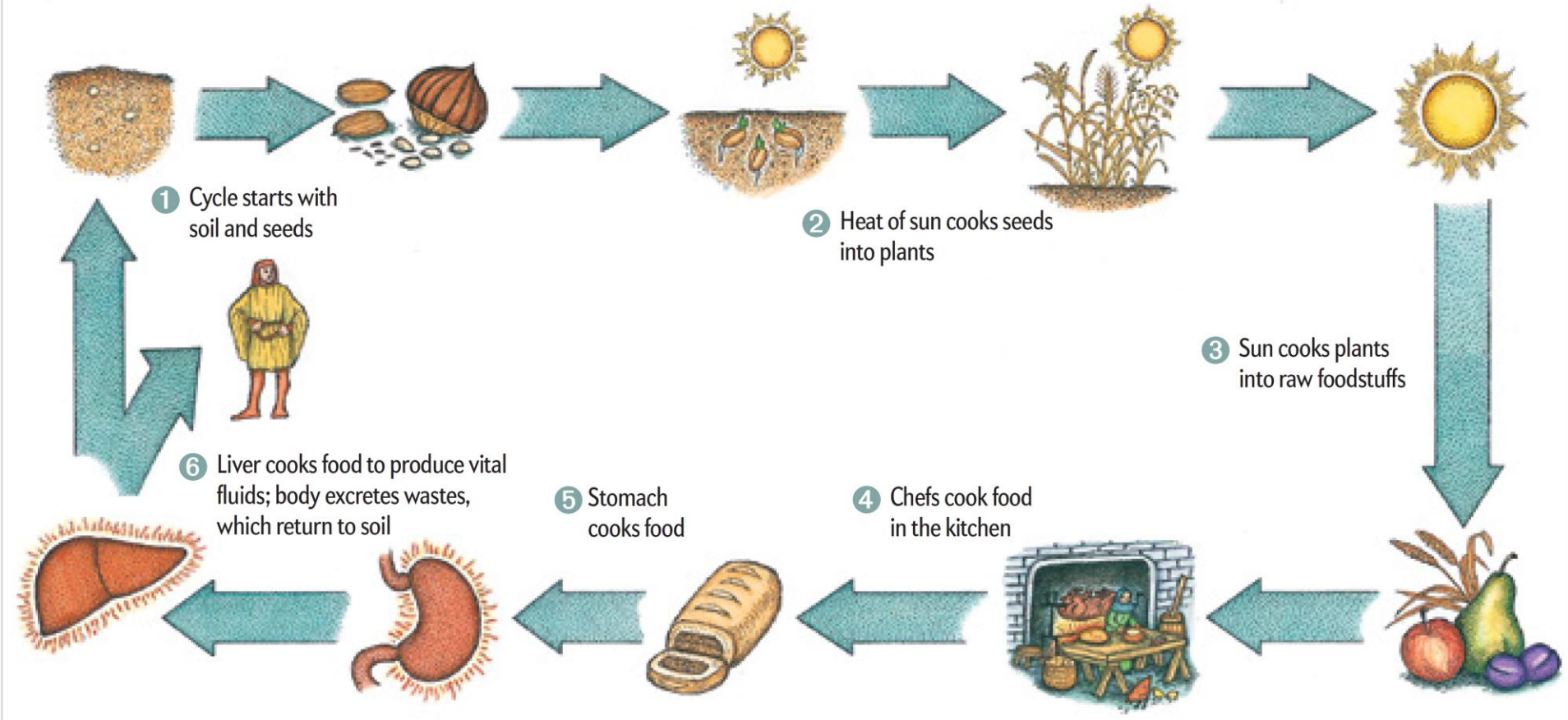


Food is Nutrition



The Cosmic Culinary Cycle before 1650

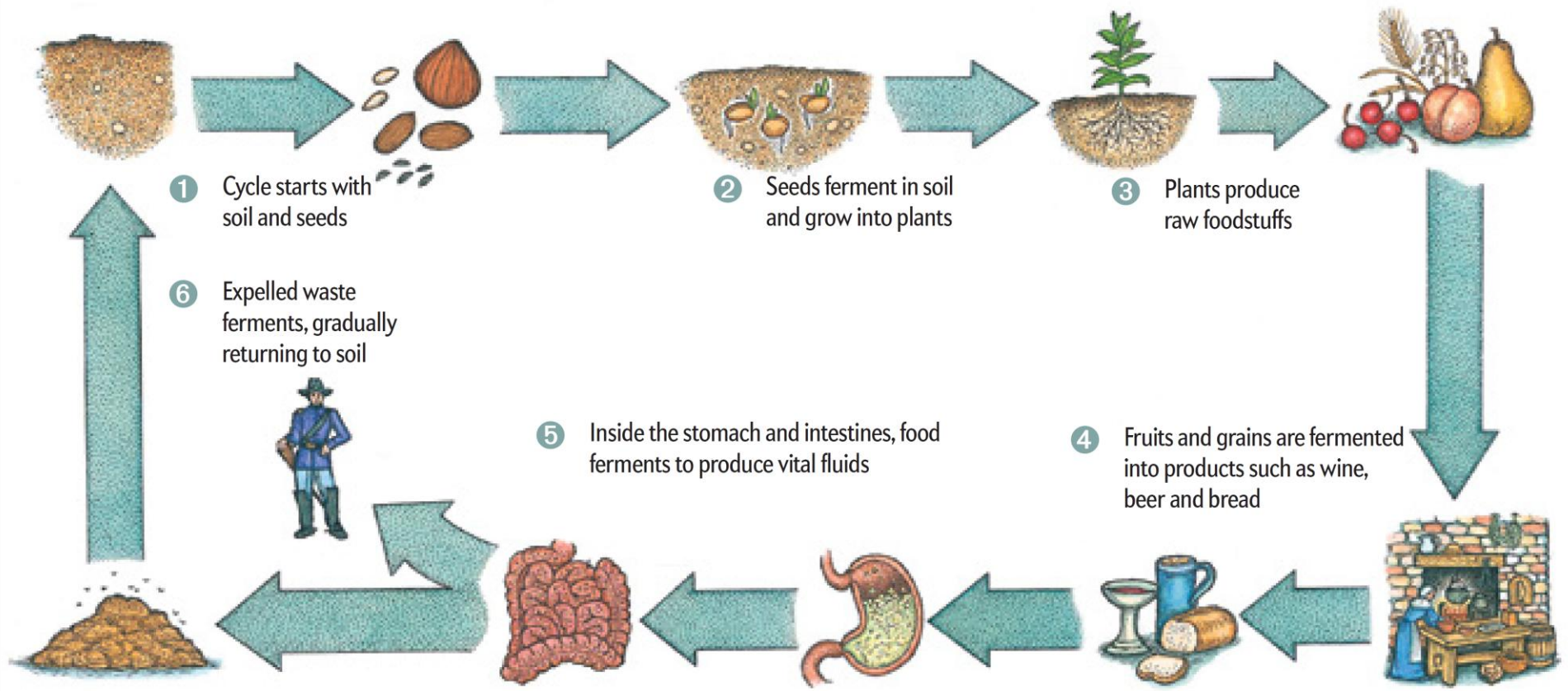
… in which cooking was believed to be the central process of life.



Scientific American, June 2015

The Cosmic Culinary Cycle after 1650

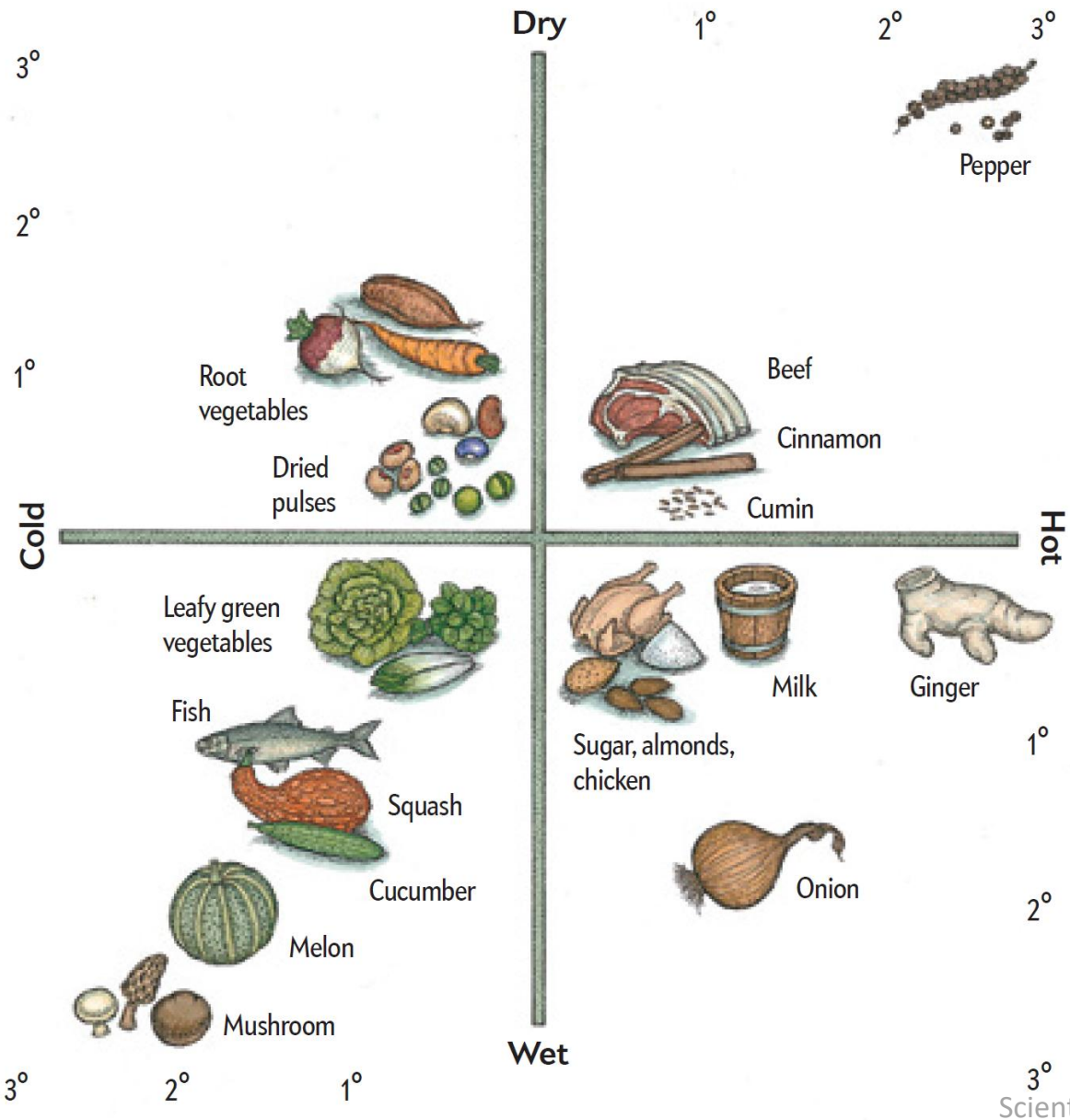
… in which fermentation was believed to be the central process of life.



Scientific American, June 2015

16th-Century Classification System

… in which foods were assigned degrees of heat, coldness, wetness and dryness.



Scientific American, June 2015

Processed Food

Scientific American, June 2015

Processed Food

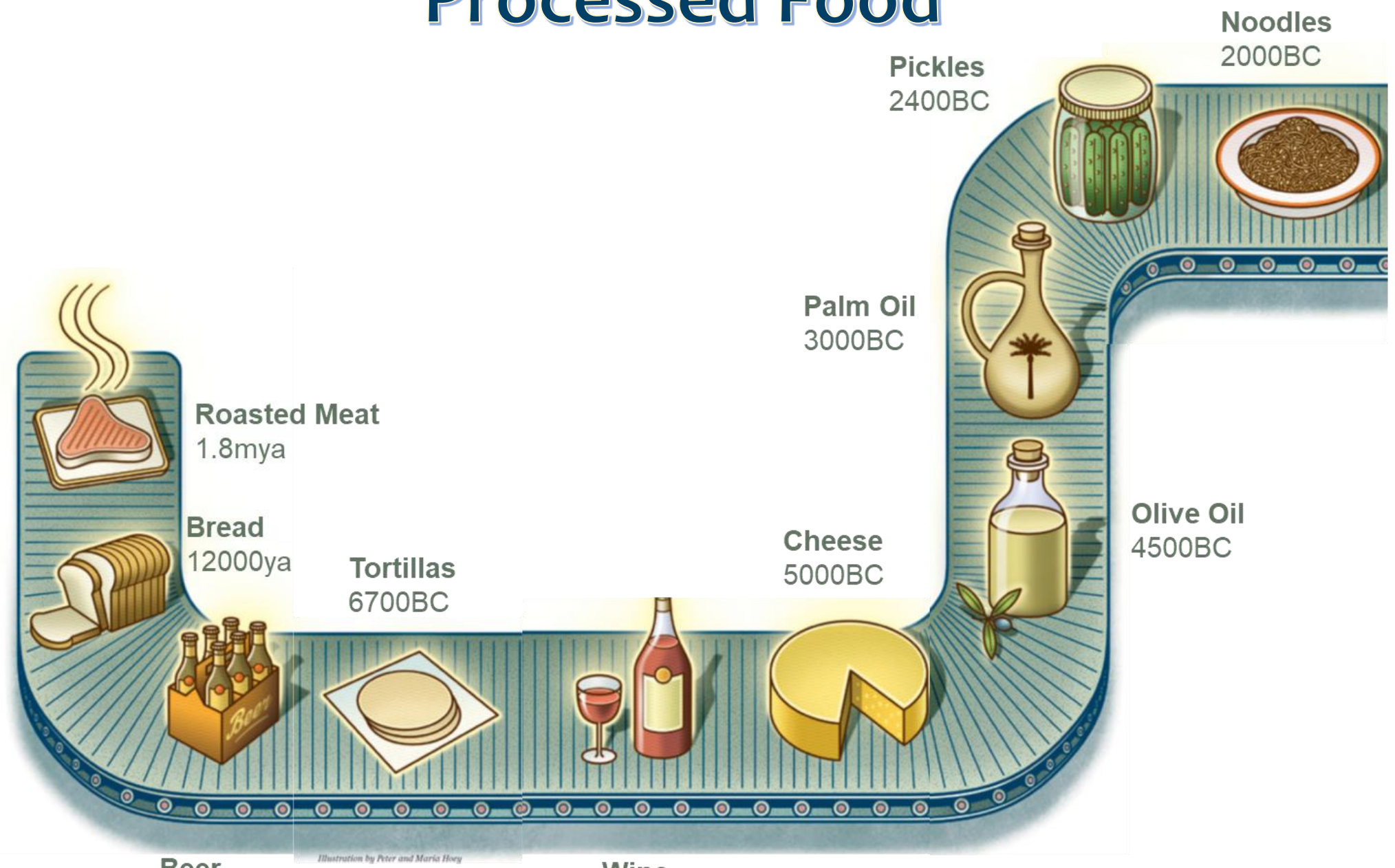
- It is the **dark force**, we're told, **behind the obesity epidemic** and the death of the family farm.

- But humans have been '**processing**' food **ever since we learned how to cook, preserve, ferment, freeze, dry or extract**.

- **Processed food** has powered the evolution of the **species**, the expansion of **empires**, the exploration of **space**.

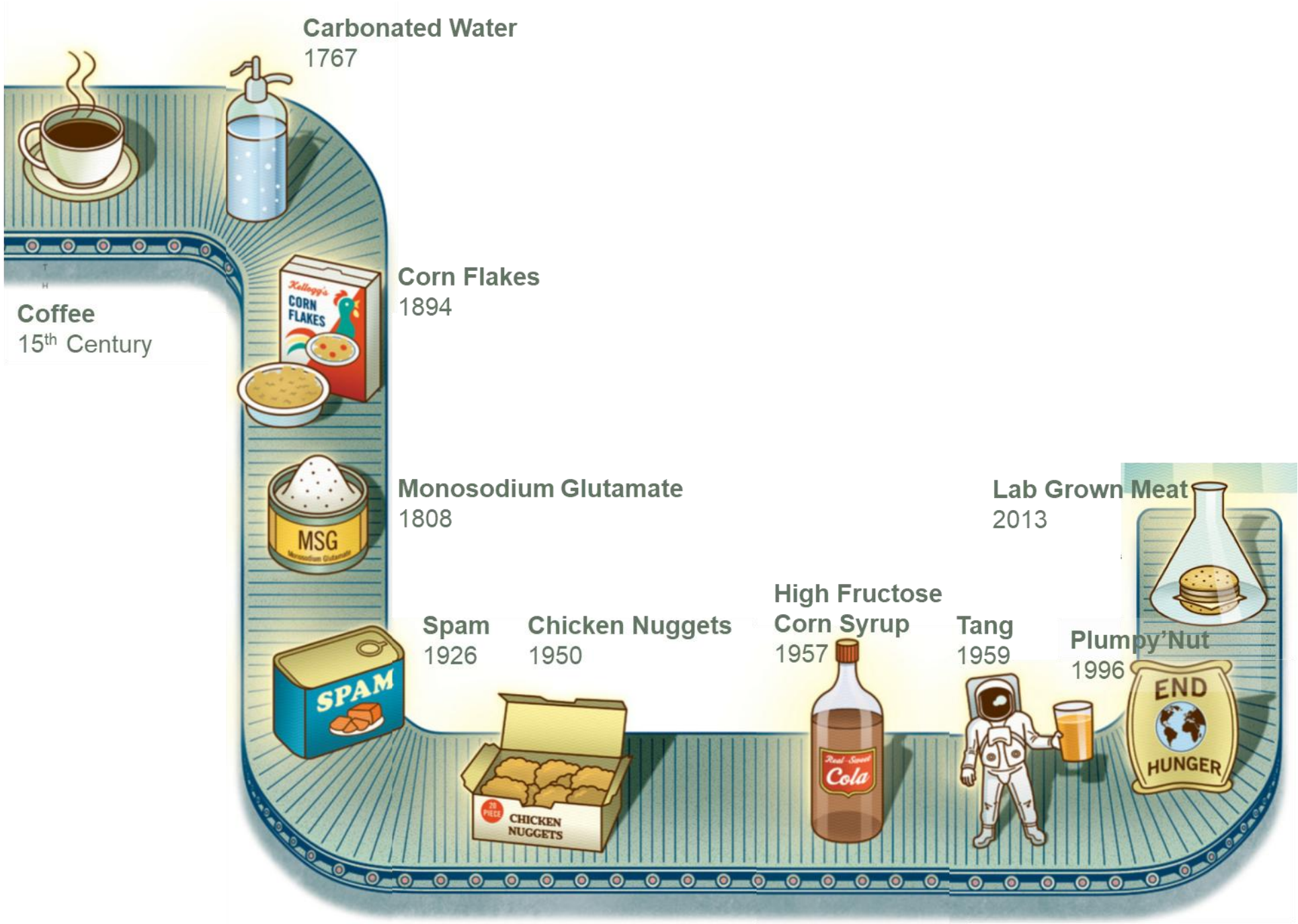
Scientific American, June 2015

Processed Food



Scientific American, June 2015

Scientific American, June 2015



Scientific American, June 2015

Cooking Innovations: Refrigeration

Google Images

Cooking Innovations: Kerosene Stove

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Cooking Innovations: LPG

Google Images

Cooking Innovations: Microwave

Google Images

Cooking Innovations: Pressure Cooker

Google Images

Cooking Innovations: Utensils

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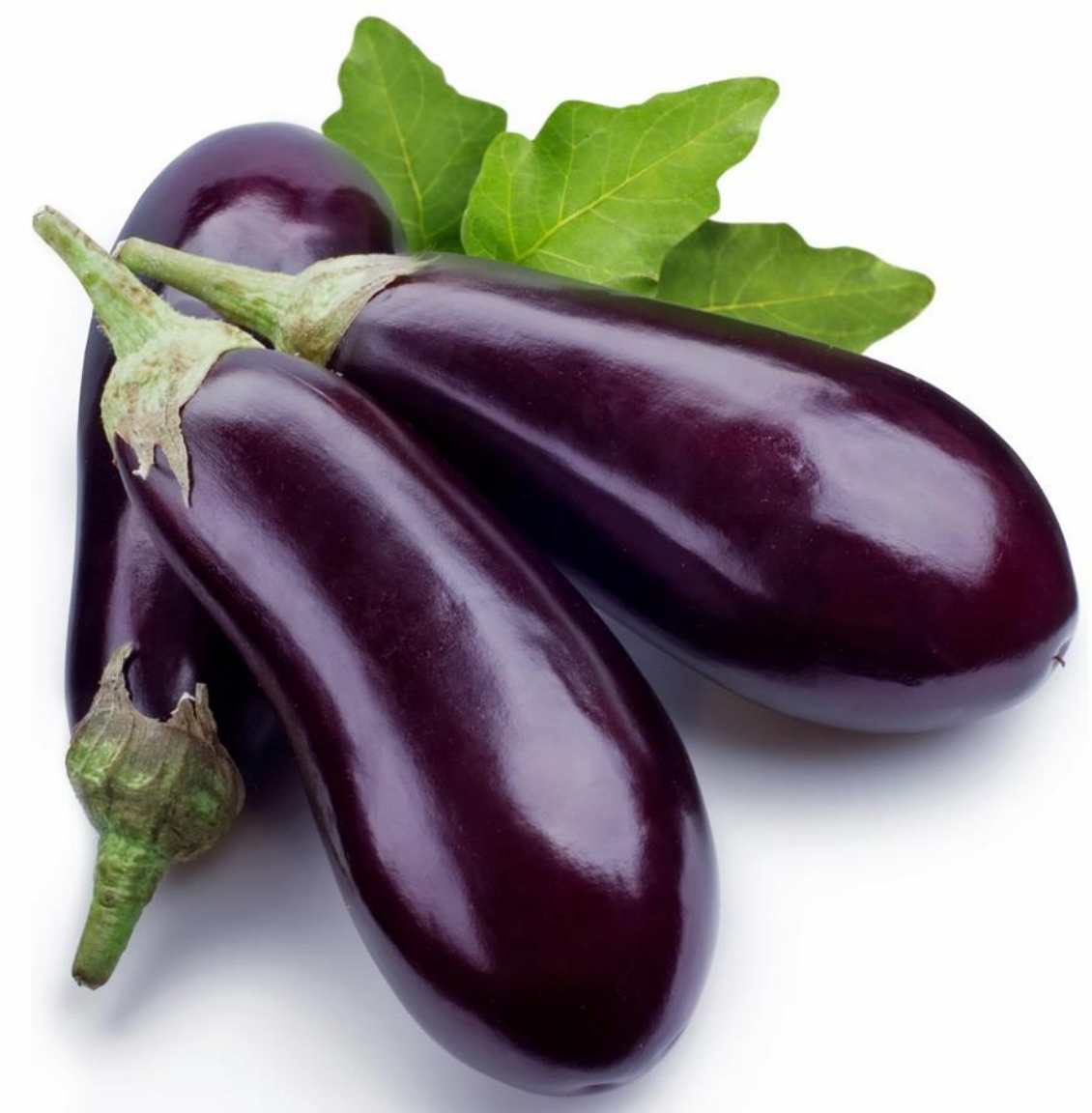
Sugar

New York Times, 2017

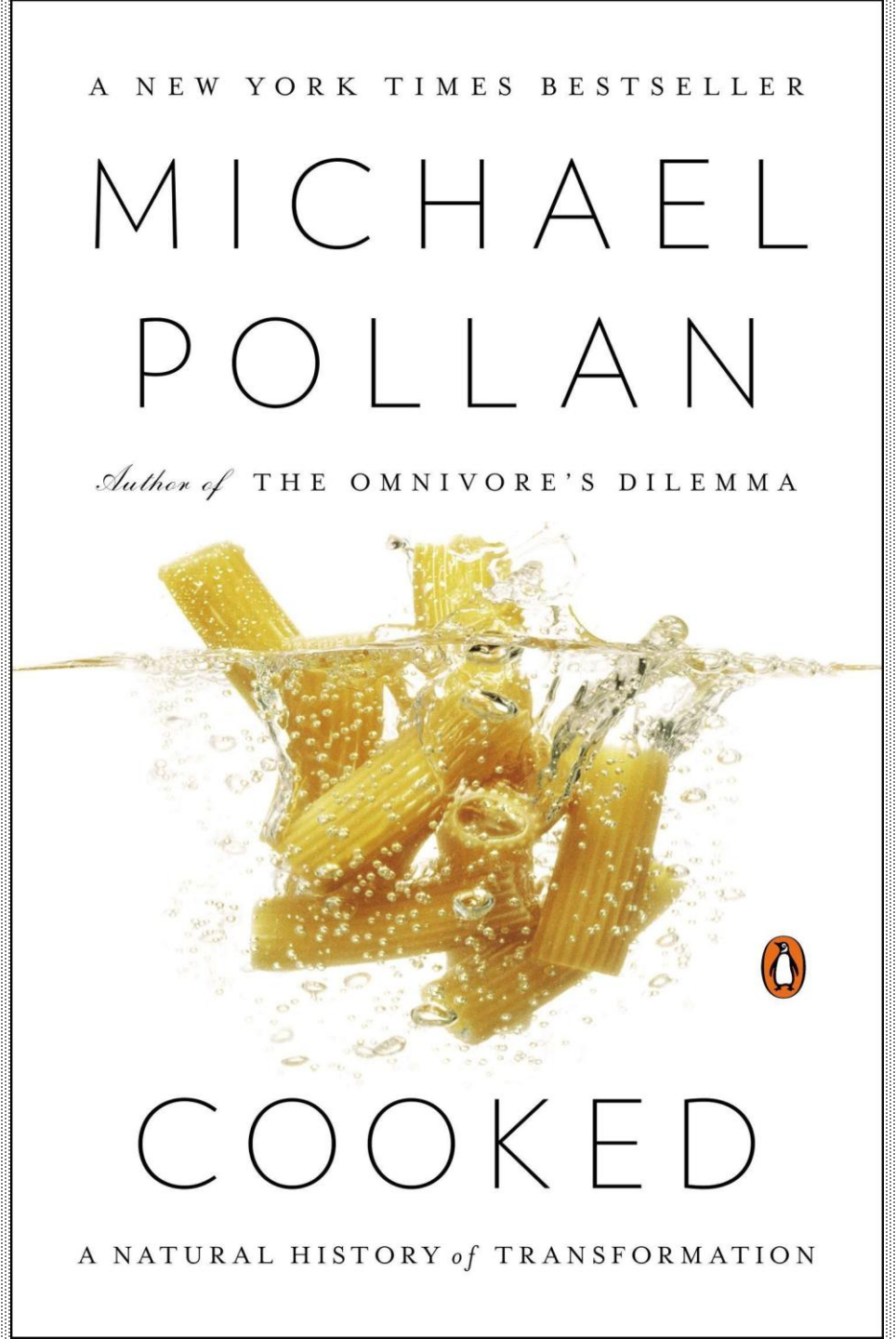
Genetically Modified Organisms



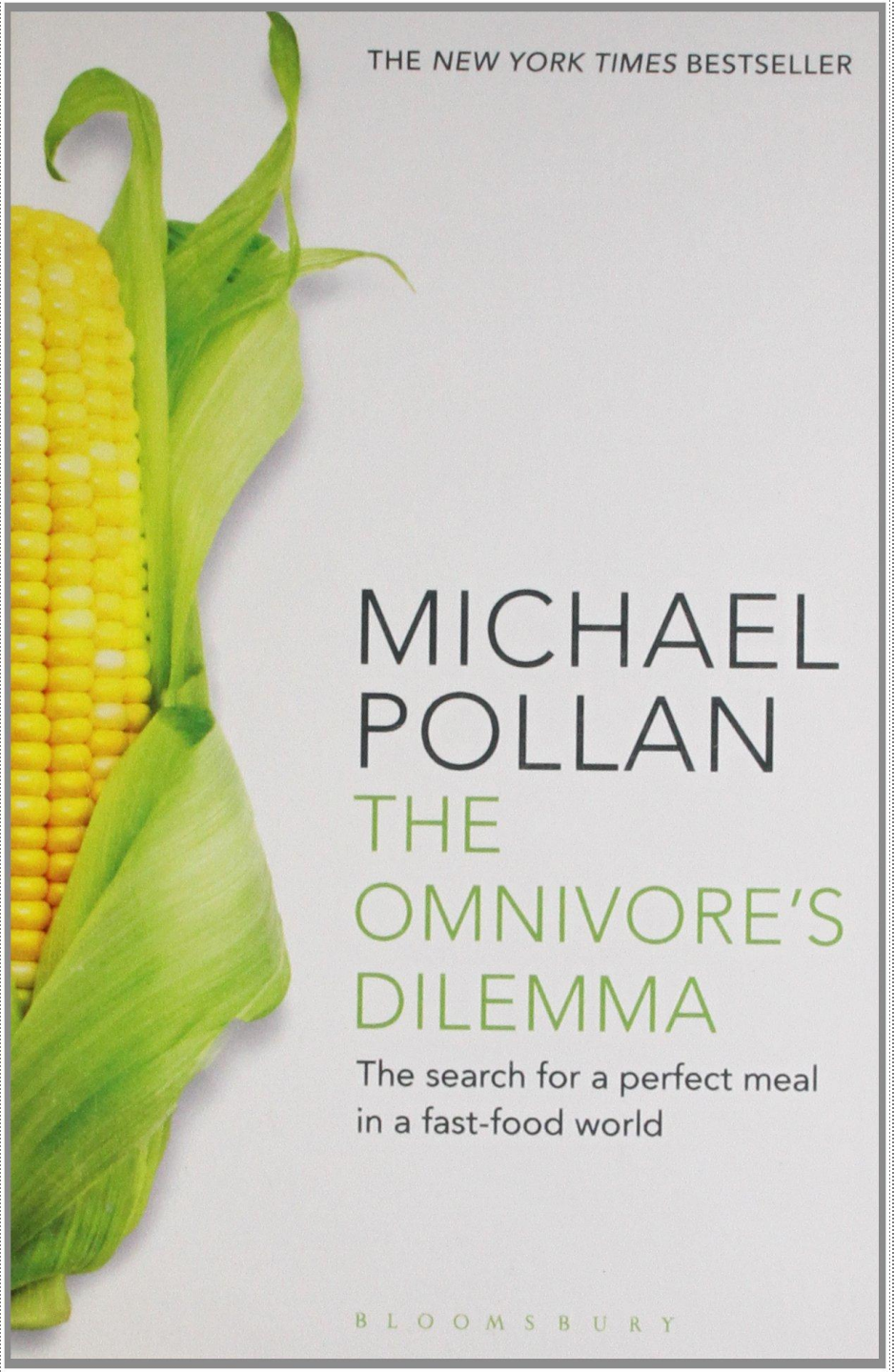
Google Images

The Impossible Burger

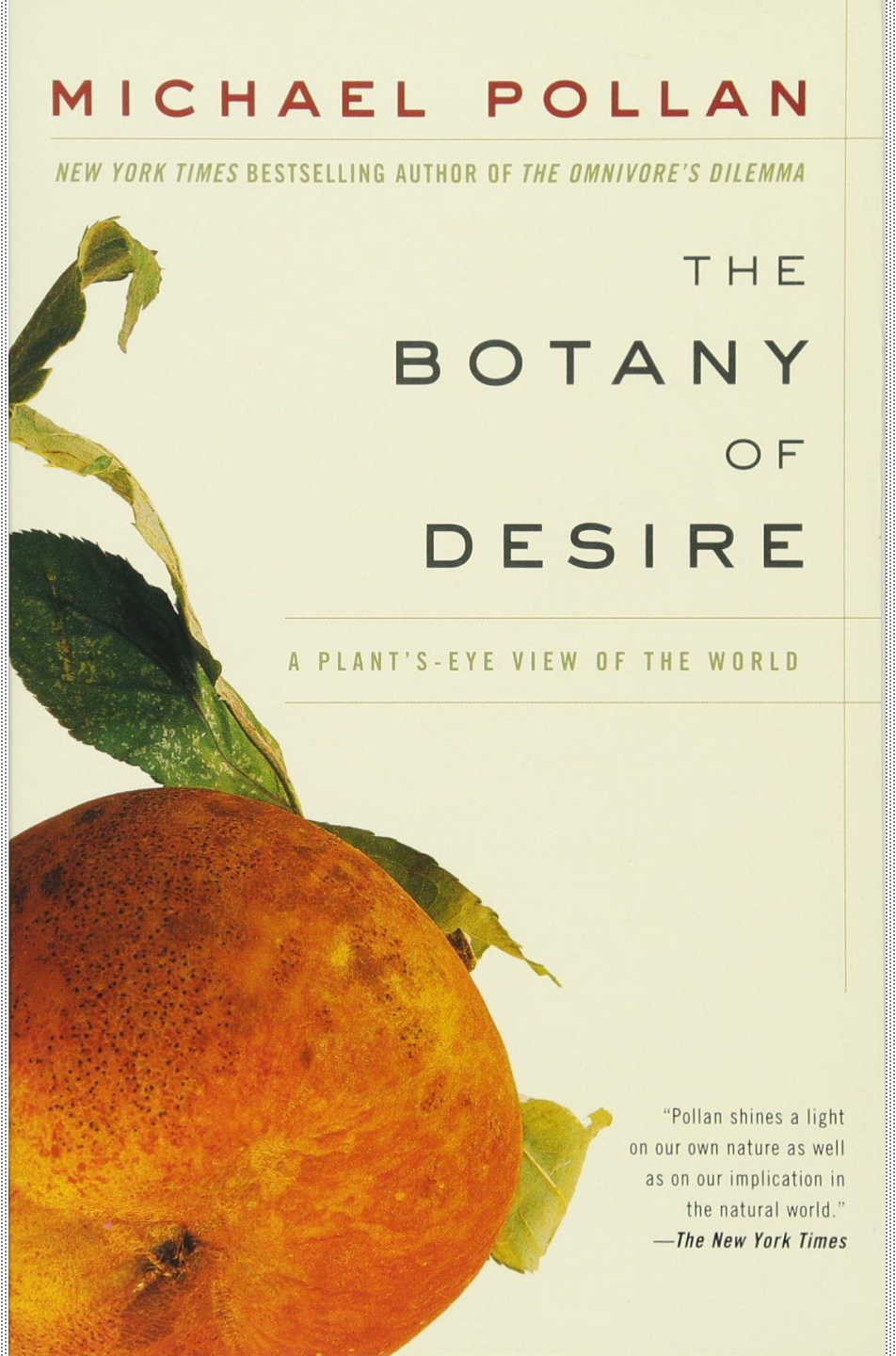
Cooked – Michael Pollan



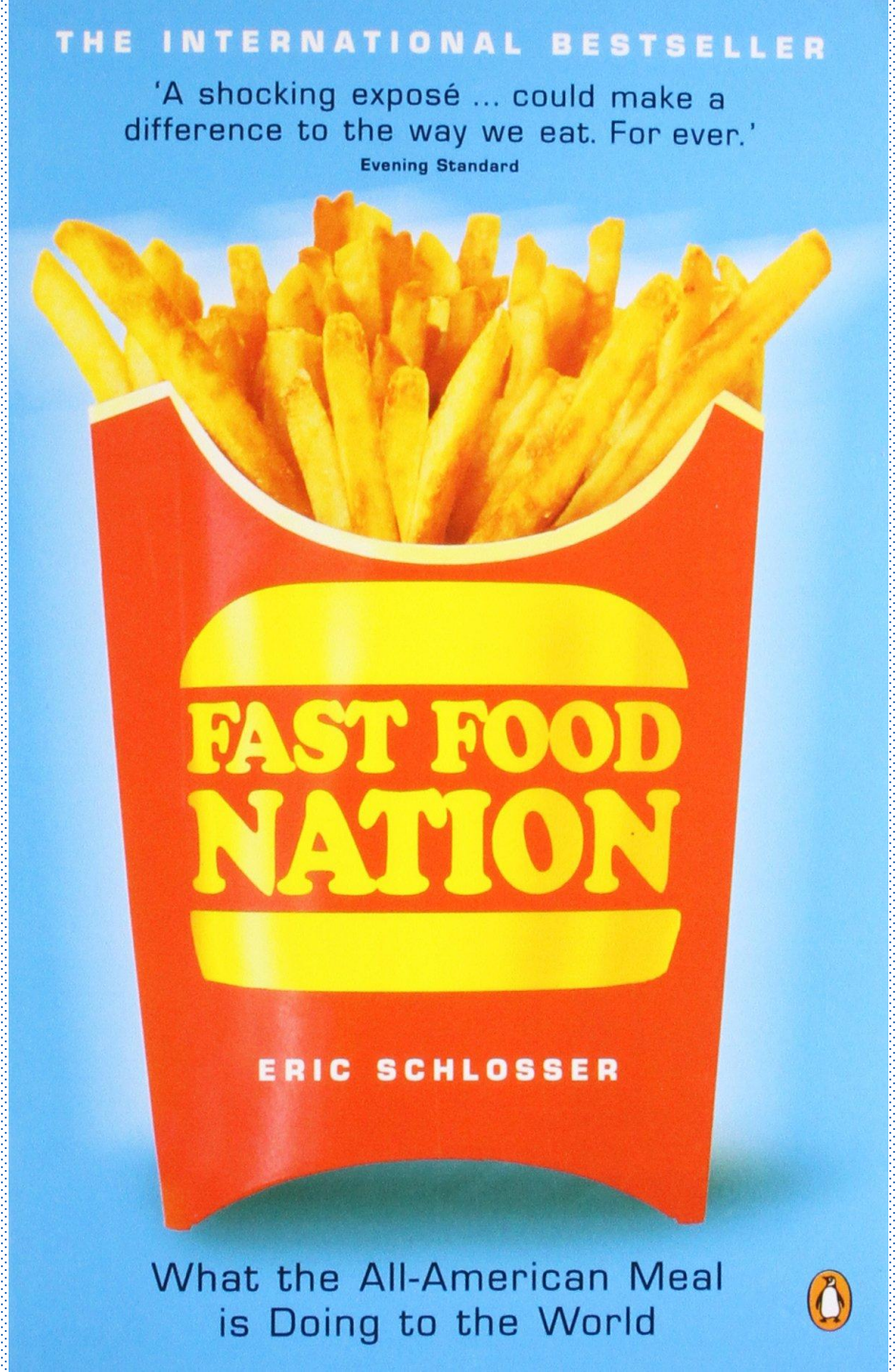
The Omnivore’s Dilemma – Michael Pollan



The Botony of Desire– Michael Pollan



Fast Food Nation – Eric Schlossler




FOOD
Science of taste
Food Pairing
Molecular Gastronomy
Flavors
olfactory-gustatory mechanisms
Trade
travel & food tourism
commercialization
economy
Subway
Kentucky
McDonalds
Starbucks
Food Chains
coke/pensi
nudge
markets (super)
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constipation
allergies
longevity
FOOD-AS-MEDICINE
fasting
Traditional Medicine
spices
medicinal value
antioxidants
probiotics
antibiotics
©blend it like bagler

Five major aspects of Computational Gastronomy Data

1. **Recipes** – Information of recipes that reflects its constituent ingredients.

Further, this could also include details of the temporal sequence of ingredients, the quantity of each ingredient, their state (chopped, ground, etc.), size and the method of processing ingredients (cook, boil, fry, saute, etc.).

Five major aspects of Computational Gastronomy Data

2. Flavor Profiles of Ingredients/Dishes: Every natural ingredient that is used in recipes is primarily selected based on its flavors—taste and odor.

The flavor profile of the ingredient represents the set of empirically reported flavor molecules.

Five major aspects of Computational Gastronomy Data

3. Health Associations of Ingredients/Dishes:

Each ingredient may be associated with the health impacts as identified from experimental studies linking them to diseases.

Five major aspects of Computational Gastronomy Data

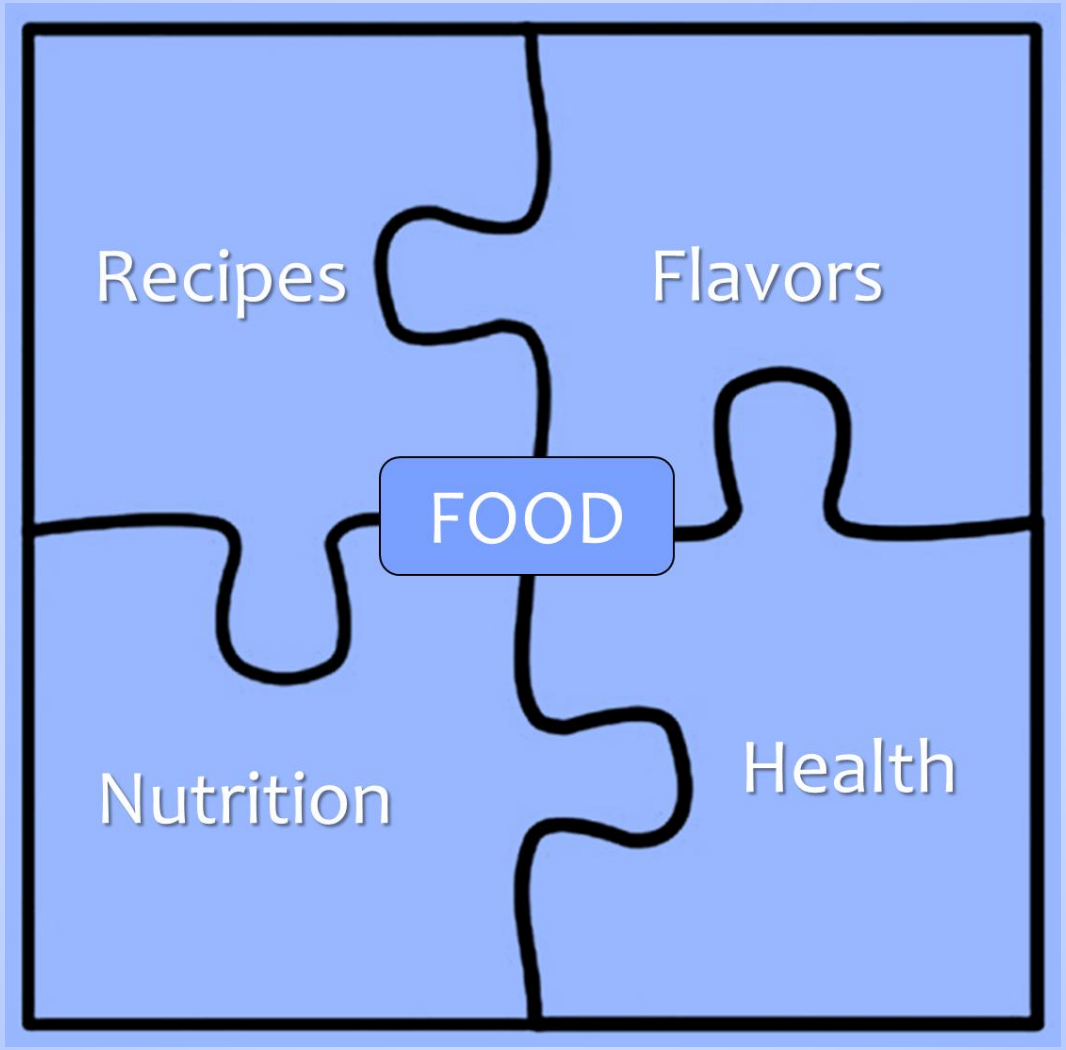
4. Nutritional Profile of Ingredients/Dishes:

Each ingredient can be associated with its nutritional profile, including macro- as well as micro-nutrients.

Five major aspects of Computational Gastronomy Data

5. Carbon Footprints of Food:

Every time we consume food, we leave an ecological footprint on the globe. The carbon footprint of our dietary consumptions consists of around 1/3rd of the total footprint.


Recipes
Flavors
FOOD
Nutrition
Health

Potential Data-Driven Food Innovations

Novel Recipes Design: Cooking is a combinatorial system that combines the raw materials (ingredients) and ways of processing them (cooking rules).

Given that the average recipe uses 10 ingredients and that there are around 1000 unique ingredients, one could create around 10^{30} recipes simply with the power of combinations.

Not every such 'recipe' would be palatable, let alone delicious. Knowing the patterns in the traditional recipes from various cuisines, one could filter recipes that conform to cultural norms.

This requires the use of statistics, data/patterns mining, and natural language processing.

Potential Data-Driven Food Innovations

Culinary Fingerprints: Starting with the tripartite data of recipes, their constituent ingredients and further the flavor profiles of ingredients, one could mine for patterns in traditional recipes to obtain the 'culinary fingerprints' of cuisines.

These fingerprints represent the characteristic pattern of ingredient co-use as well as the idiosyncratic flavor patterns of a cuisine depicting the culinary preferences of a population.

Such insights are of value for food/recipe design for targeted audiences.

Potential Data-Driven Food Innovations

Taste/Odor Prediction: Large compilation of flavor molecules along with their taste/odor attributes presents an interesting case for machine learning-based taste and odor prediction algorithms.

Here the battery of molecular properties (starting from simple ones such as the number of atoms and molecular weight to all the way up to molecular fingerprints comprising thousands of attributes) are features which could be used for building statistical models for classification into taste and odor classes.

Potential Data-Driven Food Innovations

De novo design of flavor/taste molecules: Along with *in silico* methods for generation of organic compounds, taste/odor classification models can enable de novo synthesis of compounds of desirable profile.

Potential Data-Driven Food Innovations

Healthy and Sustainable Diet Design: Systematically curated data on the health impacts of ingredients, along with rules for making recipes, can be used for designing potentially healthy recipes.

Interestingly, such strategies could be used to propel the use of ingredients for promoting a sustainable food culture.

Potential Data-Driven Food Innovations

Healthy and Sustainable Diet Design: Systematically curated data on the health impacts of ingredients, along with rules for making recipes, can be used for designing potentially healthy recipes.

Interestingly, such strategies could be used to propel the use of ingredients for promoting a sustainable food culture.

Food: Forms and shapes

Ingredient Categories: Forms and Shapes

- **Vegetable**: All kind of leafy vegetables (spinach, fenugreek), beans (kidney bean, red beans), tubers (potato, turnip, beetroot) and such.
- **Spice**: Flavorful ingredients primarily from root, bark and seeds. Examples: cumin, clove, cardamom, cinnamon, turmeric etc.
- **Herb**: Flavorful ingredients primarily from leaves and stems of plants. Examples: coriander, thyme, rosemary, mint, basil etc.
- **Pulse**: The fruit or seed. Examples: chickpeas, green gram, back gram, pigeon pea etc.

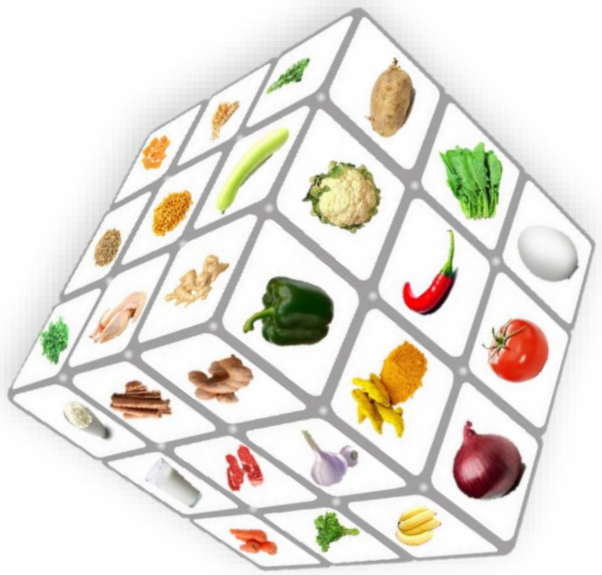
Ingredient Categories: Forms and Shapes

- **Cereal/Crop**: Examples: rice, oat, sorghum, barley etc.
- **Plant**: Examples: tea, thistle, pine, hop
- **Fruit**: Examples: apple, orange, guava, grape, papaya etc.
- **Flower**: rose, jasmine, lavender, artichoke etc.
- **Nut/Seed**: Examples: peanut, walnut, hazelnut, filbert etc.
- **Dairy:** Example: milk, curd/yogurt, butter, buttermilk, cream, cheese, whey etc.

Ingredient Categories: Forms and Shapes

- **Meat**: Examples: beef, pork, mutton, chicken etc.
- **Fish:** Examples: salmon, codfish, tuna, catfish, bluefish etc.
- **Seafood:** Examples: lobster, mollusk, oyster, prawn, shrimp, kombu, kelp etc.
- **Beverage-Alcoholic**: Examples: rum, gin, wine, whisky etc.
- **Beverage**: fruit juice, soft drink, milk shake etc.
- **Additives**: salt, sugar, Monosoldium glutamate (MSG)

Computational Gastronomy: Technology & Food



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