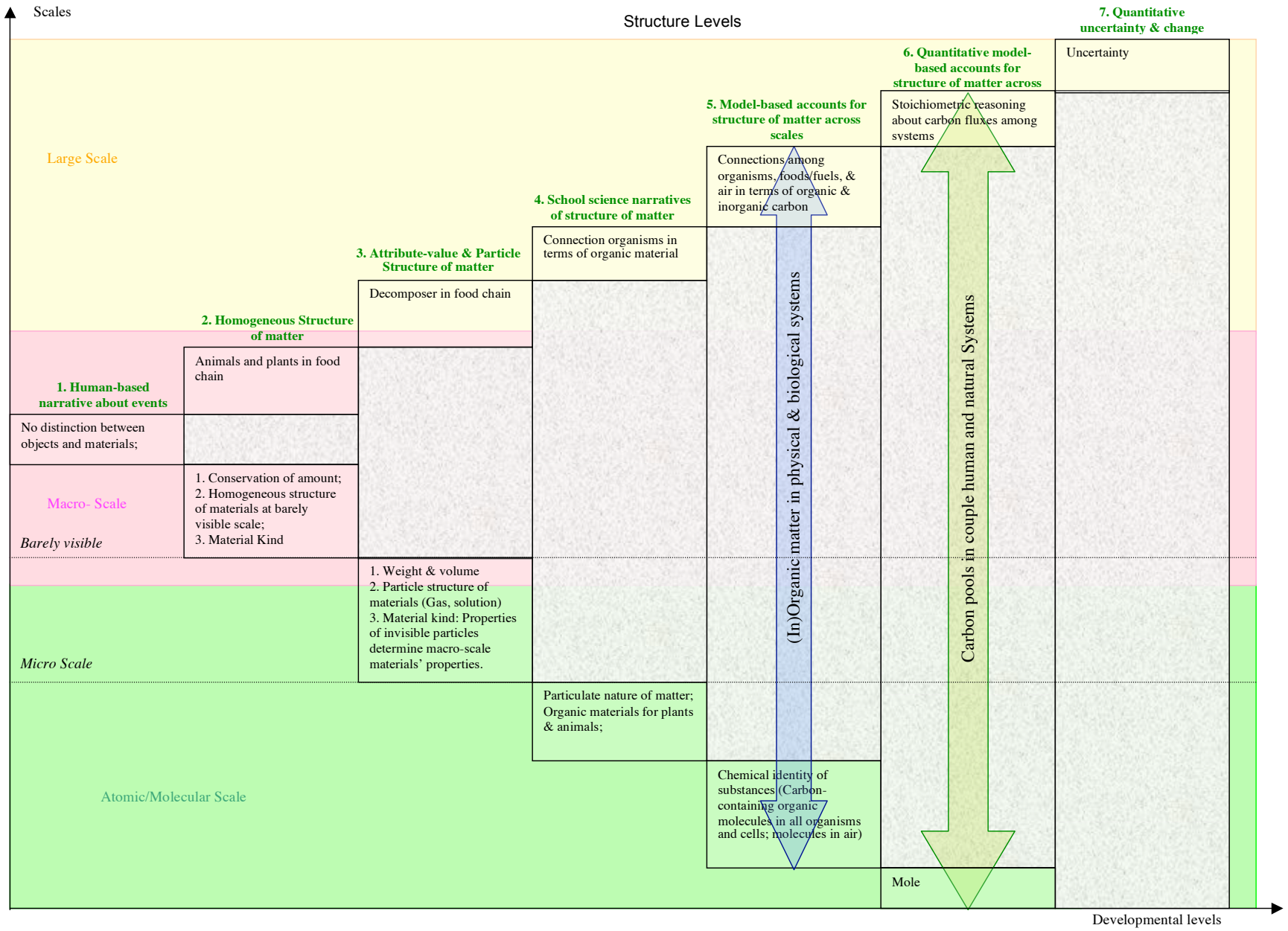
Scales
Structure Levels
7. Quantitative uncertainty & change
Uncertainty
6. Quantitative model-based accounts for structure of matter across
Stoichiometric reasoning about carbon fluxes among systems
5. Model-based accounts for structure of matter across scales
Connections among organisms, foods/fuels, & air in terms of organic & inorganic carbon
4. School science narratives of structure of matter
Connection organisms in terms of organic material
3. Attribute-value & Particle Structure of matter
Decomposer in food chain
2. Homogeneous Structure of matter
Animals and plants in food chain
1. Human-based narrative about events
No distinction between objects and materials;
Large Scale
Macro- Scale
1. Conservation of amount;
2. Homogeneous structure of materials at barely visible scale;
3. Material Kind
Barely visible
1. Weight & volume
2. Particle structure of materials (Gas, solution)
3. Material kind: Properties of invisible particles determine macro-scale materials' properties.
Micro Scale
Particulate nature of matter; Organic materials for plants & animals;
Chemical identity of substances (Carbon-containing organic molecules in all organisms and cells; molecules in air)
Atomic/Molecular Scale
(In)Organic matter in physical & biological systems
Carbon pools in couple human and natural Systems
Mole
Developmental levels

	Levels	Measurement	Hierarchy of Systems, Scale	Function/Material Kind/Properties
7	**Quantitative uncertainty & change**	Recognizes the uncertainty of the issue of global warming and takes it into account when analyzing quantitative and qualitative information from multiple media sources. (e.g. quantitative risk assessment, error bars)		
6	**Quantitative model-based accounts for structure of matter across scales.** Mole *Stochiometric reasoning* to relate molecular mass with mass of macro-scale substances and large-scale carbon flux.	Uses stochiometric reasoning to relate molecular formulas to amounts or concentrations of elements in different substances or materials (e.g. mole). Relates measures of energy (megawatt-years) to measures of mass (e.g. gigatons of CO_2). Uses measures of carbon pools in large systems. Distinguishes between measures of elements (e.g., C) from measures of compounds (e.g. CO_2).	Identifies major hydrocarbon compounds in fuels. Further explain quantitative data about human consumption of fossil fuels, carbon emission, and carbon sequestration. Identifies and compares major carbohydrates and lipids in organisms/foods in terms of the ways they are used for energy storage and for cell structural components. Further describe different ways organisms gain and use carbohydrates/lipids. Identifies chemical relationships among carbon-containing compounds in earth, living systems, atmosphere, and engineered systems.	
5	**Qualitative Model-based accounts for structure of matter across scales** Mass *Chemical identity* of substances: distinguishes between: Organic substances in all organisms; Chemical identity of gases. Distinction & connection between cellular structure and atomic/molecular structure. At large-scale, distinguishes between biological and physical systems in terms of organic or (in)organic matter.	Distinguishes mass from weight Explains mass, volume, density in terms of mass and arrangement of molecules. Recognizes the relative sizes of cell and atoms/molecules. Writes equations for phenomena such as combustion, photosynthesis, and cellular respiration.	Recognizes that molecule is the basic unit to keep substance's identity and chemical bonds hold the atoms together to form molecules. Recognizes that cells are composed of H_2O and organic substances (e.g. glucoses). Correctly describes living and non-living systems as composed of specific substances and classes of substances: CO2, O2, carbon-containing organic compounds.	Recognizes that chemical identity of a substance will not change when the substance keep its molecular structure. Recognizes gases can be reactants or products in chemical reactions. Identifies some organic molecules in cells and in all organisms including decomposers. Identifies the similarity between foods and fuels as carbon-containing organic matter. At large-scale, recognizing that organisms have similar chemical composition
4	**School science narratives of structure of matter** Measurement of intensive variables. *Particulate nature* of matter. Macroscopic properties of substances are determined by the collective effect of particle properties and behaviors. Cell as units for functions of organisms.	Compares molecules in terms of numbers of atoms of different substances. Measures and calculates mass/weight, volume, density. Balance chemical equations. Quantitative measurement of density.	Identifies all forms of matter including gases as composed of discrete atoms and molecules and recognizes that atoms/molecules are in constant motion. Recognizes that cell is the basic unit of both structure and function of living organisms and that cells are made of water and organic materials.	Distinguishes between matter and non-matter: solids, liquids, and gases are matter and heat, light, and conditions (e.g., temperature) are non-matter. Describes/compares states of matter in terms of atom/molecule movement. Correctly distinguishes mixture, compound, & element in terms of their atomic/molecular composition. (e.g. air is mixture of many compound and elements including O_2 and CO_2. Identifies solutions as mixtures) Correctly identifies some organic substances in many foods, fuels, plants, animals, detritus, and bacteria; recognizes similarities between detritus and decomposers/ bacteria and other classes of organic materials.
3	**Attribute-value & particle structure of matter** Distinction between extensive & intensive variables; Identifies *material kind at micro-scale* and constructs a relevant explanatory framework: Macroscopic materials are composed of invisible particles, so macroscopic properties of materials are determined by the properties of individual particles. Pays attention to similarity among foods, fuels, and organisms.	Identifies weight and mass as the most fundamental measure of amount of material. Relies on measured weight over felt weight. Begins to Distinguishes between extensive variables measuring amount (e.g., weight, volume) and intensive variables measuring concentration (e.g., density)	Recognizes that solids, liquids, and *gas* are made of invisible particles, which have weight and take up space, but does not recognizes the molecular structure of materials.	Hold the idea that substance-relevant (intensive) properties of macroscopic material samples (solids/liquids/gases) are determined by properties of individual particles. Based on particle structure framework, recognizes that solids, liquids, and gases have weight and take up space even when they are in solution or too tiny to see. Recognizes some materials as mixtures, but cannot consistently identify substances (e.g. compound) from mixture in terms of their molecular structure. Recognizes the similarity among classes of materials such as foods, fuels, animals, and plants, but cannot consistently identify organic materials in them.

2	**Homogeneous structure of matter** Conservation of amount; Identifies *material kind at barely visible scale* and constructs a relevant explanatory framework – Solid and liquid materials have homogeneous structure when they are at least barely visible, so materials can keep their properties somehow when they are at least barely visible.	Distinguishes between weight and volume as measures of amount (Conservation of amount).	Recognizes continuities in physical properties between small amounts of solid/liquid materials that are barely visible (e.g. sawdust, a grain of salt) and larger amounts of the same materials (e.g., a block of wood, a cup of salt). (No gas)	Describe *material kind* in terms of macroscopic substance-relevant properties (e.g. color, can burn, temperature) instead of entity-relevant properties (weight, volume). Recognizes that solids and liquids take up space and have weight at macroscopic scale. (e.g. sugar disappears in water; gas is not matter.) Identifies and classifies classes and subclasses of *material kind* including plants, animals, foods, and fuels based on macroscopic experience. Does not explain the similarity among them in terms of organic materials.
1	**Human-based narrative about objects** No distinction between objects and materials	Does not recognize that the amount of material will not change when the material changes its shape.	Does not consistently distinguish objects from the materials of which they are made. Uses functions (e.g., things to eat with) as well as perceptual characteristics to identify and classify objects or materials. Does not believe that small amounts of materials (e.g., sawdust, a grain of salt) have the same physical properties as larger amounts (e.g., a block of wood, a cup of salt). Classify objects in terms of functions, human uses.	