There is a real world with real structure. The program of mind has been trained on vast interaction with this world and so contains code that reflects the structure of the world and knows how to exploit it. This code contains representations of real objects in the world and represents the interactions of real objects.

You exploit the structure of the world to make decisions and take actions. Where you draw the line on categories, what constitutes a single object or a single class of objects for you, is determined by the program of your mind, which does the classification. This classification is not random but reflects a compact description of the world, and in particular a description useful for exploiting the structure of the world.

– Eric B. Baum [2004]

Knowledge Graphs and Ontologies

- Is there a flexible way to represent relations?
- How can knowledge/data bases be made to interoperate?

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prop(*Individual*, *Property*, *Value*) is the only relation needed:
called individual-property-value representation
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- $prop(a, parcel, true)$, where $parcel$ is a Boolean property
  Here parcel is the characteristic function of the class.

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Semantic Networks / Knowledge Graphs

When you only have one relation, *prop*, it can be omitted without loss of information.
Logic:

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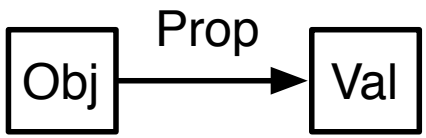

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$prop(Entity, Property, Value)$ is the only relation needed: $\langle Entity, Property, Value \rangle$ triples, semantic network, entity relationship model, knowledge graphs, ...

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- The IRI denotes the entity, not the web site; if someone uses the IRI they mean the individual denoted by the IRI.

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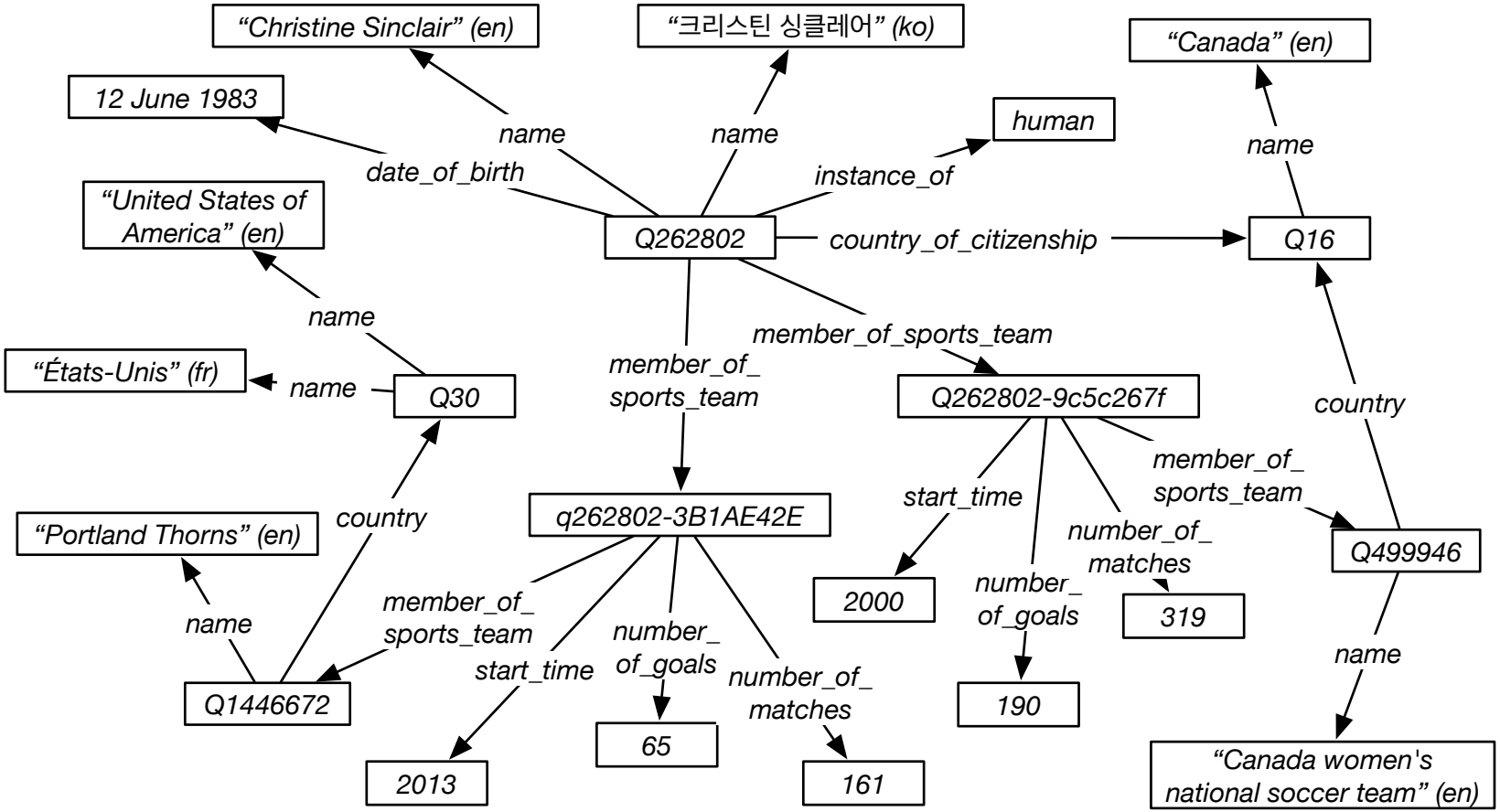
Part of the Wikidata Knowledge Graph



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- However, Air Canada does not fly from New York to Los Angeles.
  The information about flights is lost!

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- E.g., Specifying all *mammals* are warm blooded is more concise than specifying each individual is warm blooded.
- A class is the set of those actual and potential individuals that would be members of the class.
  E.g., class of chairs includes chairs that have not been build or may never be built.

Class Hierarchies

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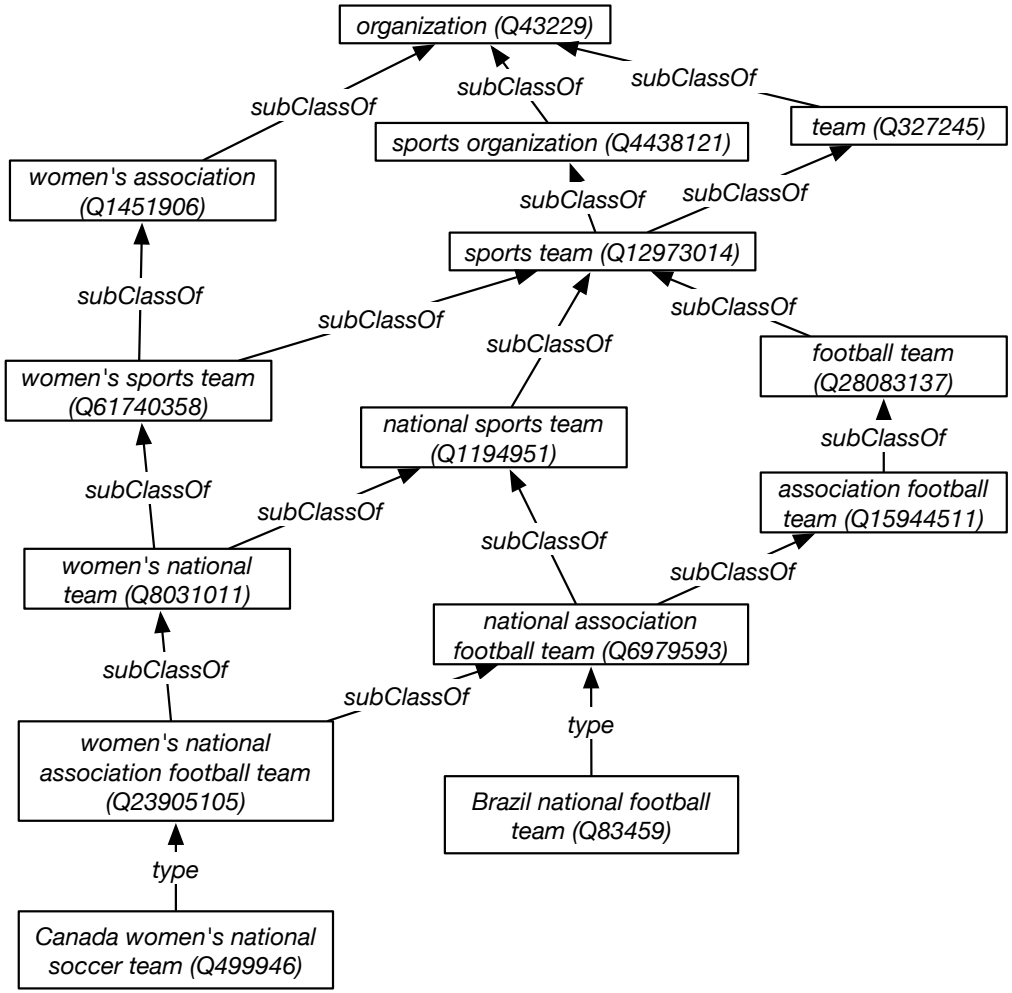

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Some sub-properties in Wikidata are

- "member of sports team" (P54) is a sub-property of "member of" (P463)
- "member of" (P463) is a sub-property of "affiliation" (P1416)
- "affiliation" (P1416) is a sub-property of "part of" (P361)
- "part of" (P361) is a sub-property of "partially coincident with" (P1382)

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These are not (currently) part of Wikidata!

Designing Classes

Aristotle [350 B.C.] suggested the definition if a class C in terms of:

- Genus: a super-class
- Differentia: the attributes that make members of the class C different from other members of the super-class

"If genera are different and co-ordinate, their differentiae are themselves different in kind. Take as an instance the genus 'animal' and the genus 'knowledge'. 'With feet', 'two-footed', 'winged', 'aquatic', are differentiae of 'animal'; the species of knowledge are not distinguished by the same differentiae. One species of knowledge does not differ from another in being 'two-footed'."

Aristotle, *Categories*, 350 B.C.

Designing Classes

The art of ranking things in genera and species is quite important, and greatly helps our judgment as well as our memory. . . . Order largely depends on it, and many good authors write in such a way that their whole account could be divided and subdivided according to a procedure related to genera and species. This helps one not merely to retain things in one's memory, but also to find them there. Writers who have laid out all sorts of notions under certain headings or categories have done something very useful.

– G. W. Leibniz [1705]

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- Each attribute gives a property and a value.
- For each property, define the domain to be most general class for which it makes sense.
- Make the range of the property another class that makes sense (perhaps requiring this range class to be defined, either by enumerating its values or by defining it using an Aristotelian definition).

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- A rhombus is a quadrilateral where all four sides have the same length.
- A square is a quadrilateral where all four sides have the same length and all inside angles are right angles.

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What is a most specific superclass of square?
A square is both a rectangle and a rhombus.
Neither is more specific than the other.