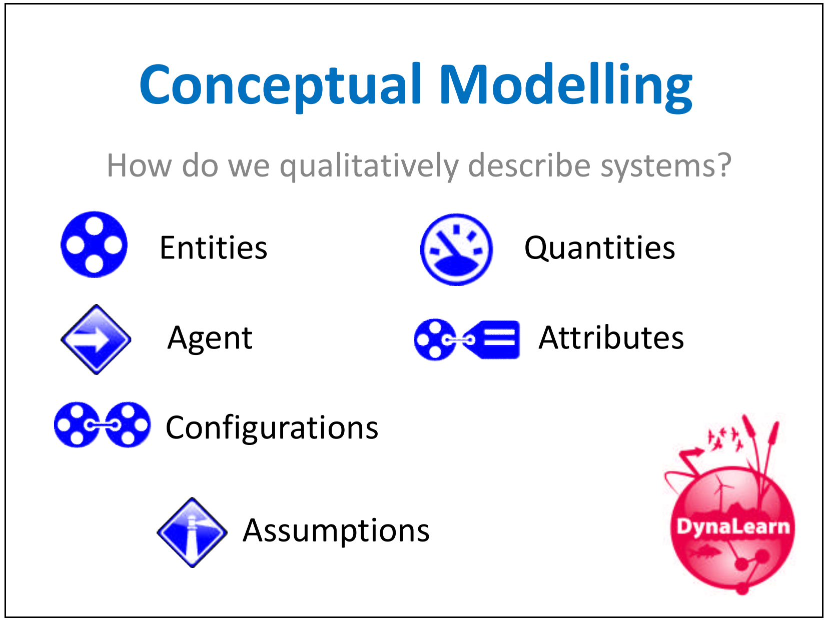
Conceptual Modelling:

How can we qualitatively describe a system?

System structure and qualitative states

This series of slides introduces the approach and ingredients of conceptual modelling using Qualitative Reasoning (QR) models in the DynaLearn software. Qualitative Reasoning modelling provides a formalised modelling language to describe the structure and behaviour of systems in a qualitative manner, with no reliance on numerical or mathematical information. The basis of QR is that behaviour can be determined from structure by describing the systems structure and the nature of causality within the system. This first series of slides shows how QR modelling ingredients are used to describe the structure of systems and their behaviour.



Conceptual modelling starts by identifying the structure and extent of the system we wish to model and the features (or behaviour) of the system we are interested in. The structure and features of the system we are interested in can be described using the following ingredients:

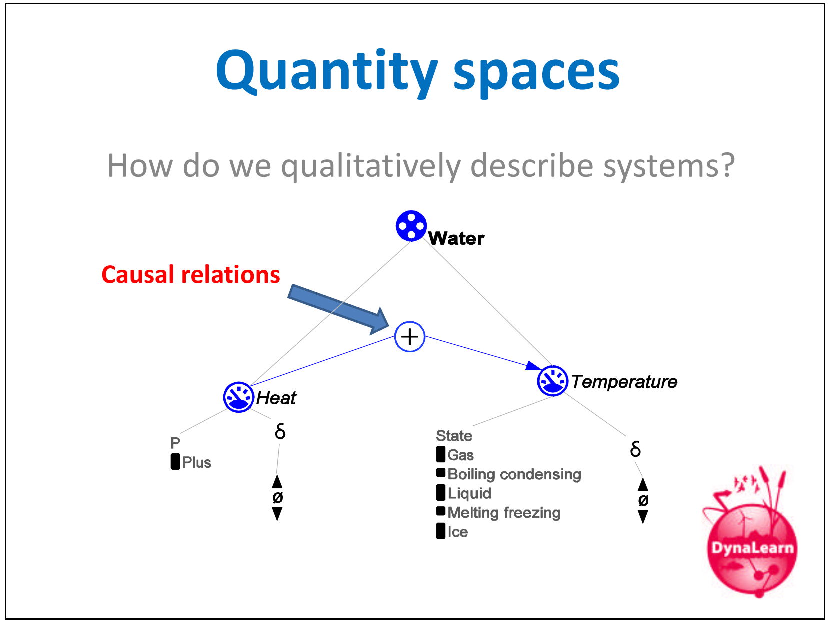
Entities: The physical objects or components of the system (e.g. Population, Habitat, cell membrane etc.). These are the primary features of the system. An alternative form of entity is an *Agent*, a factor or object acting on the system but formally not affected by the system.

Quantities: These are the characteristics and features of the system we are interested in when the behaviour of the system is considered. These are the qualities of the entity that can change during behaviour (e.g. height, density, abundance).

Configurations: These are structural relations that indicate how the entities of the system are related to each other. For example A Population *Inhabits* a Habitat.

Attributes: These are categorical features of entities that can be used to differentiate entities and instances of the same type of entity (for example colour). These are features that would not change during a simulation.

Assumptions: These are labels that can specify the assumptions under which the model holds true.



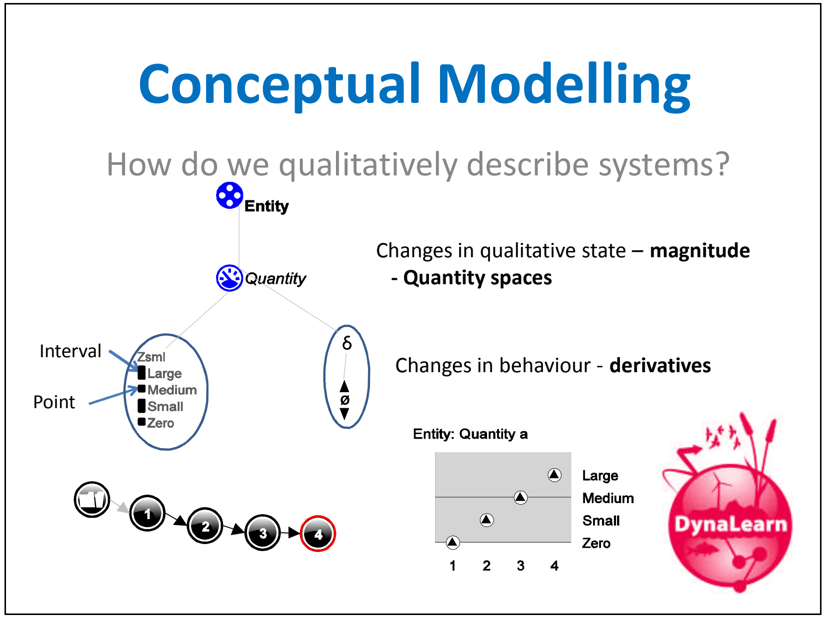
Qualitative approaches to modelling require that the model can describe the important states in which the system can be found. In this context quantities are ascribed quantity spaces that characterise important information about the possible (qualitatively discrete) states the quantity can take. These quantity spaces describe the possible magnitudes of the quantities. These can form different degrees of complexity:

Simple – undifferentiated (example of Heat in the figure): a single state of "Plus" indicating that it has only one qualitative state that we are interested in.

Simple – differentiated: The simplest form of differentiation is to recognise the value of Zero for a quantity. This leads to basic states of Zero and Plus (Absent or Present) or Minus, Zero, Plus which indicates negative and positive natures to the values.

Differentiated – semi quantitative: For example Zero, Small, Medium, Large.

Differentiated – descriptive states: For example in the diagram Water temperature is described based on the possible states water can occur in (Ice, Liquid, Gas). These different qualitative states may affect the behaviour of the system or may be the focus of our ideas about the system.



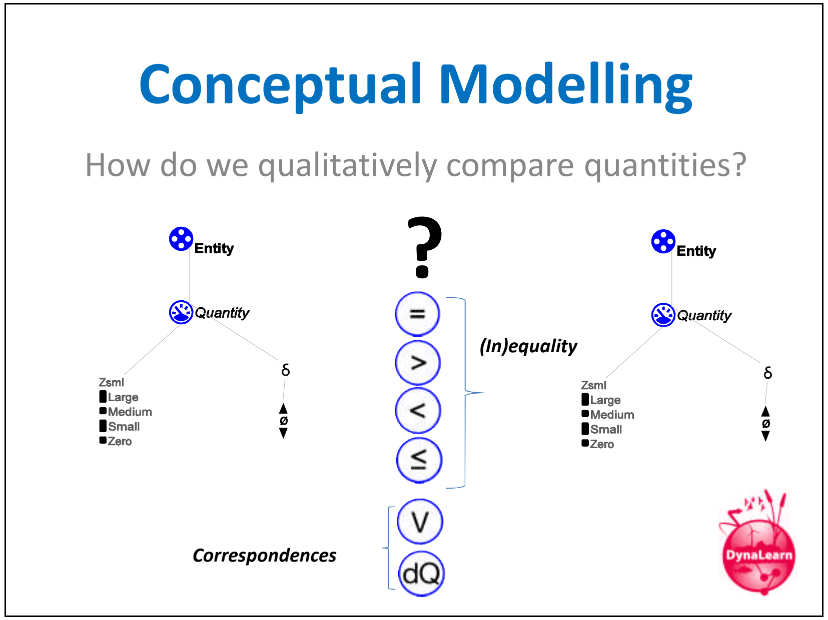
There are two ways of describing the state and behaviour of a system or of a quantity.

Firstly, as describe previously we can describe the ***magnitude*** of the quantity according to the different values or states in which it can occur. Magnitudes contain point and interval values where point values represent important threshold values for a quantity (e.g. zero, full, boiling point etc.). Intervals values represent undifferentiated values between these landmark points.

Secondly, we can describe how that quantity is changing at any point in time during behaviour. The way a quantity is changing is called the ***derivative*** δ in qualitative modelling and has three simple forms:

- Increasing (▲)
- Stable (Ø)
- Decreasing (▼)

Using these two simple and descriptive features, ones which match natural language, it is possible to describe complex behaviour patterns in very simple forms. These can be displayed visually as value history behaviour graphs, which represent the magnitude and derivatives of a chosen quantity during a simulation.



Conceptual modelling with qualitative reasoning applies simple terminology in a formalised manner to allow complex reasoning.

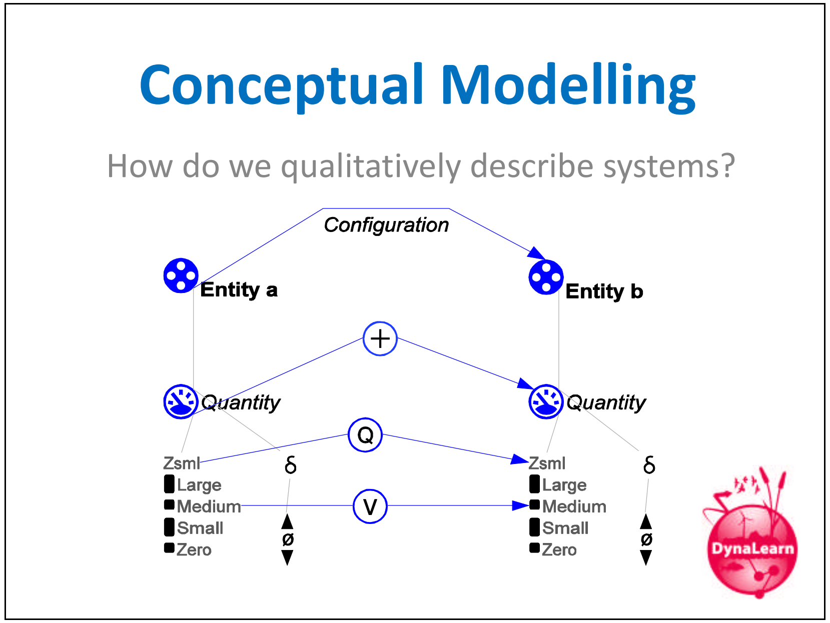
In many models and simulations it becomes important to compare and contrast different quantities. As the models have no quantities means to compare the value of quantities a simple qualitative vocabulary is used:

(In)Equalities:

- Equal to...(=)
- Less or Greater than...(<) (>)
- Equal or less (or greater) than....(≤) (≥)

Additionally, since quantity differentiation could be different for different quantities it becomes important to be able to describe which states occur at the same time during a simulation. These come in the form of value (V) or quantity space (Q) correspondences (see presentation on causality and system behaviour).

Using these basic qualitative descriptors it is possible reason about the relative magnitude of quantities and the states that they are in.



The approach used by QR is that of formalising simple terms and qualitative comparisons into a modelling language capable of generating complex reasoning about systems behaviour. The six main features described here:

- Entities
- Configurations
- Quantities
- Quantity spaces
- (In)equalities
- Correspondences

Enable a formalised description of the structure of a system, the possible states and values it can take, the way quantities compare to each other and ultimately how those quantities can change during simulation.

The key step to being able to reason from this model structure is to be able to describe causal relations (shown as a (+) in the slide) between the quantities. The causal dependencies have different forms and produce different behaviours.