Supplemental Table 1a: Definition and Common Properties of Nova-defined Ultra-processed Foods

Almost always contain	Cosmetic additives (a)	AND/OR	Food substances of no culinary use
Likely to contain	Excessive added sugar (b)	Excessive added salt (b)	Excessive added fat (b)
May also contain	Added vitamins (b)	Added minerals (a)	Preservatives (a)
Have generally undergone	Series of industrial food processes (c)		
Unlikely to contain	Whole intact foods (b)		

(a) = Only presence indicated on nutrition labels (ingredient list). Amount not displayed unless contributing to total sodium, calcium, iron, potassium, phosphorus or zinc (nutrition facts panel). Contribution unique to source not listed

(b) = Sources generally indicated on nutrition labels (ingredient list), total micro-/ macro-nutrient content in product listed (nutrition facts panel). Contribution unique to source not listed

(c) = No information presented on nutrition labels

Rows in pink are unique to Nova Group 4 and are used to differentiate Nova Group 4 from Nova group 3 products. Rows in gray include elements that may be present in any Nova group

Supplemental Table 1b: Cosmetic Additives and Food Substances of no Culinary Use Included in Ultra-Processed Foods, Common Uses, and Evidence of Health Harm*

Category	Purpose of use	Examples of compounds with unclear evidence of harm or safety under current dosage as consumed by the population	Examples of compounds with evidence of possible harm under current dosage as consumed by the population	Presence on nutrition label	Common UPF subgroups that contain category of additives
Cosmetic additives					
Colors	Impart color to food or drinks, can be applied as liquids, powders, gels or pastes. Make food more attractive, offset color loss during processing and storage, correct natural variations in color, enhance natural colors, and allow food products to be identified on sight	Turmeric (E100), carmine (E120), red No. 10 (azorubine) (E122), ponceau 4R (E124), blue No. 2 (Indigo Carmine) (E132), chlorophyllin (E140, E141), carotenoids (E160, E161, E164), betanin (E162), anthocyanins (E163)	Yellow No. 5 (tartrazine) (E102), quinoline yellow (E104), yellow No. 6 (sunset yellow) (E110), red No. 3 (erythrosine) (E127), red No. 40 (allura red) (E129), blue No. 1 (brilliant blue) (E133), titanium dioxide (E171)	IL	Sugar-sweetened beverages, Breakfast cereals and granola, Confectionery, Sweet or savory packaged snacks, Plant-based protein products
Emulsifiers, Emulsifying salts	Help mix two substances such as water and oil to create stable and homogenous mixture. Prevent separation, improves mouthfeel of products, enhances and maintains food appearance, texture and shelf-life stability	Lecithin (E322), alginic acid and alginates (E400-405), guar gum (E412), gum tragacanth (E413), xanthan gum (E415), karaya gum (E416), soybean hemicellulose (E426), cassia gum (E427), polysorbates except 80 (E432, 434-436), mono- and diglycerides of fatty acids (E471), esters and sucroglycerides (E473-474). Polyglycerols esters of fatty acids (E475), polyglycerol polyricinoleate (E476), stearoyl lactylates (E481-482), sorbitan esters (E491-495), polyvinylpyrrolidone (E1201), polyvinylpolypyrrolidone (E1202), , starches (E1400-E1414), castor oil (E1503), polyethylene glycol (E1521)	Carrageenan (E407), polysorbate 80 (E433), cellulose including carboxymethyl cellulose (E460-E469)	IL	Dairy desserts, Ultra-processed breads, Salad dressings and sauces, Cakes and biscuits, Processed meat
Bulking agents	Increase and stabilize volume to achieve desirable texture and appearance. Prevent undesirable changes during production, storage and transportation	Alginic acid and alginates (E400-405), agar (E406), locust bean gum (E410), guar gum (E412), gum tragacanth (E413), gum arabic (E414), xanthan gum (E415), karaya gum (E416), konjac flour (E425), gelatin (E441), sucrose esters and sucroglycerides (E473-474), polyglycerols esters of fatty acids (E475), quillaia extract (E999), polyvinylpyrrolidone (E1201), polyvinylpolypyrrolidone (E1202), starches (E1400-E1414), triethyl citrate (E1505), propylene glycol (E1520)	Carrageenan (E407), cellulose including carboxymethyl cellulose (E460-E469)	IL	Plant-based protein products, Canned soup, Packed bakery products, Dairy products and non-dairy alternatives, Salad dressings and sauces
Gelling agents	Modify the viscosity and/or texture of food to give a more desirable sensory perception to consumers. Usually used with emulsifiers and thickeners	Calcium acetate (E263), alginic acid and alginates (E400-405), agar (E406), locust bean gum (E410), guar gum (E412), gum tragacanth (E413), gum arabic (E414), xanthan gum (E415), karaya gum (E416), gellan gum (E418), konjac flour (E425), soybean hemicellulose (E426), cassia gum (E427),	Carrageenan (E407)	IL	Cookies, cakes, pies, Confectionery, Frozen desserts, Ready-to-eat/heat meals, Canned soup, Dairy products and non-dairy alternatives, Processed meats, Plant-based protein products

		pectin (E440), gelatin (E441), starches (E1400-E1405, E1410-1414, E1420-E1423, E1440-E1443, E1450, E1451), polyvinylpyrrolidone (E1201), polyvinylpolypyrrolidone (E1202), pullulan ((E1204),			
Flavors, Flavor enhancers	Alter or enhance the taste of food or drinks	Glutamate (E621-E625), Disodium guanylate (E627), inosinic acid and inosinates (E630-E633), ethylmaltol (E637), ethyl vanillin, methyl anthranilate	Insufficient evidence within humans	IL	Protein drinks, Sports drinks, Sugar sweetened beverages, Mixed dishes and soups, Confectionery, Cookies, cakes, pies, Frozen desserts, Ready-to-eat/heat meals, Canned soup, Sweet or savory packaged snacks, Plant-based protein products, Salad dressings and sauces
Thickeners, Anti-foaming agents	Reduce or remove foam formation to make it possible to form or maintain a uniform dispersion of a gaseous phase in liquid or solid food	Polysorbates except 80 (E432, 434-436), ammonium phosphatides (E442), polyglycerol esters of fatty acids (E475), silicon dioxide (E551), fatty acids (E570), dimethylpolysiloxane (E900), castor oil (E1503), polyethylene glycol (E1521)	Polysorbate 80 (E433)	IL	Ice cream and frozen desserts, Salad dressing and sauces, Protein drinks, Dairy beverages, Dairy products and non-dairy alternatives, Processed meats, Plant-based proteins
Glazing agents	Give a shiny and/or protective coating for more desirable appearance and/or longer shelf life	Gum arabic (E414), konjac flour (E425), mineral oil, vegetable oils or animal fats (E471), sucrose esters of fatty acids (E473), talc (E553b), waxes such as beeswax (E901), candelilla wax (E902), carnauba wax (E903), shellac (E904), microcrystalline wax (E905), hydrogenated poly-1-decenes (E907), polyvinylpyrrolidone (E1201), polyvinylpolypyrrolidone (E1202), polyvinyl alcohol (E1203), copolymers (E1205-E1209), castor oil (E1503), polyethylene glycol (E1521)	Carrageenan (E407)	IL	Packaged baked goods, Chocolate products, Confectionery, Sweet or savory packaged snacks
Carbonating agents, Foaming agents	Used to provide carbonation in a food or make it possible to maintain a uniform dispersion of a gaseous phase in a liquid or solid food	Alginic acid and alginates (E400-405), calcium stearoyl lactylate (E482(i)), carbon dioxide (E290), hydroxypropyl cellulose (E463), methyl ethyl cellulose (E465), microcrystalline cellulose (E460(i)), Nitrogen (E941), nitrous oxide (E942), sodium stearoyl lactylate (E481(i)), sucrose esters of fatty acids (E473), xanthan gum (E415)	Cellulose including carboxymethyl cellulose (E460-E469)	IL	Ready-to-eat/heat meals, Dairy desserts, Ultra-processed breads, Salad dressings and sauces, Cakes and biscuits, Processed meat, Sugar sweetened beverages, Dairy beverages and non-dairy alternatives
Sweeteners	Sweeten, enhance flavor while adding little to no calories	Acesulfame K (E950), saccharin (E954), sucrose, steviol (E960), neotame (E961), erythritol (E968), monk fruit	Aspartame (E951), sucralose (E955)	IL	Protein drinks, Sports drinks, Sugar sweetened beverages, Confectionery, Breakfast cereal, Dairy products and non-dairy alternatives
Food substances of no culinary use					

Varieties of sugars	Sweeten, enhance flavor and texture, preserve	Fructose, invert sugar, maltodextrin (E1400), dextrose (E1200), lactose, sorbitol (E420), xylitol (E967), maltitol (E965), mannitol (E421), isomalt (E953), hydrogenated starch hydrolysate	High-fructose corn syrup, high fructose inulin syrup	IL AMT	Cookies, cakes, pies, Breakfast cereals and granola, Confectionery, Frozen desserts, Ready-to-eat/heat meals, Frozen dinners, Canned soup, Protein drinks, Sports drinks, Sugar sweetened beverages,
Modified starches	Thickeners, mouthfeel enhancement and emulsification.	Monostarchphosphate (E1410), acetylated starch (E1420), starch sodium octenyl succinate (E1450), starch aluminum octenyl succinate (E1452), hydroxypropyl starch (E1440), distarch phosphate (E1412), phosphate distarch phosphate (E1413), acetylated distarch phosphate (E1414), acetylated distarch adipate (E1422), hydroxypropyl distarch phosphate (E1442), acetylated oxidized starch (E1451)	Insufficient evidence	IL	Dried pasta and noodles, Fruit gels, Bakery fillings, Frozen desserts, Canned soups
Modified oils that are hydrogenated, partially hydrogenated, or interesterified	Improve flavor, shelf-stability, durability of products	Cocoa butter, palm oil, lard	Partially hydrogenated oils, trans fats	IL AMT)	Sweet or savory packaged snacks, Packaged bakery products, Spreads and margarines
Protein sources	Improve microbiological shelf life, increase versatility of use, better functional properties	Hydrolysed proteins (E621), soya protein isolate, gluten, casein, whey protein, ‘mechanically separated meat’	Insufficient evidence	IL AMT	Savory packaged snacks, sausages, luncheon meat, Meat-replacement products

Category	Example of UPF subgroups that contains the additive in question and qualifies for HFSS	Evidence of health harm of example UPF subgroups with long term consumption at current population intakes	Is the example UPF subgroups considered a staple or an important sources of nutrients at the population level?	Is it possible to reformulate the example UPF subgroups?	Potential of the example UPF subgroups to be recommended for reduced intake
Cosmetic additives					
Colors	Yes – Sugar-sweetened beverages for sugar	Yes – T2diabetes, dental caries	No	Yes	
Emulsifiers, Emulsifying salts	Yes – Ultra-processed breads for salt	Insufficient evidence at product level	Yes – Source of fiber	Yes	
Bulking agents	Yes – Canned soup for salt	Insufficient evidence at product level	No	Yes	
Gelling agents	Yes – Processed meats for salt	Yes – Colorectal cancer	No	Yes	
Flavors, Flavor enhancers	Yes – Frozen desserts for sugar	Insufficient evidence at product level	No	Yes	
Thickeners, Anti-foaming agents	Yes – Dairy beverages for sugar	Insufficient evidence at product level	Yes – Source of high quality protein	Yes	
Glazing agents	Yes – Chocolate products for sugar	Insufficient evidence at product level	No	Yes	
Carbonating and foaming agents	Yes – Condiments for sugar	Insufficient evidence at product level	No	Yes	
Sweeteners	Yes – Confectionery for sugar	Insufficient evidence at product level	No	Yes	
Food substances of no culinary use					
Varieties of sugars	Yes – Breakfast cereals and granola for sugar	Insufficient evidence at product level	Yes – Source of fiber	Yes	
Modified starches	Yes – Frozen desserts for sugar	Insufficient evidence at product level	No	Yes	
Modified oils that are hydrogenated, partially hydrogenated, or interesterified	Yes – Packaged bakery products for salt	Insufficient evidence at product level	No	Yes	
Protein sources	Yes – Meat-replacement products for salt	Insufficient evidence at product level	Yes – Source of protein	Yes	

*A rapid review approach was employed to assemble this table. Evidence from numerous sources including original research, reviews, FDA guidance documents, expert input, and Center for Science in the Public Interest (CSPI) reports were reviewed to identify additives with unclear

evidence of harm or safety, common UPFs, exemplar categories, and their contribution to excess consumption of HFSS foods, and the potential to reformulate/modify population intake of certain subgroups of UPFs based on their contribution to intake of foods and nutrients of public health concern (e.g., whole grains and dietary fiber). This was a subjective interpretation by a panel of experts. For example, foods like whole grain breads were deemed to have low potential for guidance to reduce intake because they are important contributors to dietary fiber and whole grain intake in the US population. Nevertheless, it is important to note that all subgroups identified were deemed to have potential for reformulation. Thus, while whole grain UPFs may not have high potential to be recommended for reduced intake, it is possible to reduce their sodium content and potentially content of additives.

Legend: IL= ingredient listed; AMT=amount listed on Nutrition Facts Panel (total amounts only, not contributions unique to source), HFSS=high in saturated fat, salt, or sugar
Red shading denotes low potential and green shading denotes high potential, based on current evidence. Continued research is warranted.

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Supplemental Table 1c: Industrial food processes and common usages

Examples of series of industrial processes	Purpose of use	Examples of ultra-processed subgroups that utilize some or a combination of these processes
Industrial processes		
Fractioning	to separate certain component(s) from a mixture	plant-based protein products, processed eggs and egg products
Grinding	to reduce the size of materials by fracturing	processed meats, plant-based protein products, processed eggs and egg products
Hydrolysis	to break down the chemical bonds in large molecules such as carbohydrates and proteins with addition of water	processed meats, plant-based protein products, processed eggs and egg products, dairy products and non-dairy alternatives, packaged bakery products, sweet or savory packaged snacks
Hydrogenation	to add hydrogen to the unsaturated fatty acids and turn them into saturated fats to increase its melting point and allow conversion of liquid oil to a solid fat	dairy products and non-dairy alternatives, packaged bakery products, sweet or savory packaged snacks, beverages, processed meats, plant-based protein products, chocolate products
Chemical modifications	to improve the texture, functionality, shelf-life, and slow down deterioration	packaged bakery products, sweet or savory packaged snacks, processed meats, plant-based protein products, chocolate products, candy and other confectionery, sauces and salad dressings, processed eggs and egg products, dairy products and non-dairy alternatives
Extrusion	to enable mass production of food products that are uniformed in size and shape in a continuous process of forcing a mixture through a shape opening at a defined throughput	packaged bakery products, sweet or savory packaged snacks, processed meats, plant-based protein products, chocolate products, candy and other confectionery, chewing gum, processed eggs and egg products
Molding	to shape the finished food products	packaged bakery products, sweet or savory packaged snacks, processed meats, plant-based protein products, chocolate products, candy and other confectionery, chewing gum, processed eggs and egg products, dairy products and non-dairy alternatives
Pre-frying	to reduce moisture and increase fat content	sweet or savory packaged snacks, processed meats, plant-based protein products

Supplemental Table 1d: Operational Definition of Ultra-processed Foods (UPFs) and guide for phased policy guidance

	Operational definition	Phase 1	Phase 2	Phase 3
Ultra-processed Foods (UPFs)*	Foods that have: • Cosmetic additives • Food substances of no culinary use	• Advance policy to reduce accessibility, promotion, and consumption of poor nutritional profile UPFs (i.e., HFSS): ○ Sugar-sweetened and artificially sweetened beverages ○ Processed meats ○ Packaged baked goods and snacks like cookies, candy, chips, and frozen desserts, canned soups high in salt, sweetened yogurts • Advance streamlined and efficient evaluation and regulation of food additives • Policy to support comprehensive reporting of additives and processing on food labels and in food databases. • Updating nutrition composition databases and dietary data collection instruments to reflect processing elements	• Reformulate or reengineer UPFs to improve overall nutritional profile[1] when feasible; apply an evidence-based approach to reformulate along multiple parameters to reduce or eliminate extensive use of cosmetic additives and/or food substances of no culinary use, and/or altering orosensory properties (e.g. texture) and energy density to reduce excess consumption	• Ongoing surveillance
Poor nutritional profile†	Nutri-Score C/D/Eand/or misaligned with AHA Dietary Guidance, i.e., HFSS			
Good nutritional profile†	Nutri-Score A or B and/or aligned with AHA Dietary Guidance	• Advance streamlined and efficient evaluation and regulation of food additives • Policy to support comprehensive reporting of additives and processing on food labels and in food databases.	• Evaluate the health effects of UPFs of good nutritional profile ○ Effects of industrial processes ○ Effects of good nutritional profile foods with vs. without additives and/or food substances of no culinary useon health outcomes	• Develop more convenient, accessible, culturally-appropriate, 'smartly processed'[2] foods of good nutritional profile. • Ongoing surveillance

*Ultra-processed foods (UPFs) have been defined by the Nova system[3] and operationalized to refer to foods that have cosmetic additives and/or food substances of no culinary use (i.e., used only in industrial production and unavailable in home kitchens or restaurants) as part of their formulation. These foods are subject to extensive physical or chemical industrial processes, packaged, and branded; however, because these aspects are not currently reported on food labels, they are not included within the operational definition. Nova does not consider nutritional profile and while many UPFs are poorer nutritional profile on average (i.e., higher in added sugars, salt, saturated fat: unsaturated fat ratio (i.e., HFSS), and lower in fiber based on Nutri-Score)[4,5], and lower in whole grains (American Heart Association (AHA) Dietary Guidance) Guidance[6], it is not collinear with nutritional profile. The

use of complementary systems allows prioritization of evidence-based policies targeting UPFs of poor nutritional profile where evidence is strongest and aligns between nutrient, food-based, dietary pattern, and food processing-based guidance.

[†]Nutri-Score is a nutrient profiling system that considers total energy, sugar, sodium, saturated fat, dietary fiber, protein, and the proportion per 100g or mL of fruits/vegetables/pulses and provides 5 levels of overall nutritional value ranging from (A=high nutritional profile to E= low nutritional profile).Higher Nutri-Score ratings (A and B) denote foods with a more favorable profile while lower ratings denote foods with less favorable profiles. While the recent 2023 update to Nutri-Score made changes to the point system for sugar and salt to ensure less favorable ratings were provided for foods with higher sugar or salt content and to fiber (to help differentiate between whole and refined grains), AHA Dietary Guidance[6] was used to supplement Nutri-Score in any places where misalignment may occur (i.e., to consistently distinguish between whole grain pastas/brown rice relative to refined versions).[4,5]

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Supplemental Table 1e. Timely, Evidence-Based Policy, System, and Environmental Actions That May Reduce Ultraprocessed Food Intake and Improve US Dietary Quality

Potential policy, system, environment changes	Evidence	Anticipated impact
Drastically limit and support reduced intake of highly available "junk" foods—most of which are ultraprocessed—that exceed recommended levels of added sugar, salt, and unhealthy fat	Longstanding dietary guidance, including the recent 2021 AHA Guidance, shows that patterns built on "junk" or unhealthy foods increase the risk of mortality and heart disease	Shifts in the pricing, promotion, and availability of "junk foods" would reduce excess consumption of foods that have been strongly and consistently associated with adverse health.
Substantially increase availability and support intake of nutrient-dense vegetables, fruits, whole grains, beans, nuts, seeds, nontropical vegetable oils, and lean proteins	Longstanding dietary guidance, including the 2021 AHA Guidance, shows that optimal dietary patterns are built on these foods and are associated with better health and lower mortality.	Shifts in the pricing, promotion, and use of nutrient-dense foods would promote consumption of dietary patterns aligned with better health outcomes.
Improve labeling, strengthen regulation of food additives, and the pricing and marketing of UPFs and eliminate the most harmful additives allowed in the US food supply	Certain additives have been associated with adverse health outcomes and have been removed from the food supply in other countries. Current regulation in the United States makes it challenging to eliminate potentially health-harming food additives in a timely way.	Eliminating some additives may marginally improve health outcomes; improving regulatory processes for food additives will make it easier to develop a food supply that is safe and promotes nutrition security in a way that remains affordable, convenient, and acceptable to modern societies. Regulating pricing and marketing of UPFs will limit the prolific consumption patterns
Differentiate between nutrient-dense foods with a UPF marker and UPFs that are "junk foods" (UPF markers are one or more ingredients that people don't usually cook with at home or additives used to make food look or taste better.)	Emerging evidence shows that some nutrient-dense foods with UPF markers have neutral or beneficial associations with health. Differentiating between "junk foods" and nutrient-dense foods with UPF markers supports targeted policy action to improve the healthfulness of the food supply while also ensuring access to foods that remain affordable, convenient, and acceptable to modern societies	Inclusion of some nutrient-dense foods with UPF additives in a healthful dietary pattern can make it easier to consume a healthful diet pattern by making foods more affordable, less time-consuming to prepare, and longer-lasting, which addresses some key barriers related to regularly consuming a healthy diet pattern.[1, 2] Differentiation between nutrient-dense foods with a UPF marker and "junk food" UPFs reduce opportunities for the food industry to make otherwise unhealthy foods appear healthy by eliminating UPF markers from the formulation. Differentiation between nutrient dense foods with a UPF marker and "junk food" UPFs challenges food manufacturers to reformulate or develop nutrient-

		dense foods that are affordable, tasty, and convenient.
Develop guidelines for federal nutrition programs that support increased consumption of nutrient-dense foods and drastically limit "junk foods"[3]	Regulations around unhealthy fats, added sugars, and sodium limits in federal food programs along with increased availability of nutrient-dense foods aligns with longstanding dietary guidance and feasibly promotes better health outcomes	Strengthened nutrition standards in federal food programs would help align people's diets with longstanding dietary guidance; inclusion of limited nutrient-dense foods with UPF markers would increase the feasibility and acceptability of doing so.

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