Classification of Unelaborated Culinary Products: Scientific and Culinary Approaches Meet Face to Face

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Short title: Scientific & Culinary Classifications of Food Products

Abstract

The ongoing academization of gastronomic studies indicates the necessity for a commonly accepted classification system for cooks that does not contradict scientific approaches. This work discusses the fundamentals used to classify unelaborated food products by chefs and scientists; proposes taxonomic gastronomy as a new interdisciplinary framework that studies the taxonomy surrounding gastronomy; and presents a categorization of unelaborated food products that follows commonly accepted culinary criteria yet avoids contradiction with scientific knowledge. As little literature focuses on these issues, and similar experiences are scarce, we conclude that further cross-disciplinary endeavors such as this will continue to be greatly fruitful.

Keywords: gastronomy, academization of cooking, classification systems, unelaborated culinary products, plants, fungi, animals, microorganisms, minerals, interdisciplinary approach.

Introduction

One of the oldest and most significant endeavors that human beings have embarked on is to name and classify a myriad of objects surrounding them, especially those used for specifically relevant purposes (Berlin 1992). Outstanding among such entities are living organisms and mineral products used as food and drink, because they have been and continue to be particularly germane for survival and human evolution. In addition, the classification of foodstuffs has been highly important not only on a general scale, but especially for professional cooks, as well as—although many times indirectly—for scientists of various academic fields.

We address in this paper unelaborated products, understanding by this food products that are used directly in cooking activities, not after a process that could transform them, or obtain from them, elaborated products; for instance, an orange is an unelaborated product, but its juice or a jam made with them are elaborated products.

Folk, professional and scientific classifications of unelaborated food products (and their parts) are not requiredforcibly always coincidental between them—or even within them—as the ways in which distinct groups of people observe and conceptualize food can be remarkably different. At the same time, systems and outcomes of such classifications are, certainly, in constant evolution according to the knowledge and beliefs people have in a particular sphere and moment. As an example, the scientific classification of the elements of nature in three kingdoms, i.e., animals, plants and minerals, proposed in 1675 by Nicolas Lemery (Lemery 1713),and popularized by Karl von Linnaeus (Linnaeus 1766), common in textbooks up to the second half of the 19th century (Hogg 1860; Haeckel 1866), was replaced by newer proposals with the development of microscopy, cell biology and genetics, amongst other disciplines and with the incorporation of other major biological groups such as monera (bacteria), protists and fungi (Margulis 1974; Margulis and Schwartz 1982; Woese *et al.* 1990).

New advances in science and cooking —with the ongoing "academization" of gastronomic studies —reflected in many regulated studies for professional cooks, even at a university degree level—point out to the necessity for a commonly accepted system of classification for cooks, that does not contradict scientific approaches, yet very little has been done in this respect. Such a classification system could benefit from previous ones, in order to create a solid and robust categorization structure, which is nevertheless flexible and adaptablive to change. Furthermore, to our knowledge no attempt has been done to analyze and conciliate the classification of food products between scientific and culinary approaches. In fact, no scientific literature seems to address the caveats of classification systems within the sphere of professional cooks, while cooks have usually not addressed the lack of consensus within culinary classifications of food products.

Based on these premises, the aims of the present work are: (i) to discuss the fundamentals used to classify unelaborated food products and their parts by professional cooks on one side, and by scientists (~~organismic~~ biologists studying organisms along with geologists) on the other; (ii) to propose a new interdisciplinary framework—termed here as taxonomic gastronomy—that studies and analyses the taxonomy surrounding gastronomy (e.g., products, tools, techniques), within a systemic approach to food studies; and, (iii) to offer a consensual and flexible framework for the categorization of unelaborated food products (and their parts) derived from the direct collaboration of chefs and academics, ~~that~~ which follows commonly accepted culinary criteria yet avoids contradiction with scientific knowledge.

In what follows, we present the methodology employed in this research, followed by the conceptual background on existing classification systems from both the culinary and scientific points of view. A taxonomy of gastronomy is proposed later, ensued by the consensus classification system reached by co-authoring scientists and cooks, with concluding remarks.

Methodology

This work has been carried out transdisciplinarily by elBulliLab culinary team (elBulliFoundation, led by Chef Ferran Adrià) and the UB-Bullipedia academic unit at the Food and Nutrition Torribera Campus of the Universitat de Barcelona (University of Barcelona). Academic collaborations from the Universitat de Barcelona included~~:~~ the Laboratory of Botany (Faculty of Pharmacy), the Departments of Animal Biology and Microbiology (Faculty of Biology), along with the Department of Crystallography and

Mineralogy (Faculty of Geology). Equally, the Institut Botànic de Barcelona (Botanical Institute of Barcelona, CSIC-ICUB), the Department of Animal and Food Sciences (Universitat Autònoma de Barcelona, Autonomous University of Barcelona), and the Department of Agri-Food Engineering and Biotechnology (Universitat Politècnica de Catalunya, Polytechnic University of Catalonia) also participated during the whole taxonomic process. These teams have defined the multifaceted nature of the resulting understandings and classification system.

This classificatory process began in 2013 by a team of cooks from elBulliLab and a small team from the UB-Bullipedia Unit—by then recently created—with an initial analysis of the state of the art. Such analysis was used to build a first proposal of classification that merged culinary and scientific perspectives. In March-April 2013 ~~the~~ a team of experts from the UB-Bullipedia Unit was created in order to bring together the team of cooks from elBulliLab with academics from the UB-Bullipedia Unit. Various meetings were organized, one every two months approximately. In the light of the conclusions reached in these meetings, elBulliLab team created new versions of the classification, which were then sent to the UB-Bullipedia Unit experts for corroboration. Following this methodology, a first agreement was reached in September 2013; however, it was later on adapted. The second and final agreement was reached in July 2014 and the classification was first presented in September 2014 in the new undergraduate joint degree in Culinary and Gastronomic Sciences offered by the Universitat de Barcelona and the Universitat Politècnica de Catalunya.

In this article, we propose a classification of food products (and their parts) with the idea of converting it into a collectively accepted classification by disparate types of professionals. In concrete, we focus here on unelaborated products (i.e., unprocessed foods such as the apple ~~tree~~, brewer's yeast, chicken or sea salt), leaving the classification of elaborated products (e.g., cider or jam), tools (e.g., pots and pans) and techniques (e.g., ethanol fermentation or jellification) for future work. Moreover, the main target group of this endeavor cannot go unmentioned, i.e., professional cooks. The proposed classification has been built from a culinary perspective and with a culinary purpose, that is, to organize the culinary products in an efficient, practical and understandable way for cooks. However, this is not incompatible with a general and interdisciplinary consensus. Despite this clear cooking-oriented perspective, this classification has considered the scientific views of different fields. In addition, we have limited our scope here mostly to European cuisine, to further delimit our analysis of unelaborated food products.

Conceptual background in the taxonomy of foodstuffs

Interestingly, culinary scientists, anthropologists, ethnotaxonomists or other cognitive scientists have not studied the food classification systems used amongst professional cooks, while folk taxonomies of food products or scientific classifications have been analyzed in much greater detail (Berlin 1967; Anderson 1980; Anderson 2014). We focus first on the poorly-documented conceptual background in the professional classifications of food, followed by a few paragraphs on scientific taxonomies, while leav~~tt~~ing aside folk conceptualizations from our ~~examination~~ scrutiny in this article, as they have been analyzed elsewhere (Messer 1981; Nichter 1986; Manderson 1986; Douglas 1997).

Theoretically, professional cook vocabularies, classifications and categorizations could be considered intermediate between folk and scientific ones, in the sense that they are not carried out with a systematic scientific method, but require the application of some technical aspects that are not necessary in folk thinking (Figure 1). In addition, such gastronomic taxonomies are restricted to a small group of people;~~,~~ that is, they correspond to a specialized or professionalized knowledge.

INSERT FIGURE 1

As previously stated, academically speaking little has been written about how chefs and professional cooks classify food. Historically, cookbooks are collections of recipes, generally only numbered and not grouped under any criteria, such as the Ancient Rome book *De re culinaria* (Apicius 1541) or the medieval *Libre de Sent Soví* (Grewe 1979). From the first attempts to the present day, culinary classifications by professionals have been varied and heterogeneous, while following distinct systematization criteria: La Varenne (La Varenne 1651), for instance, had listed seasonal meat products according to religious dates (e.g., meats from Easter to Saint John's Day); Menon organized foods according to elaborations (e.g., pâté) (Menon 1749); Escoffier classified them according to products, elaborations or even the courses of meals without distinguishing between them (e.g., fishes, sauces, appetizers) (Escoffier 1903). Until recently, these classifications were not explicitly commented upon and were simply used as a base for structuring recipes in books.

More ~~lat~~recently, the nouvelle cuisine chef Michel Bras, following the tradition of French cooks including the innovations of this school, classified dishes in categories such as vegetables, meats, soups, appetizers and desserts (Bras 2002). Chef Joan Roca (Roca 2014), in turn, used the following categories: vegetables; fruits; herbs, spi~~e~~c~~i~~es, flowers and sprouts~~; at the pantry~~; fish; seafood and cephalopods; and meats. Since Ferran Adrià became chef of elBulli at 1985, his team showed an increased interest in the classification of culinary products and gastronomic knowledge in general. The initial volume of the first catalogue of dishes ~~catalogue~~ published~~,~~ already presents a classification of culinary products: waters, nuts, fish, eggs, preserved foods, wines, etc (Adrià *et al.* 2002). When Adrià ended elBulli's culinary activity (in 2011), he devoted himself even more to ~~the~~his reflection -shared with members of the academy- on several gastroculinary aspects, among which the classification of products, which he did not consider to be sufficiently resolved. An evolution of such ideas, reflections and work is the classification presented in this article.

Classification systems of food products amongst scientists vary according to the discipline, be it biology, nutrition, food science and technology, agronomy, geology, chemistry or physics. The bases for such taxonomies are in direct relation to the core subject in each discipline, varying from organisms, nutrients, agronomic units, minerals, molecules, ~~to state and change just~~ to name just a few. New approaches and methodologies allow constant evolution of such concepts and their categorizations. For instance, conceptual frameworks and categorization proposals for living organisms in science have varied greatly through time (Morton 1981). The first classification systems were far from using biological characters; Pedanius Dioscorides (1st century AD), for example, classified plants, animals and inorganic products by their uses. Later on, artificial systems such as the one created by Karl von Linnaeus in plants, started to consider biological traits, but only a few of them. The natural method—formulated in its more complete form by Augustin Pyrame de Candolle (19th century)—aimed to use a representative diversity of traits for classification purposes. After Charles Darwin (19th century), phylogenetic systems could adopt evolutionary concepts. Later on, important efforts have been mad~~done~~e to incorporate to systematics not only morphological characters, but others such as chemical, cytogenetic as well as genomic (Stuessy 2011).

The above-mentioned classical classification of living organisms in a two-kingdom system was first questioned by Haeckel (1866), who, additionally to plants and animals, established the kingdom of protista, which comprised mostly single-celled organisms such as the protozoa, bacteria, and some algae and fungi. From then on, several changes have been made in this classification, with the proposal of different numbers of kingdoms (Margulis and Chapman 2009), which facilitate classifying all kinds of organisms into discernible groupings. Nevertheless, the biggest paradigm change in biological classification w~~h~~as~~ been~~ facilitated by the discovery of the polymerase chain reaction (PCR) (Saiki *et al*. 1985), and its great potential in DNA sequencing, leading, from the 1990s, to molecular systematics. To summarize, nowadays, based on and developed from Woese *et al.* (1990), living organisms are classified into three big domains (two of which are composed of prokaryotes, i.e., microorganisms without a nucleus), and what was classically considered as plants or animals are nowadays split into four kingdoms. Detailed-level classifications are today in process such as the 'Tree of life project' (Maddison and Schulz 2007), but the simple long-established animal/plant dichotomy prevailing until the 20th century, clearly is no longer of use. For a thorough analysis of the evolution of taxonomic systems in biology during the last century, see Williams and Forey (2004). Mineral products are kept apart from living organisms as ~~it~~ has been the case from the onset of~~ancient~~ the three kingdoms of nature of antiquity.

Taxonomic gastronomy: A new approach to professional cooking and science

Over the past years, gastronomic sciences have become a new frontier in academic fields and the professional world of cooks, with increasing holistic and transdisciplinary approaches to food and gastronomy (Caporaso and Formisano 2015). Nonetheless, the relationship between science and cooking is long-standing and has provided a foundation for the academization of cooking, although classification systems from both sides have not yet converged. In the 19th century, explicit references existed already to such a relationship (Accum 1821; Liebig 1847; Kellogg 1895).

In the 20th century, two crucial moments are the talk by Nicholas Kurti at the Royal Society titled "The physicist in the kitchen" in 1969, and when in 1992 the term “molecular gastronomy” was coined in the framework of the “Workshop on Molecular and Physical Gastronomy” by the scientists Harold McGee (1984), Hervé This (1993), and Nicholas Kurti (1988), the three most relevant figures of the molecular gastronomy movement. In 2007, Chef Ferran Adrià was the recipient of an Honorary Doctorate from the Department of Chemical Engineering at the Universitat de Barcelona and in the same year he delivered his first conference at Harvard University entitled “Cooking and Science with Ferran Adrià”. This conference was the first step towards the launching in 2010 of the annual course on “Science and Cooking” in the Physics Department at Harvard University. Also w~~W~~orth mentioning is ~~also~~ the emergence of the field of computational gastronomy, which consists in applying massive data analysis (big data) to gastronomic knowledge (Ahnert 2013). Specialized workshops such as “Computational Gastronomy: Food in the Age of Data” are proof of the interest of this new research field. Philosophy and arts are also turning their focus o~~i~~nto gastronomy; an example of this is the subject “Gustatory Aesthetics” within the undergraduate studies of Philosophy at the Universitat Autònoma de Barcelona.

Moreover, university level studies on cooking and gastronomy are being created, such as the ones offered at the Università degli Studi di Scienze Gastronomiche (University of Gastronomic Sciences in Bra, Italy), the Master of Liberal Arts in

Gastronomy at Boston University Metropolitan College or the new Bachelor's Degree in Culinary and Gastronomic Sciences offered by the Universitat de Barcelona and the Universitat Politècnica de Catalunya. These are just a few examples of what we can call the emerging academization of cooking. Last but not least, another sign of the emergence of culinary science is the increase in SCI- and/or SSCI-indexed journals dealing with professional cooking and the science behind it, such as *Flavour, Food, Culture and Society, Food Research International*, ~~or~~ *Food Reviews International* or *International Journal of Gastronomy & Food Science*. This academization process has led to the emergence, in the intersection of the areas of science and cooking, of a thought collective (Fleck, 1935), i.e. a community of people participating in a mutual exchange of ideas and intellectual opinion, which has been, among other things, the breeding ground of the consensus classification here presented. In fact, the above-mentioned academization process means the crystallization of a new academic discipline, which is interdisciplinary by nature and entails the need for a reconceptualization of concepts coming from other disciplines. For example, the parsley is seen and has to be defined from a different perspective in integrative gastronomic sciences than in botany or in cooking as considered separately. Gastronomic sciences cannot be the sum of their sibling disciplines, but require a change of paradigm and a process of distillation, to which the present paper–built by representatives of different approaches converging in the gastronomic sciences thought collective–aims to contribute.

Following this trend, we propose here a new branch within the systemic research approach to gastronomy: taxonomic gastronomy. Taxonomic gastronomy encompasses the scientific study of the description, identification, nomenclature, and classification of culinary products (unelaborated and elaborated), along with tools and techniques used for cooking. Such a definition is especially suited (but not exclusively) for systems of food classification by professional cooks in present and past times. As molecular gastronomy did (see above), taxonomic gastronomy requires a similar framework that combines contributions from two major human spheres: the culinary arts and a myriad of scientific disciplines, mainly physical, analytical and organic chemistry, biology, geology, nutrition, and food science and technology.

Hav~~Be~~ing set the background~~ set~~ in previous sections, in the following stage~~,~~ we present the taxonomic scheme of the classification agreed upon between chefs and academics, along with its different divisions, subdivisions and components.

Consensus classification for unelaborated culinary products

The classification system consensually obtained by scientists and expert cooks for unelaborated products is based on consecutive subcategories, beginning from living beings vs. inorganic materials, further subdivided into worlds and, in the case of living beings, into specific organisms and their anatomical parts (Table 1).

INSERT TABLE 1

Within unelaborated food products, two mutually exclusive categories were established: living beings and inorganic materials, the former with three subcategories (here known as "worlds") and the latter with two. On one side, the three living worlds include a joint category of plants and fungi (considered together, but as distinct groups, owing to the tradition of them being studied under the discipline of Botany), and two additional categories, that is, animals and microorganisms. A previous consensual arrangement following the kingdoms of living organisms was discarded, as a complete agreement does not exist among biologists on the number and delimitation of these kingdoms and, in addition, we did not find any of those classifications to be, in our opinion, functional and simple enough for culinary products. We adopted the term “world” to define each unit, because it did not bear any biological taxonomical connotation and it is clear, evocative and intuitive. Within each group of organisms, according to their main habitat along with morphological and phylogenetic relations, distinct categories can be found, where the primary level corresponds to the biological species in question (e.g., lemon tree or trout), and following levels vary according to distinct groups of organisms (e.g., peel of lemon or trout fillet). Such levels, which are very relevant to cooks, reflect one of the many contributions of gastronomy to the consensual taxonomy presented. On the other side, within inorganic materials two worlds were established: the world of waters and the world of minerals, and within them further categories were created according to their origin. For greater detail on the taxonomy and categorization within living beings see ~~Annex~~ Table 2~~1~~, and for inorganic materials see ~~Annex~~ Table 3~~2~~.

I- Living beings

For all living beings, we basically follow the most recent biological classifications, some of them still in construction, at least at the lower taxonomic levels, according to the evolution of molecular datasets. Comprehensive projects, such as Tree of Life (Maddison and Schulz 2007), along with some other restricted to specific biological groups, such as the Angiosperm Phylogeny Website for plants (Stevens 2013), the List of Prokaryotic names with Standing in Nomenclature for bacteria (LPSN 2015), and Introduction to the Metazoa for animals (UCMP 2015), may provide ideas on the state of the art in biological systematics. However, this classification being conceived as a consensual one between different professional worlds (scientific and gastroculinary), these strictly biological scenarios could not be completely followed. For example, we could not use the structuring of life in several kingdoms (Margulis and Chapman 2009), because it did not work at a convenient and convincing level to both scientific and ~~cook~~ culinary professionals. Therefore, the classification of living beings was finally structured in what we called “worlds” (to avoid words such as “kingdom” or “domain”, with more biological connotation): plants and fungi (with both groups clearly mentioned); animals; and microorganisms. This classification does not strictly fit with current biological systematics and phylogenetics, but is understandable for all professionals and does not fall outside biological logics. As shown later, some major groups in the plant and fungi, and animal domains have been established on the basis of habitats, which does not constitute a biological systematic criterion, but is adequate for cooking professionals, and makes the incorporation of new gastronomic groups, whenever necessary, easier. In another case, cooks had to avoid the use~~ing~~ of the term *family* for some food products (and to replace it with *category* or *group*), because such a term has a different and concrete sense in biological systematics. In the following paragraphs we explain and exemplify the solutions adopted for the different groups of living beings. The distinction between wild and cultivated (plants and fungi) or raised (animals), not relevant in biological classification (irrespective of the existence of infraspecific taxa and races), has been ado~~a~~pted, ~~a~~since it is meaningful for culinary~~cook~~ professionals.

a) Plants and fungi

Following the above-mentioned habitat criterion, within the world of plants and fungi (~~Annex~~ Table 2~~1~~A), a first distinction between terrestrial and aquatic organisms is mad~~don~~e, establishing four subgroups, two for terrestrial (plants and fungi) and two for aquatic (macroalgae, and bryophytes and vascular plants); note that~~n~~ in the terrestrial habitat we do not explicitly mention bryophytes, as they are comprised within plants, but in the aquatic habitat we must separate the three stated categories, all of them belonging to plants, and fungi are not mentioned, since to date no aquatic fungus has culinary uses.

Within terrestrial plants a distinction is made between grasses, subshrubs, shrubs, lianas and trees. Within fungi, three groupings are proposed: ascomycota, basidiomycota and lichens. Within macroalgae, three types are distinguished: green, red and brown algae. Aquatic plants, all herbs, do not contain further subgroupings. It is to be noted that different criteria have been used in the classification of different organisms, for the sake of consensus. For plants the differentiation does not fit at all with taxonomical categories, but with life forms, which are much more intuitive. For instance, the distinction between pteridophytes and spermatophytes or that between gymnosperms and angiosperms has been avoided, as well as the lower categories (e.g. monocots, core eudicots, asterids…), because it was meaningless for cooking professionals. Conversely, for fungi and macroalgae, the basic biological categories have been followed (e.g. ascomycetes, red algae).

The aspects commented above deal with what we have called primary level, i.e., the whole plant or fungal organism. The secondary level consists of parts of plants or fungi (e.g. leaves, branches with leaves, fungal stipe) and the tertiary is composed of parts of parts of those organisms (e.g. seeds, peduncles). Those levels contain different categories depending on the primary level. These parts of plants or fungi, again, do not exactly fit plant and fungal morphology, but are not against it, and function without problems for culinary~~cook~~ professionals. One case is the parts we named "fruits, fructifications and infructescences"; for cooking professionals, "fruits" was convenient, but they did not object to the larger and multiple term, which was correct from a scientific point of view. See ~~Annex~~ Table 2~~1~~A for greater detail and some more examples than those here provided.

In some cases, the search for a compromise between scientific and culinary~~cook~~ professionals le~~a~~d to the proposal of a neologism. Cooks termed "albedo" the white tissue found in figs (*Ficus carica* L.), by analogy with the similar part in citric fruits (*Citrus* sp.). This was not correct from a botanical standpoint, as oranges and their relatives are fruits, but figs are infructescences. Finally, we agreed in proposing the term "pseudoalbedo" for such a structure in figs. Nevertheless, terminological proposals of this kind have to be further analyzed also with linguists.

b) Animals

The world of animals (~~Annex~~ Table 2~~1~~B) establishes an arrangement that, being scientifically correct, allows cooks to classify animals and their derived products easily and comprehensively. An agreement was reached to cluster animals according to their habitat: aerial, terrestrial, aquatic and terrestrial-aquatic. In each environment up to four levels have been contemplated, from primary to quaternary.

A following step included taking into consideration the different groups with a culinary interest, to be included in each of these categories. In the primary level (whole organism), the zoological groups selected are presented in ~~Annex~~ Table 2~~1~~. Within each environment, the criterion used to arrange categories has been to consider most consumed culinary groups. Such ordering allows, as new gastronomic groups arise, to add to the corresponding type. In some cases, such a classification has required certain adaptations to reality. Insects are probably the most complex case, with several species being edible. When we think about insects we imagine terrestrial organisms that move in the air, hence being included within aerial organisms. But most edible insects have terrestrial larvae, which are generally more gastronomically valued than adults, while larvae live longer than adults. That makes it difficult to include them undoubtedly within the aerial or terrestrial habitat, hence its being more practical to consider their aerial habitat when the adult is eaten, and the terrestrial in the case of larvae. Other examples include mollusks, which comprise terrestrial and aquatic organisms, and within the latter, marine and freshwater. In such circumstance each species is located where it corresponds. On the other hand, reptiles, generally terrestrial (e.g., lizards, snakes), also consist of taxa such as turtles that can be terrestrial and aquatic. Marine turtles, even having an aquatic life, reproduce ~~i~~on ~~the~~ land. The opposite occurs amongst amphibians, ~~which~~ most of which have a terrestrial life (e.g., toads, frogs) yet reproduce in aquatic environments.

While ordering groups within categories in each habitat, criteria of biological taxonomy have prevailed. This has been easier in certain cases but had to be adapted in others. Birds, for instance, are situated in the aerial environment. Within such grouping, organization follows taxonomic criteria: Galliformes, Estrucioniformes, Passeriformes, Anseriformes, etc. The advantage behind such a structure is that, if a bird starts to have culinary interest and is not represented by the existing orders, it only needs to be added ~~up~~. Internal classification for mollusks has been simple as there exist three zoological groups: bivalves (e.g., clams), gastropods (e.g., terrestrial and marine snails) and cephalopods (e.g., squid, cuttlefish and octopus). In the terrestrial environment all are gastropods, and in the aquatic there is only the need to differentiate marine vs. freshwater species. In other taxa, adapting to culinary criteria was more practical. Such is the case of mammals. In such a cluster, a bio-taxonomic ordering was followed:

bovids, porcines, etc. Nonetheless, for bovids–a group that includes most edible mammals (e.g., veal, sheep, goat and buffalo)–such grouping under its taxonomic name, popularly evoking mostly cow and related animals, is not discernible enough for a cook. In such case the taxon has been subdivided into bovine bovids (e.g., veal, cow and ox), ovine bovids (e.g., sheep, lamb), caprine bovids (e.g., kid, goat) and other bovids (e.g., buffalo, bison). For crustaceans–all aquatic–we have opted for a practical classification, taking into account the means of locomotion. Three categories have been created: swimmers (moving in a water column such as shrimp, lobster and langoustine), walkers (moving on top of the substrate such as brown crab and velvet crab) and cirripedia (living fixed to the substrate such as barnacles). Not all crustaceans are marine;~~,~~ there are also freshwater species such as the river crab. ~~For~~ In the case of other groups with very specific characteristics, for instance echinoderms (sea cucumbers), tunicates (sea potato) or cnidarians (sea anemones, jellyfish), ordering has been easier.

The secondary level includes the morphological parts easily identifiable externally, in which the animal can be divided, i.e., head, body and extremities. Nevertheless, not all animals have their bodies anatomically organized in the same manner and this affects the number and structure of pieces used in the kitchen. For instance, adult insects have their bodies divided in head, thorax (includes legs) and abdomen, while larvae have their head differentiated from the rest of the body. In crustaceans, decapods (the most valued, i.e., shrimp, crab) have their body divided in cephalothorax (fusion of head and thorax including legs) and abdomen (known as tail). For fish, the body is simplified and the head, body and fins are recognized. The most complex case is for terrestrial vertebrates, such as birds and mammals where main parts are identifiable but their utilization requires the establishment of more parts. The neck belongs to the trunk yet gastronomically is treated separately. Further, a distinction is also needed between anterior extremities (wings, shoulders) from posterior (thigh) although usually, combinations of parts occur (e.g., forequarter, hindquarter and half carcass).

The tertiary level refers to the parts of the parts (secondary level), with examples such as the brain or the tongue as parts of the head. In the world of animals, in contrast to that of plants and fungi, a quaternary level was necessary. It corresponds to the tissues, such as tendons, which can come from different parts of the animal body. Not all groups of animals have the four above-described levels. An interesting challenge has been to describe the derived products. At ~~the beginning~~first, it seemed clear to define a derived product as a product obtained from an organism without causing it any injury. It could include some resins, pollen or nectar in the case of plants and eggs or milk in the case of animals. The problem appears when facing immature eggs or blood of animals, which cannot be obtained without damaging them. In this case we decided to treat them as quaternary level items.

c) Microorganisms

Even though~~if~~ it has some important representatives, the world of culinary microorganisms (~~Annex 1~~Table 2C) is much small~~hort~~er. It has been structured in four groups: viruses, to date without culinary use; bacteria (including archaea), comprising organisms such as lactobacillus and the blue-green algae or cyanobacteria (among which *Spirulina* sp. is well known in cooking); protozoa and microalgae, to which, for instance, *Chlorella* sp. belongs~~ to~~; and microfungi (unicellular and filamentous ones), including yeasts and molds. In this case the transactions for a consensus have led to consider in the microbiological world some animals (protozoa), some plants (microalgae) and some fungi (microfungi), apart from the genuine microorganisms (viruses, archaea and bacteria). Their microscopic condition, clearly intuitive, has primed over the strict biological classification, although not being in contradiction with it. As ~~it~~ is logical, no different (primary, secondary…) levels are distinguished in this world.

II- Inorganic materials

Regarding the inorganic materials classification (~~Annex 2~~Table 3), two different worlds have been considered, i.e., waters and minerals. For the two cases, previously used classifications in gastronomic scena~~e~~rio~~e~~s have been modified and adapted by applying scientific standards. As an example, scientific terms such as *geological origin* or *crystal morphology* and *crystal size* were employed in order to develop the classification of waters and minerals, respectively. The main criterion used to carry out such a classification distinction in both~~e two~~ cases was the origin of the material. However, some additional aspects related to each world should be taken into account.

d) Waters

Most commonly used classifications for potable waters are based on their composition in major cations (such as Na^{+}, Ca^{2+} or Mg^{2+}) and anions (CO_3H^{-}, Cl^{-}, SO_4^{2-}, F^{-}, SH^{-}, etc.) (Domenico and Schwartz 1990), which strongly depends on the travelled paths through their evolutionary history. In the present work, we classified the world of waters (~~Annex 2~~Table 3A) according to their origin: superficial, subterraneous and seawater. The superficial waters category includes river, lake and glacier waters (all of them being non-carbonated waters), whereas the subterraneous waters category comprises natural mineral and natural spring waters, which can be non-carbonated or carbonated through natural and/or artificial methodologies. Subterraneous waters eventually emerge from below the Earth's surface or they can be forced by using specific techniques. Nevertheless, the main difference between natural spring and natural mineral waters resmaidens ion the fact that natural spring waters are not characterized by their mineral composition, so thusat ithey can become variable. As to natural mineral waters, only two actions are permitted: i) to modify and normalize the carbon dioxide content; and, ii) to reduce or eliminate the presence of unstable compounds in order to avoid unpleasant flavors and/or colors.

e) Minerals

The most commonly used classifications for the world of minerals (Annex 2Table 3B) is based on their chemical composition and structure (Gaines *et al.* 1997), where, according to new actualizations, biominerals, understood as minerals produced by the activity of living things (e.g. bones, shells), may also be considered. In the present work, we focused on common salt (sodium chloride, with mineral name of *halite*), which is commonly used in cooking, and, depending on its origin, it may provide specific characteristics to the end food product. As an example, one may note that pink or black colored fossil salt may occur due to the presence of other minerals impurities. In the different types of salt obtained from salt lakes and salt flats, such as flower of salt or salt flakes, the different crystal morphologies may play dominant roles for determining some physical properties (e.g. rapid solubility) which may be directly applicable to specific food products.

As in other scientific classifications from the periodic table of elements to molecular taxonomy of living beings, the current classification will evolve according to new parameters and criteria, while maintaining its culinary application. Nonetheless, the essence of the classification will not change drastically.

Concluding remarks

The existing gap in the taxonomy of professional cooking, with the interaction between cooks and scientists has allowed the creation of a combined system of classification that is useful for cooks and consistent with scientific knowledge. Such a new taxonomy establishes five worlds (plants and fungi, animals, microorganisms, waters and minerals) each with a variety of hierarchical subcomponents, mutually exclusive and subdivided into distinct levels according to their parts.

The resulting classification generates a flexible ordering, highly practical, that allows modifications and new introductions without changing its main structure. Hence, it is not a closed system but a taxonomy allowing all incorporations that may rise. Being conceived to be flexible enough to adapt to change when needed, it intends to be valuable for professional cooks as well as for food scientists, amongst others.

Despite major background differences between botanists, zoologists, microbiologists, mineralogists, nutritionists, food scientists, agronomists, chemists, linguists, cooks, and people from other disciplines, a diverse team has worked side by side on the project, obtaining an overall agreement in the resulting classification.

We hope that this classification system will be useful in the classroom, as well as at home and in restaurants, for chefs, bartenders and foodies. This classification is already part of the curriculum of the new undergraduate studies in Culinary and Gastronomic Sciences (Universitat de Barcelona and Universitat Politècnica de Catalunya) with the idea of being later included in other culinary studies.

We are now in the process of the categorization of most common ingredients in Western cuisine–over a milliard–into the different ranks, levels and categories. Future work in this taxonomic effort will involve the classification of elaborated products, i.e., those having undergone some kind of processing (e.g., bread or guacamole), in addition to cooking tools, techniques, and other culinary aspects. We are also working o~~i~~n the terminological analysis and standardization of all the terms that appear in the classification. We are focusing, at this point, on the Catalan language and we are working together with the linguistic services of the Universitat de Barcelona and TERMCAT, the center for terminology in Catalan of the Government of Catalonia.

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Disclosure statements

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Figure caption

Figure 1: Classification systems of food (simplified) by different human groups

Table 1: Classification of unelaborated products: living beings

Unelaborated product	World	Main habitat	Group of organisms	Primary level (biological species)	Secondary level	Tertiary level	Quaternary level	Examples of levels*
Living beings	Plants and fungi	Terrestrial	Plants	Grass	Root, stem, stem with leaves, leaves, flowers & inflorescences, flowering aerial parts, and fruits and infructescences, seeds	Types of specific organs, specific tissues and parts within organs	n/a	*Triticum aestivum* (wheat)-seed-endosperm
				Subshrub				*Rosmarinus officinalis* (rosemary)- leaf-parenchyma
				Shrub				*Sambucus nigra* (elderberry)-inflorescence-
				Liana				*Humulus lupulus* (hops)-inflorescence
				Tree				*Mangifera indica* (mango)-fruit-mesocarp
			Fungi	Ascomycota	For some species: stalk, cap	Specific tissues and parts within organs	n/a	*Tuber melanosporum* (black truffle)
				Basidiomycota	Stalk, cap			*Agaricus bisporus* (portobello mushroom)-stalk & cap
				Lichens	n/a	n/a		
		Aquatic	Macroalgae	Green algae	Rhizoid, cauloid and phylloid	Specific tissues and parts within organs	n/a	*Ulva lactuca* (sea lettuce)-phylloid
				Red algae				*Chondrus crispus*

Unelaborated product	World	Main habitat	Group of organisms	Primary level (biological species)	Secondary level	Tertiary level	Quaternary level	Examples of levels*
								(carrageen moss)- phylloid
				Brown algae				*Undaria pinnatifida* (sea mustard)- phylloid
			Bryophyta and vascular plants	Mosses(terrestrial)	Root, stem, stem with leaves, leaves, flowers and inflorescences, flowering aerial parts, and fruits and infructescences		n/a	
				Aquatic vascular plants				*Nelumbo nucifera* (sacred lotus)- stem-
	Animals	Aerial	Birds	Galliformes, Estucioniformes, Columbiformes, Anseriformes, Passeriformes, Ciconiiformes, Phenicopteriformes, Charadriiformes.	Head Neck Trunk Forelimbs-Wings Full Legs	Crest, Brain (Head) Breast, Keel, Liver, Heart, Lungs, Gizzard, hen yolks, tail (Trunk) Thigh, leg, feet (Full leg)	Chest skin, Neck skin (Skin) Chest cartilage (Cartilage) Carcass (Bones) Chicken blood (Blood) Wings tendons (Tendons) Spinal Chord	*Alectoris rufa* (red-legged partridge). *Struthio camelus* (ostrich), *Columba livia* (rock dove), *Anser anser* (greylag goose), *Turdus philomelos* (song thrush). *Ciconia ciconia* (White Stork), *Phoenicopterus roseus* (greater flamingo), *Scolopax rusticola* (woodcock)
			Insects	Insects	Head	n/a	n/a	*Sphenarium sp.*

Unelaborated product	World	Main habitat	Group of organisms	Primary level (biological species)	Secondary level	Tertiary level	Quaternary level	Examples of levels*
					Thorax Abdomen Extremities			(grasshopper).
		Terrestrial	Mammals	Bovine Ovine Caprine Other bovines Camelids Cervids Swine Equine Leporidae Marsupials	Head Neck Trunk Forelimbs Hind limb Combinations of parts Half carcass Forequarter Hindquarter	Snout, Cheek, Tongue, Brain (Head) Brisket Ribs, Short loin Sirloin Rump Short plate Flank Tail Liver Heart Kidneys, Testicles, Stomach-guts, Intestine, udder (Trunk) Blade Chuck Hock, Hands (Forelimbs-Shoulders) Hock Topside Silverside Eye round, Outside, Foot (Hindlimbs)	Skin Shoulder cartilage (Cartilage) Bone marrow Cannon bone, Knee bone, spine bones (Bones) Veal blood (Blood) Fat Limbs tendons (Tendons) Spinal cord, (Cord)	*Bos taurus* (cow), *Ovis aries* (sheep), *Capra hircus* (domestic goat), *Syncerus caffer* (African buffalo), *Camelus dromedarius* (dromedary), *Cervus elaphus* (elk), *Sus scrofa* (wild boar), *Equus caballus* (horse), *Oryctolagus cuniculus* (European rabbit), *Macropus rufus* (red kangaroo)

Unelaborated product	World	Main habitat	Group of organisms	Primary level (biological species)	Secondary level	Tertiary level	Quaternary level	Examples of levels*
			Mollusks	Land snails	Foot with head Organs Shell			*Helyx pomatia* (snail)
			Insects and other arthropods	Insects Other arthropods (Insects and spiders)	Head Thorax and abdomen Extremities			*Atta* sp. (ant), *Haplopelma sp.* (spider)
			Reptiles	Reptiles (Lizards)	Head Neck Trunk Forelimbs Headquarters Combinations of parts	n/a	n/a	*Timon lepidus* (jewel lizard)
			Worms	Worms	---			---
		Aquatic	Fish	Seawater Freshwater Diadroms	Head Trunk Fins Combinations of parts	Jowls, Cheeks, Eyes (Head) Loin, Belly, Flank, Liver, Eggs, Gizzard (Trunk)	Trunk skin, Fins skin (Skin) Head cartilage (Cartilage) Spine-herringbone, Fins' spines (Spines) Blood Fat Tendons	*Merluccius merluccius* (hake), *Salmo trutta* (trout), *Salmo salar* (salmon)

Unelaborated product	World	Main habitat	Group of organisms	Primary level (biological species)	Secondary level	Tertiary level	Quaternary level	Examples of levels*
							Cord	
			Mollusks	Seawater: Bivalves Gastropods Cephalopods Freshwater: Bivalves Gastropods	Mantle (meat) Organs Shell	Food (Mantle)	n/a	*Mytilus edulis* (mussel), *Bolinus brandaris* (sea snail), *Sepia officinalis* (sepia)
			Crustaceans and other arthropods	Seawater: Swimmers Walkers Cirripedes Freshwater: Swimmers	Cephalothorax (head) Abdomen (Tail) Extremities Nail or upper part Peduncle or bottom part Cephalothorax (head) Abdomen (Tail) Extremities	Digestive system, shell, head (Cephalothorax) Muscle (meat), Shell (Abdomen)	n/a	*Palinurus elephas* (bobster), *Necora puber* (necora), *Pollicipes cornucopia* (barnacle) *Procambarus clarkii* (red swamp crawfish)
			Echinoderms	Seawater	Shell Organs	n/a	n/a	*Paracentrotus lividus* (sea urchin)
			Cnidarians	Seawater	Tentacles Organs	n/a	n/a	*Anemonia viridis* (sea anemone)
			Tunicates	Seawater	Mantle (meat) Tunic	n/a	n/a	*Microcosmus sabatieri* (sea squirt)
			Mammals	Seawater Freshwater	Head Trunk Fins Combinations of	Loin, Belly, Liver, Heart (Trunk)	Trunk skin, Fins skin (Skin)	*Delphinus delphis* (common dolphin),

Unelaborated product	World	Main habitat	Group of organisms	Primary level (biological species)	Secondary level	Tertiary level	Quaternary level	Examples of levels*
					parts		Cartilage Backbone, Fins' bones (Bones) Whale blood (Blood) Sebum (Fat) Tendons Marrow (Cord)	*Sotalia fluviatilis* (gray dolphin)
		Terrestrial and aquatic	Amphibians	Amphibians (Frogs)	Head Neck Trunk Forelimbs Combinations of parts	n/a	n/a	*Pelophylax perezi* (common frog)
			Reptiles	Reptiles (Crocodiles, Turtles)	Head Neck Trunk Forelimbs Headquarters Shell Combinations of parts			*Alligator mississipiensis* (alligator)
	Microorganisms		Bacteria	Wild	Lactic or acetic fermenting bacteria	n/a	n/a	*Lactobacillus* sp.
				Cultured	Lactic or acetic fermenting			*Acetobacter* sp.

Unelaborated product	World	Main habitat	Group of organisms	Primary level (biological species)	Secondary level	Tertiary level	Quaternary level	Examples of levels*
					bacteria			
			Microfungi	Yeasts	Wild	n/a	n/a	*Saccharomyces* sp.
					Cultured			
				Molds	Wild			*Penicillium* sp.
					Cultured			
			Microalgae	Wild	n/a	n/a	n/a	*Chlorella* sp.
				Cultured				
	Derivatives (not a world *per se*)		Considered for each world and group of organisms					*From plants:* Gums, resins, mastic *From animals:* Fresh milk, fresh eggs, honey *From microorganisms:* Xanthan gum

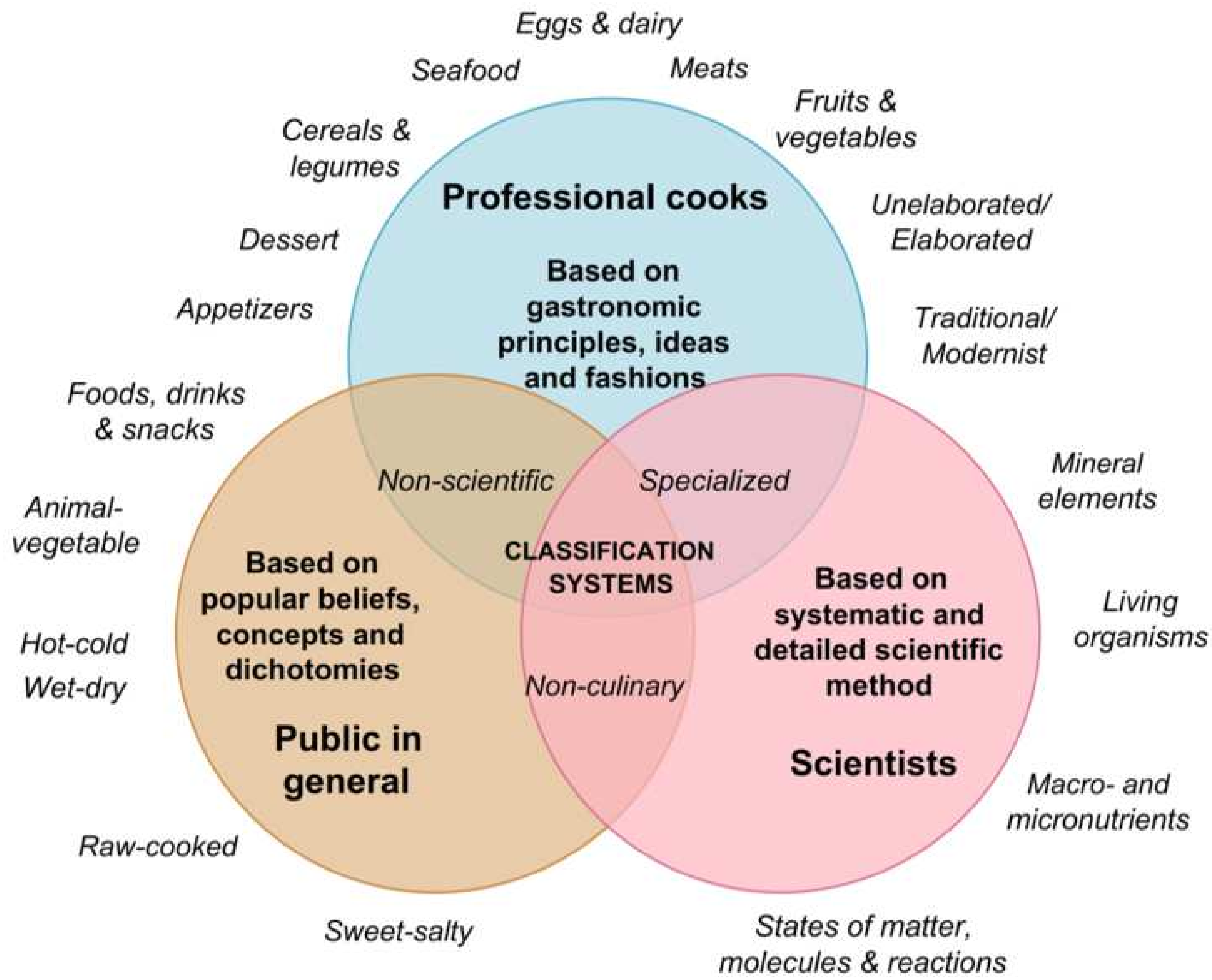
*For each world, the column 'examples of levels' corresponds to distinct levels, beginning with the primary, and separated with a hyphen from following levels.
n/a: Non-applicable.

Table 2: Classification of unelaborated products: inorganic materials

Unelaborated product	World	Origin	Sub-origin	Type	Examples
Inorganic materials	World of waters	Superficial	River	Non-carbonated	Prepared water from public supply
			Lake		Prepared potable water
			Glacier		Glacier water of weak mineralization
		Subterraneous	Natural mineral	Non-carbonated or carbonated	Ferruginous natural mineral water
			Natural spring		Decarbonated spring water
		Seawater			Deep seawater
	World of minerals (salt)	Fossil		In white, pink or black rock	Himalayan pink salt Sanchal black salt
		Salt lakes and salt flats		Fine common salt, coarse common salt, flower of salt, or salt flakes	Hawaiian salt, Maldon salt

Table 3: Overall classification of major culinary elements in an increasing ranking order

1st rank	2nd rank	3rd rank - Worlds	4th rank - Levels & categories	Example of primary level
Unelaborated products	Living beings	Plants and fungi	Primary to up to tertiary levels	Apple tree (*Malus domestica*) Portobello mushroom (*Agaricus bisporus*)
		Animals	Primary to up to quaternary levels	Brown trout (*Salmo trutta*)
		Microorganisms	Primary to up to secondary levels	Yeast (*Saccharomyces cerevisiae*)
	Inorganic materials	Waters	-	Spring water (H_2O)
		Minerals	-	Sea salt (NaCl and other salts)


Eggs & dairy
Seafood
Meats
Fruits & vegetables
Cereals & legumes
Professional cooks
Unelaborated/ Elaborated
Dessert
Based on gastronomic principles, ideas and fashions
Appetizers
Traditional/ Modernist
Foods, drinks & snacks
Non-scientific
Specialized
Mineral elements
Animal-vegetable
CLASSIFICATION SYSTEMS
Based on popular beliefs, concepts and dichotomies
Based on systematic and detailed scientific method
Living organisms
Hot-cold
Wet-dry
Non-culinary
Public in general
Scientists
Macro- and micronutrients
Raw-cooked
Sweet-salty
States of matter, molecules & reactions