Ontology Development 101

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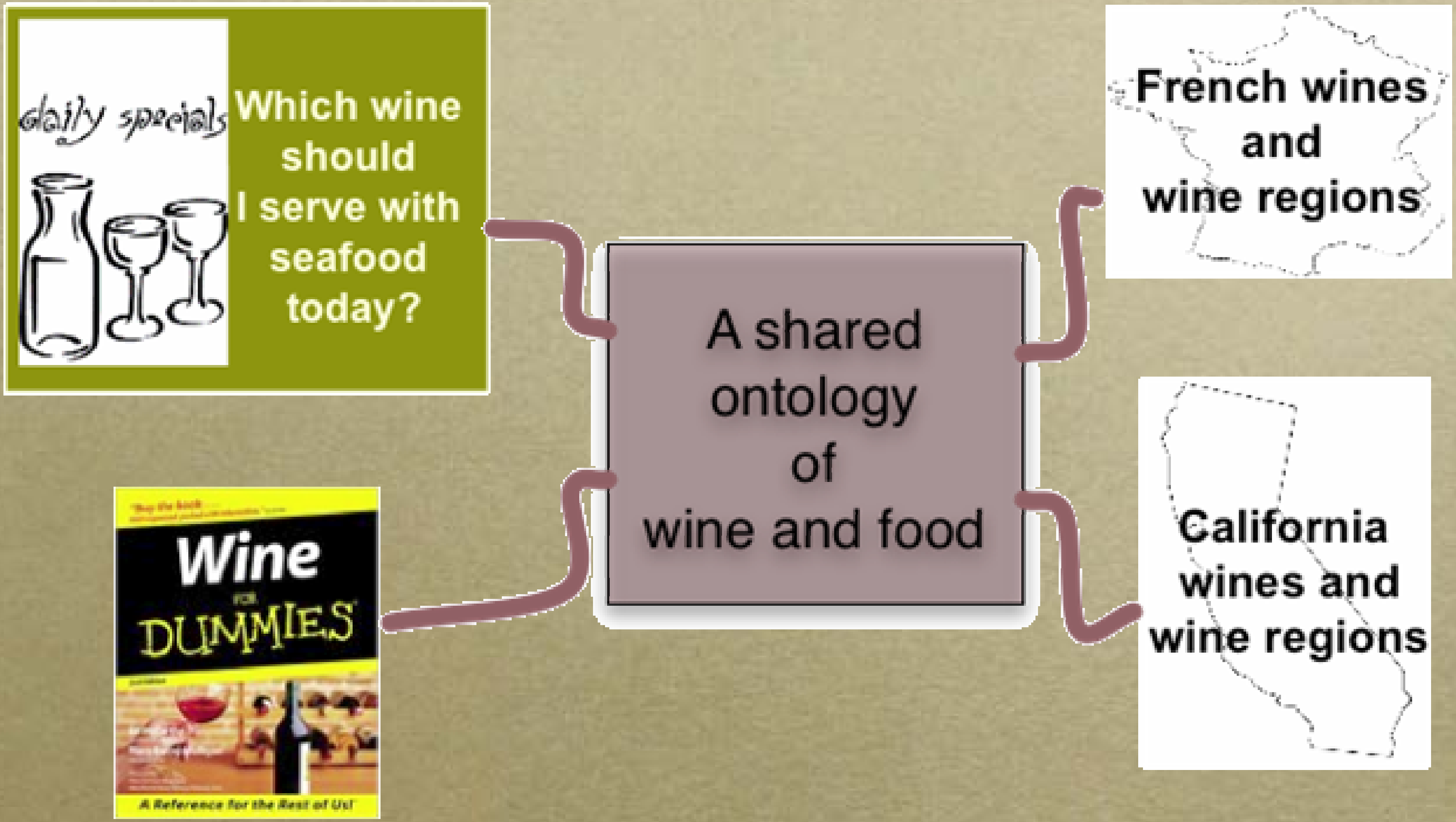
A large part of this tutorial is based on
"Ontology Development 101: A Guide to Creating Your First Ontology"
by Natalya F. Noy and Deborah L. McGuinness
http://protege.stanford.edu/publications/ontology_development/ontology101.html

Outline

- *What is an ontology?*
  - *definition*
  - *terminology*
- *Why develop an ontology?*
- *Step-By-Step: Developing an ontology*
- *Underwater ??*
  - *What to look out for*


daily specials
Which wine should I serve with seafood today?
A shared ontology of wine and food
French wines and wine regions
California wines and wine regions
Wine for DUMMIES
A Reference for the Rest of Us!

What is an ontology

- *An ontology is an explicit description of a domain:*
  - *concepts*
  - *properties and attributes of concepts*
  - *constraints on properties and attributes*
  - *individuals*
- *An ontology defines*
  - *a common vocabulary*
  - *a shared understanding*

Ontology examples

- *Taxonomies on the Web*
  - *Yahoo! categories*
- *Catalogs for on-line shopping*
  - *Amazon product catalog*
- *Domain-specific standard terminology*
  - *Unified Medical Language System (UMLS)*
  - *UNSPSC - terminology for products and services*

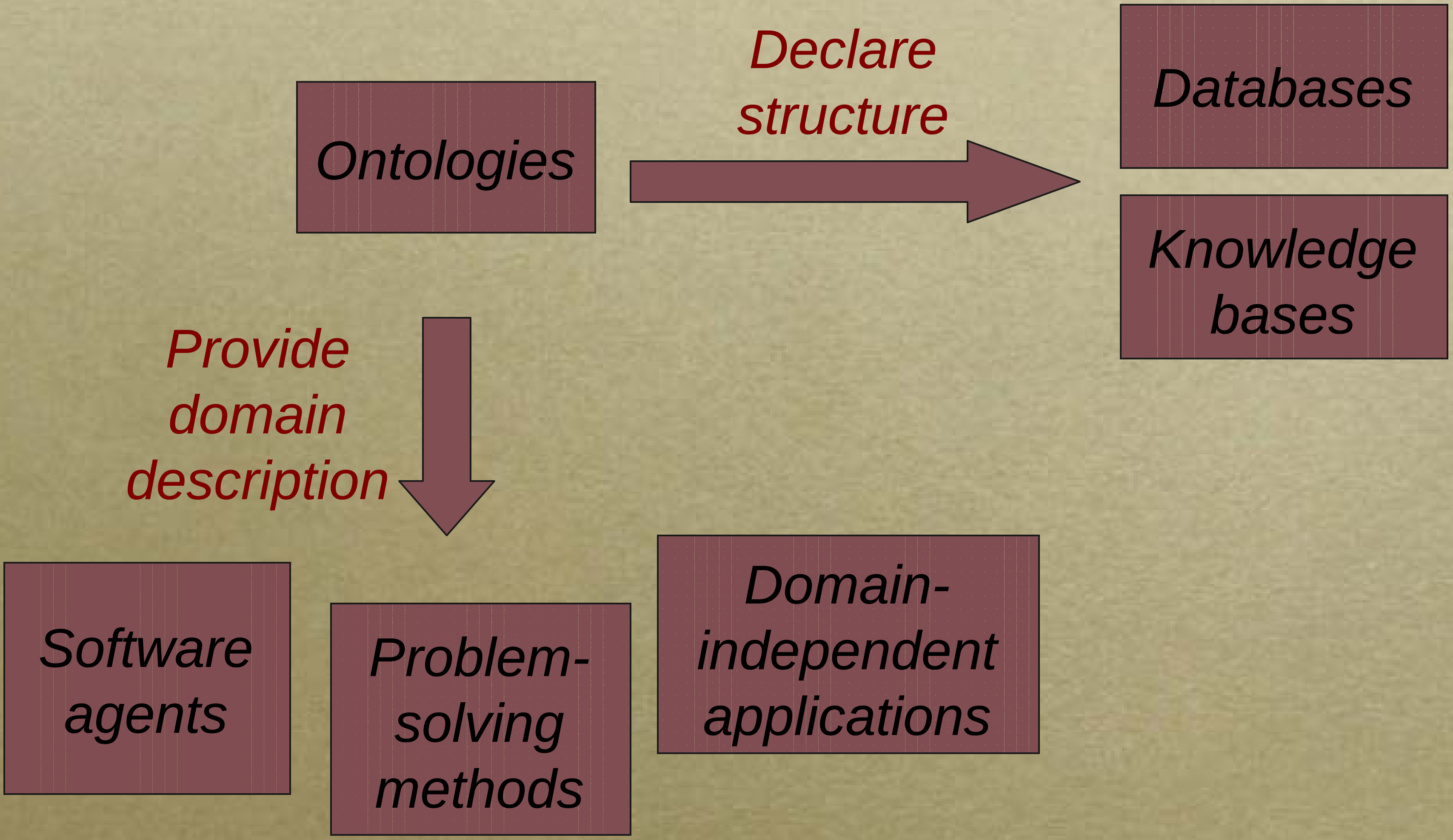
Why develop an ontology?

- *To share common understanding of the structure of information*
  - *among people*
  - *among software agents*
- *To enable reuse of domain knowledge*
  - *to avoid “re-inventing the wheel”*
  - *to introduce standards*

More reasons

- *To make domain assumptions explicit*
  - *easier to change domain assumptions (consider a genetics knowledge base)*
  - *easier to understand and update legacy data*
- *To separate domain knowledge from the operational knowledge*
  - *re-use domain and operational knowledge separately (e.g., configuration based on constraints)*

An ontology is often just the beginning



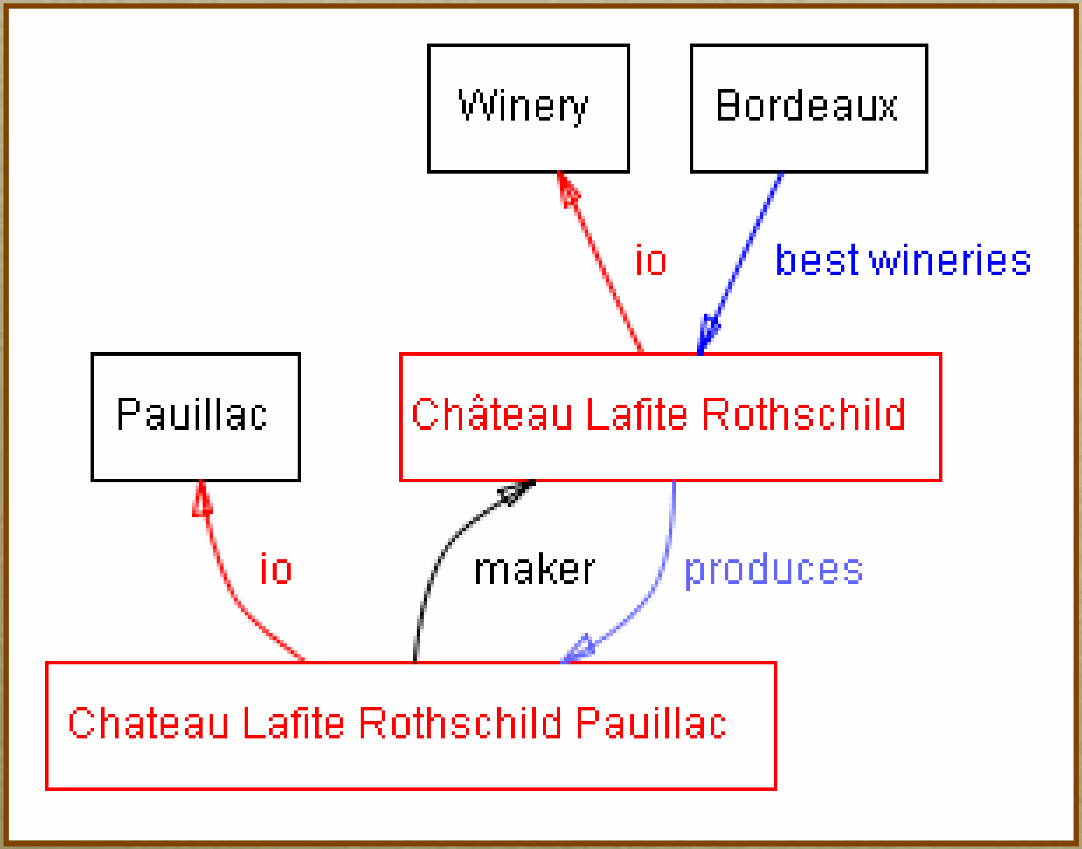
Outline

- *What is an ontology?*
- *Why develop an ontology?*
- *Step-By-Step: Developing an ontology*
- *Underwater ??*
    - *What to look out for*

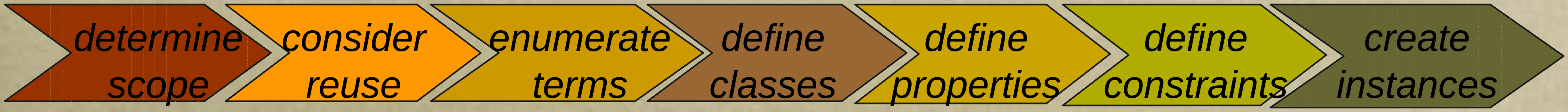
What Is “Ontology Development”?

- *Defining terms in the domain and relations among them*
  - *Defining concepts in the domain (classes)*
  - *Arranging the concepts in a hierarchy (subclass-superclass hierarchy)*
  - *Defining which attributes and properties (slots) classes can have and constraints on their values*
  - *Defining individuals and filling in slot values (instances)*

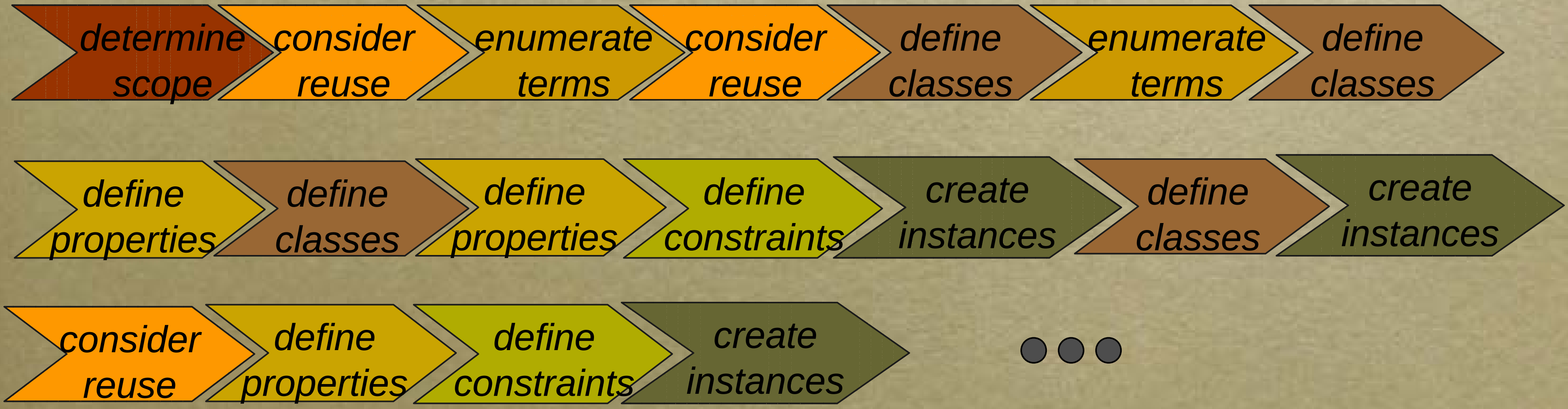
Wines and wineries



Ontology-development process



In reality - an iterative process:



Ontology development versus Object-oriented modeling

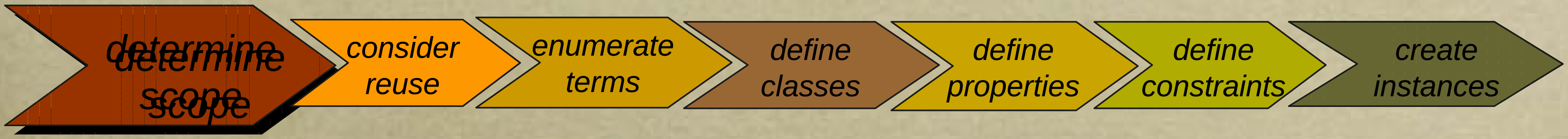
An ontology

- reflects the structure of the world
- is often about structure of concepts
- actual physical representation is not an issue

An OO Structure

- reflects the structure of the data and code
- is usually about behavior (methods)
- describes the physical representation of data (long int, char, etc.)

Determine domain and scope



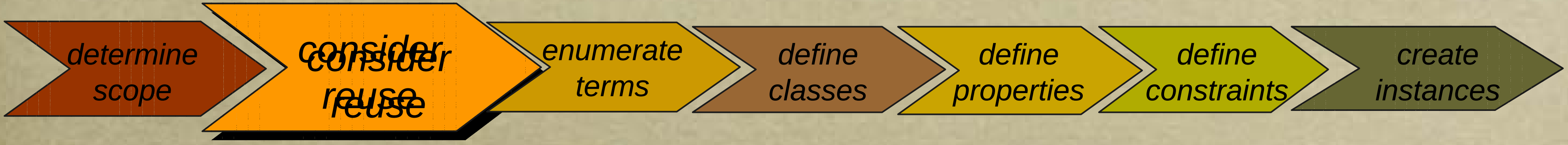
- *What is the domain that the ontology will cover?*
- *For what we are going to use the ontology?*
- *For what types of questions the information in the ontology should provide answers?*
- *Who will use and maintain the ontology?*

Answers to these questions may change during the ontology lifecycle

Competency question for the Wine ontology

- *Which wine characteristics should I consider when choosing a wine?*
- *Is Bordeaux a red or white wine?*
- *Does Cabernet Sauvignon go well with seafood?*
- *What is the best choice of wine for grilled meat?*
- *Which characteristics of a wine affect its appropriateness for a dish?*
- *Does a bouquet or body of a specific wine change with vintage year?*
- *What were good vintages for Napa Zinfandel?*

Consider reuse

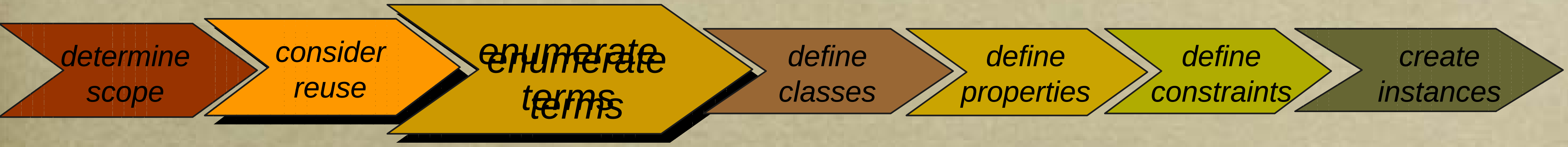


- *Why reuse other ontologies?*
  - *to save the effort*
  - *to interact with the tools that use other ontologies*
  - *to use ontologies that have been validated through use in applications*

What to reuse?

- *Ontology libraries*
  - *Protégé ontology library (protege.stanford.edu)*
  - *Ontolingua ontology library (www.ksl.stanford.edu/software/ontolingua/)*
- *Upper ontologies*
  - *IEEE Standard Upper Ontology (suo.ieee.org)*
  - *Cyc (www.cyc.com)*
- *Domain-specific ontologies*
  - *UMLS Semantic Net*
  - *GO (Gene Ontology) (www.geneontology.org)*
  - *OBO (Open Biological Ontologies) (obo.sourceforge.net)*

Enumerate important terms

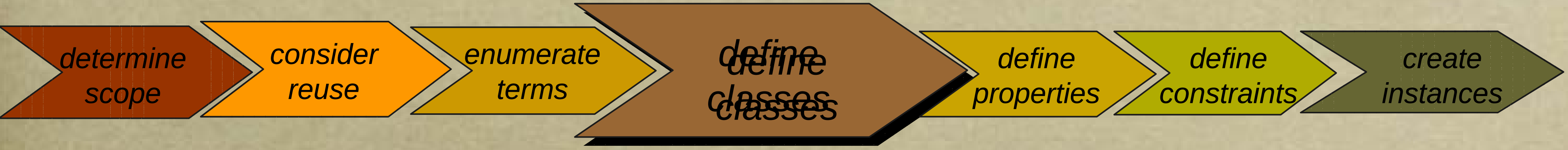


- *What are the terms we need to talk about?*
- *What are the properties of these terms?*
- *What do we want to say about the terms?*

Enumerating terms: The Wine ontology

- *wine, grape, winery, location,*
- *wine color, wine body, wine flavor, sugar content*
- *white wine, red wine, Bordeaux wine*
- *food, seafood, fish, meat, vegetables, cheese*

Define classes and the class hierarchy



- *A class is a concept in the domain*
  - *a class of wines*
  - *a class of wineries*
  - *a class of red wines*
- *A class is a collection of elements with similar properties*
- *Instances of classes*
  - *a glass of California wine you'll have for lunch*

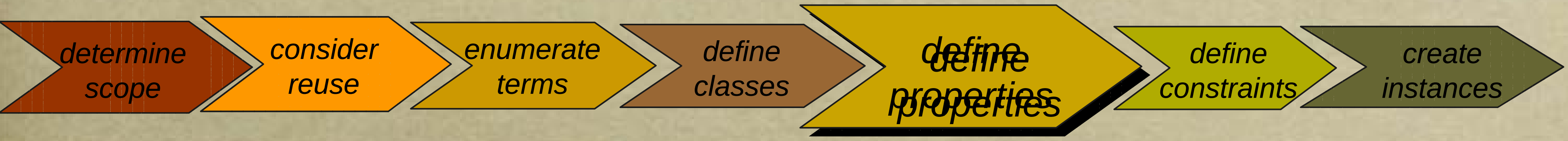
Class inheritance

- *Classes usually constitute a taxonomic hierarchy (a subclass-superclass hierarchy)*
- *A class hierarchy is usually an IS-A hierarchy:*
  - *an instance of a subclass is an instance of a superclass*
- *If you think of a class as a set of elements, a subclass is a subset*

Class inheritance: Examples

- *Apple is a subclass of Fruit*
  - *Every apple is a fruit*
- *Red wines is a subclass of Wine*
  - *Every red wine is a wine*
- *Chianti wine is a subclass of red wine*
  - *Every Chianti wine is a red wine*

Define properties of classes: Slots

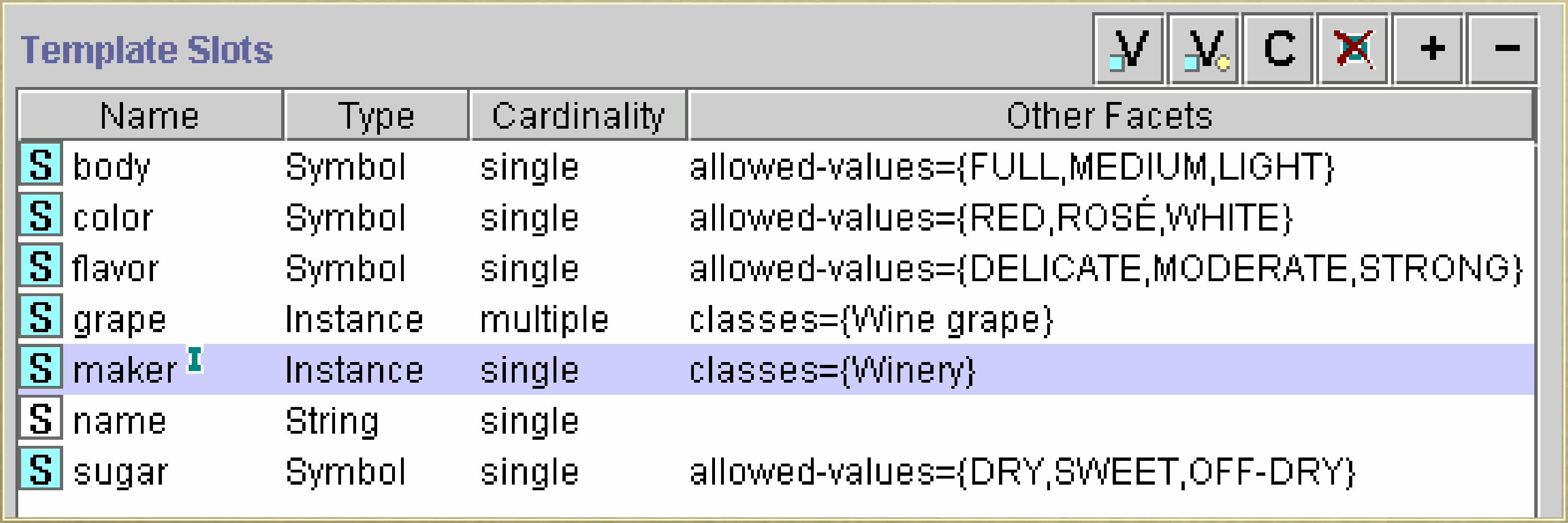


- *Slots in a class definition describe attributes of instances of the class*
  - *each wine will have color, sugar content, producer, etc.*

Slots

- *Types of properties*
  - *“intrinsic” properties: flavor and color of wine*
  - *“extrinsic” properties: name and price of wine*
  - *parts: ingredients in a dish*
  - *relations to other objects: producer of wine (winery)*
- *Simple and complex properties*
  - *simple properties (attributes): contain primitive values (strings, numbers)*
  - *complex properties: contain other objects (e.g., a winery instance)*

Slots for the class Wine

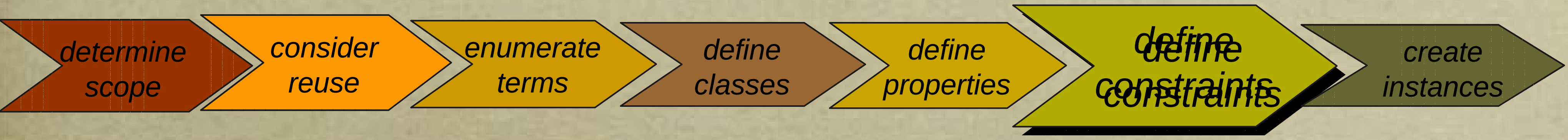


Name	Type	Cardinality	Other Facets
S body	Symbol	single	allowed-values={FULL,MEDIUM,LIGHT}
S color	Symbol	single	allowed-values={RED,ROSÉ,WHITE}
S flavor	Symbol	single	allowed-values={DELICATE,MODERATE,STRONG}
S grape	Instance	multiple	classes={Wine grape}
S maker	Instance	single	classes={Winery}
S name	String	single	
S sugar	Symbol	single	allowed-values={DRY,SWEET,OFF-DRY}

Slot and class inheritance

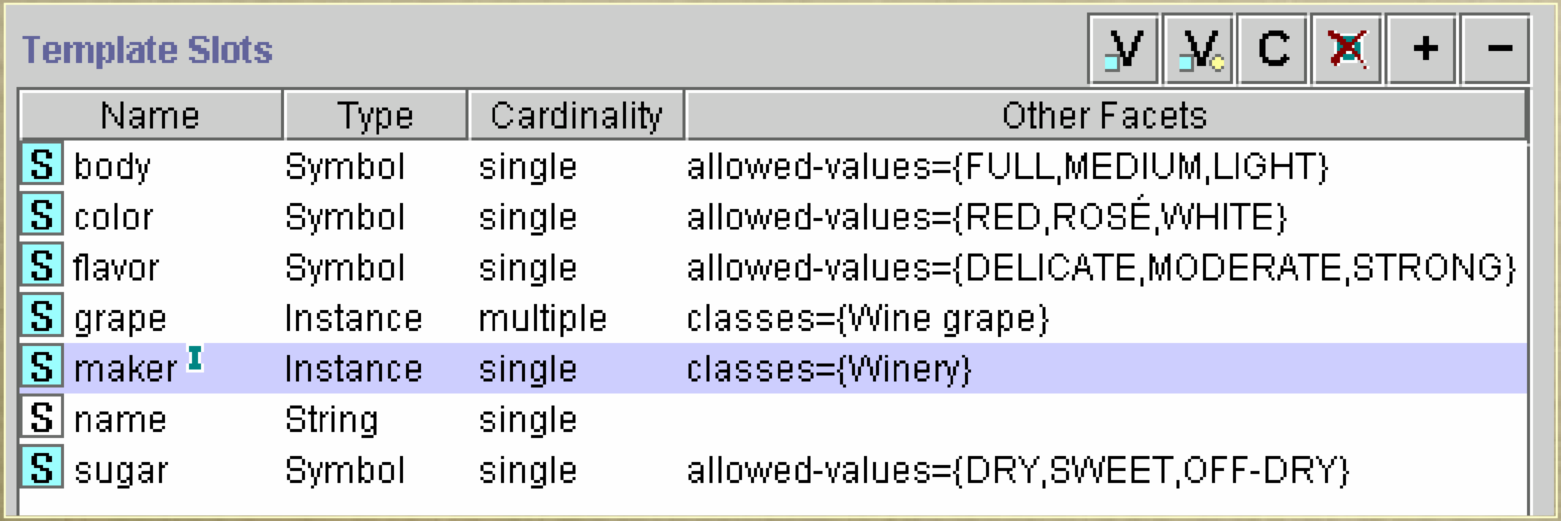
- *A subclass inherits all the slots from the superclass*
    - *If a wine has a name and flavor, a red wine also has a name and flavor*
- *If a class has multiple superclasses, it inherits slots from all of them*
    - *Port is both a dessert wine and a red wine. It inherits "sugar content: high" from the former and "color:red" from the latter*

Property constraints



- *Property constraints (facets) describe or limit the set of possible values for a slot*
  - *the name of a wine is a string*
  - *the wine producer is an instance of Winery*
  - *a winery has exactly one location*

Facets for slots at the Wine class



Template Slots

Name	Type	Cardinality	Other Facets
S body	Symbol	single	allowed-values={FULL,MEDIUM,LIGHT}
S color	Symbol	single	allowed-values={RED,ROSÉ,WHITE}
S flavor	Symbol	single	allowed-values={DELICATE,MODERATE,STRONG}
S grape	Instance	multiple	classes={Wine grape}
S maker	Instance	single	classes={Winery}
S name	String	single	
S sugar	Symbol	single	allowed-values={DRY,SWEET,OFF-DRY}

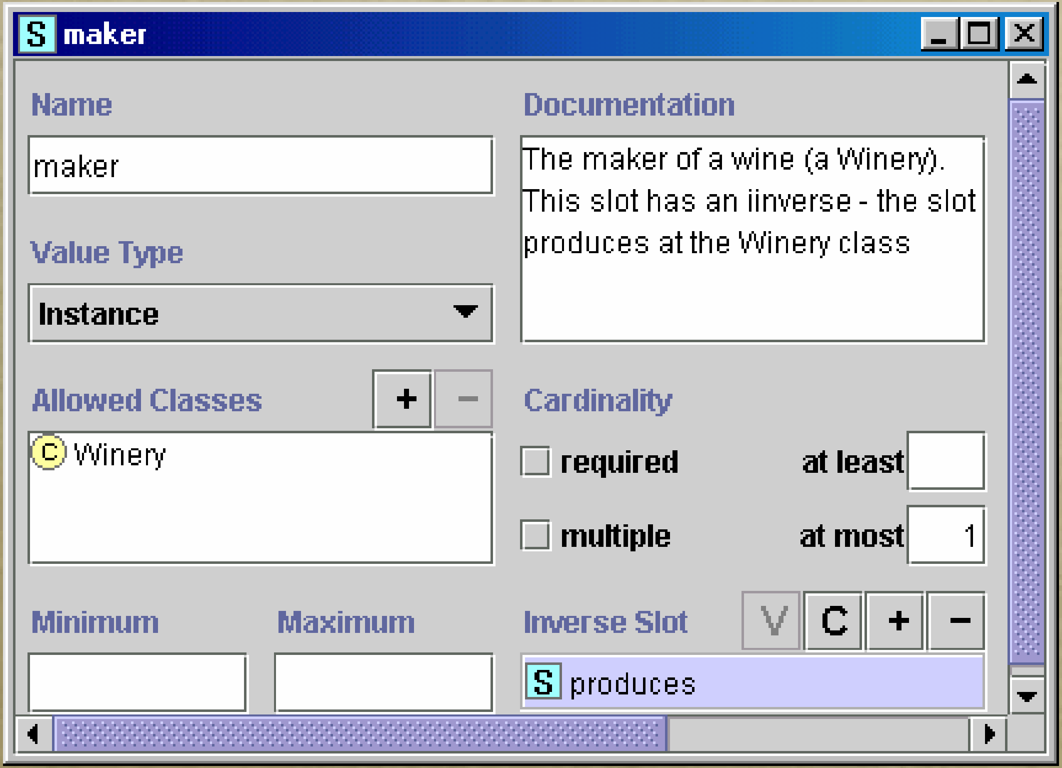
Common facets: Cardinality

- *Slot cardinality – the number of values a slot can or must have*
  - *Minimum cardinality*
    - *Minimum cardinality 1 means that the slot must have a value (required)*
    - *Minimum cardinality 0 means that the slot value is optional*
  - *Maximum cardinality*
    - *Maximum cardinality 1 means that the slot can have at most one value (single-valued slot)*
    - *Maximum cardinality greater than 1 means that the slot can have only one value (multiple-valued slot)*

Common facets: Value Type

- *Slot value type – what values can the slot have*
  - *String: a string of characters ("Château Lafite")*
  - *Number: an integer or a float (15, 4.5)*
  - *Boolean: a true/false flag*
  - *Enumerated type: a list of allowed values (red, white, rosé)*
  - *Complex type: an instance of another class or a class itself*
    - *Specify the class to which the instances belong*
    - *For example, the Wine class is the value type for the produces slot at the Winery class*

Defining facets: Example


maker

Name: maker

Documentation: The maker of a wine (a Winery). This slot has an iinverse - the slot produces at the Winery class

Value Type: Instance

Allowed Classes: Winery

Cardinality:
required at least
multiple at most 1

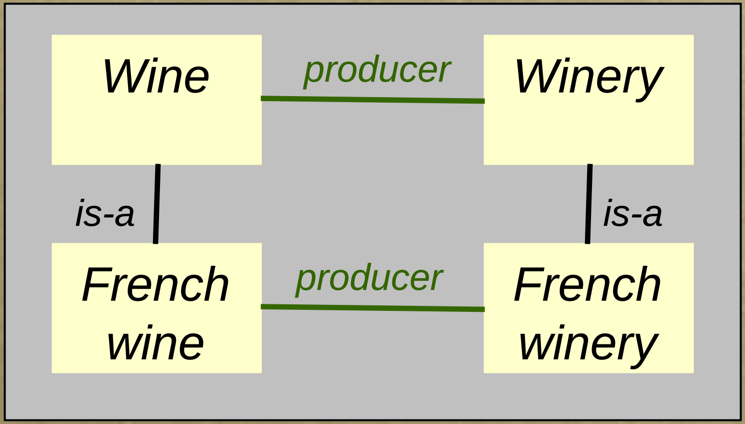
Minimum

Maximum

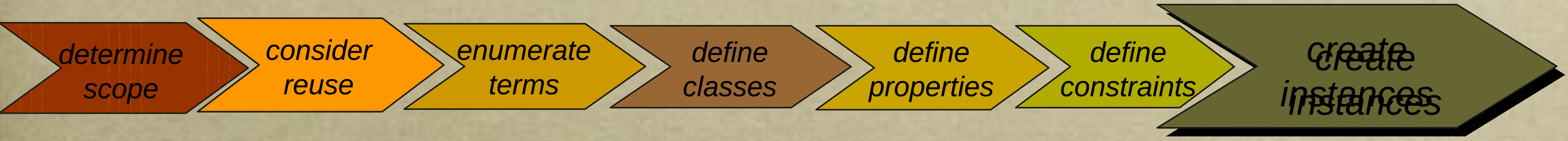
Inverse Slot: produces

Facets and class inheritance

- *A subclass inherits all the slots from the superclass*
- *A subclass can override the facets to “narrow” the list of allowed values*
  - *Make the cardinality range smaller*
  - *Replace a class in the range with a subclass*

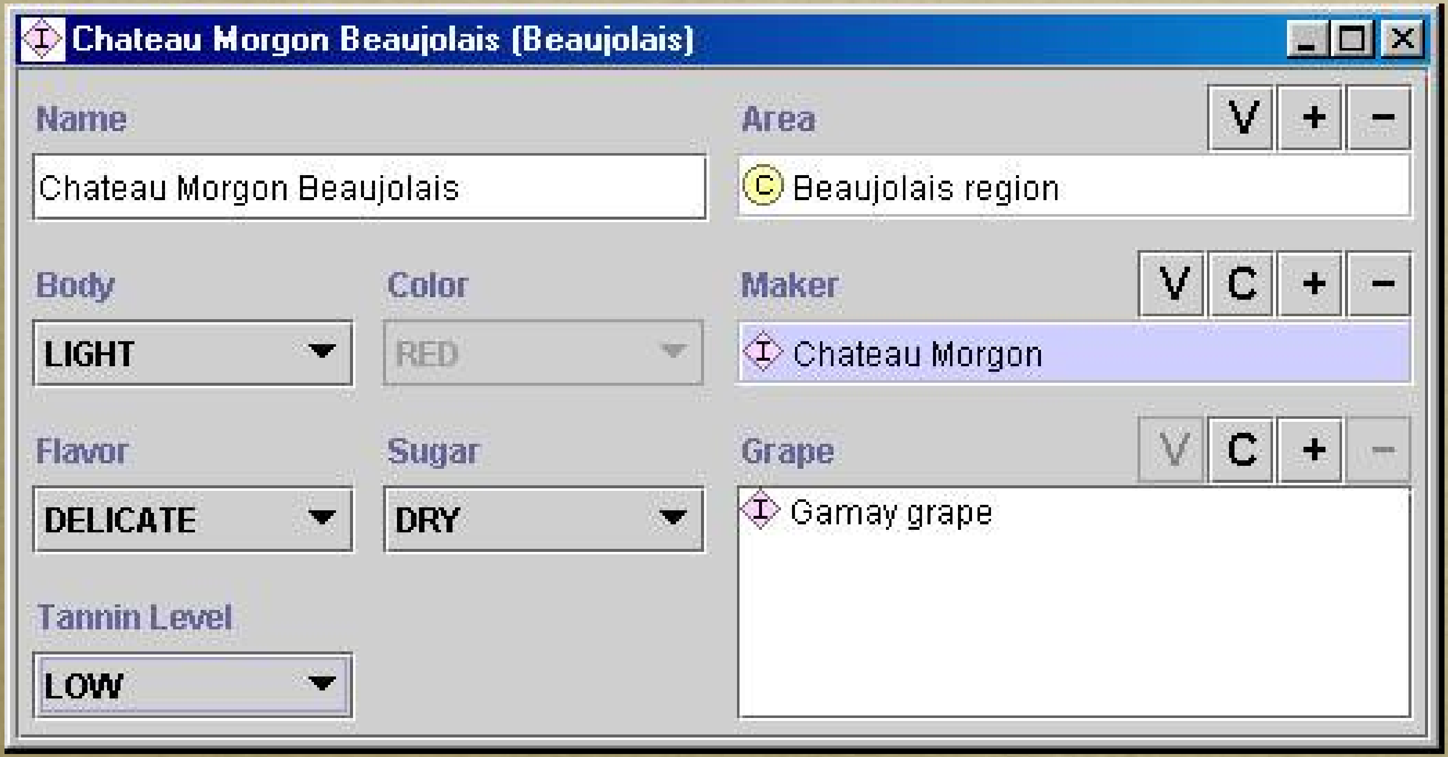


Create instances



- *Create an instance of a class*
  - *The class becomes a direct type of the instance*
  - *Any superclass of the direct type is a type of the instance*
- *Assign slot values for the instance frame*
  - *Slot values should conform to the facet constraints*
  - *Knowledge-acquisition tools often check that*

Creating an instance: Example



Chateau Morgon Beaujolais (Beaujolais)

Name: Chateau Morgon Beaujolais

Area: Beaujolais region

Body: LIGHT

Color: RED

Maker: Chateau Morgon

Flavor: DELICATE

Sugar: DRY

Grape: Gamay grape

Tannin Level: LOW

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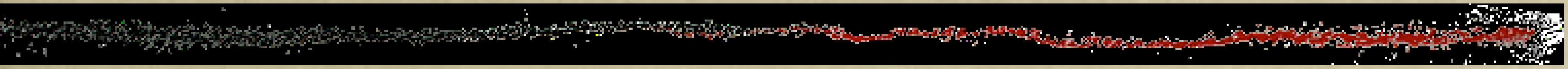
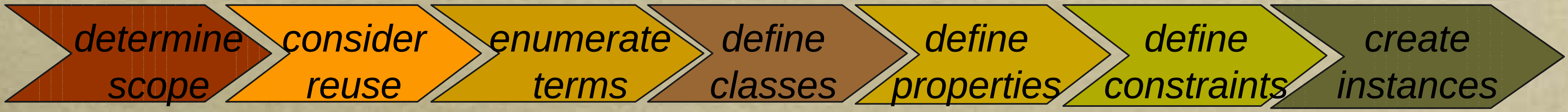
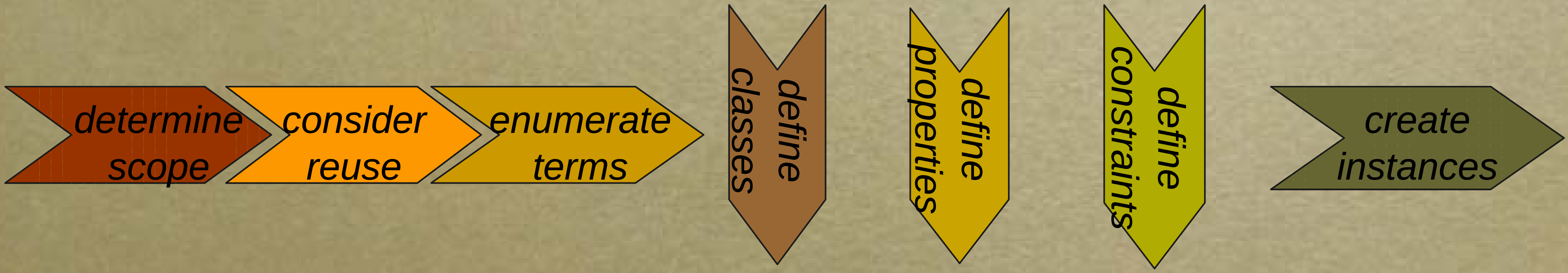
Going deeper





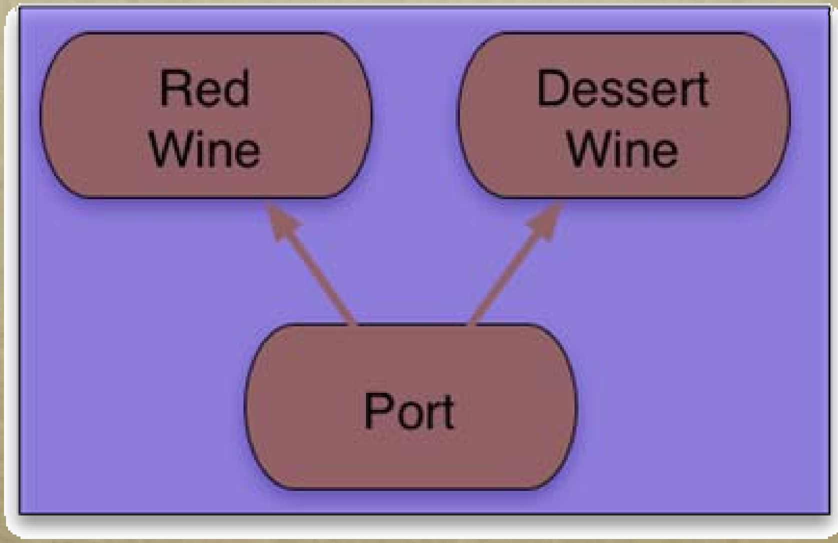


Defining classes and a class hierarchy

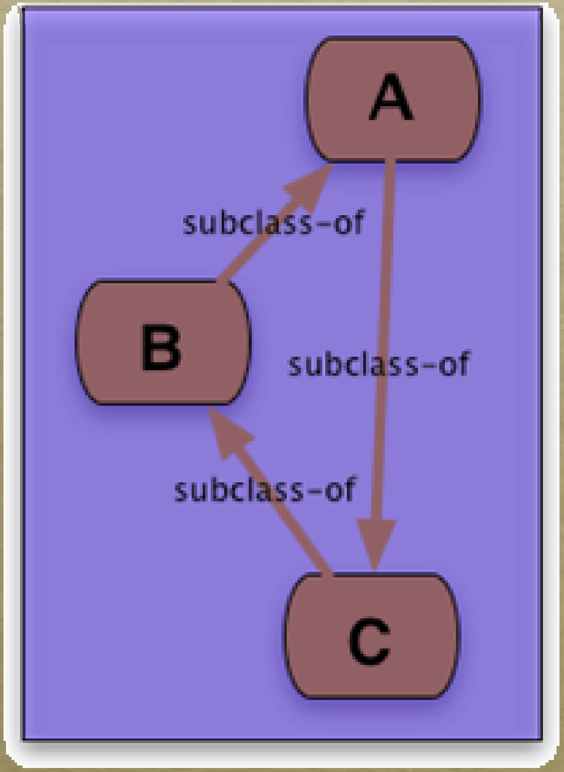
- *The question to ask:*
  - *"Is each instance of the subclass an instance of its superclass?"*
- *The things to remember:*
  - *There is no single correct class hierarchy*
  - *But there are some guidelines*

Multiple inheritance

- *A class can have more than one superclass*
- *The subclass inherits slots and facet restrictions from all the parents*
- *Different systems resolve conflicts differently*



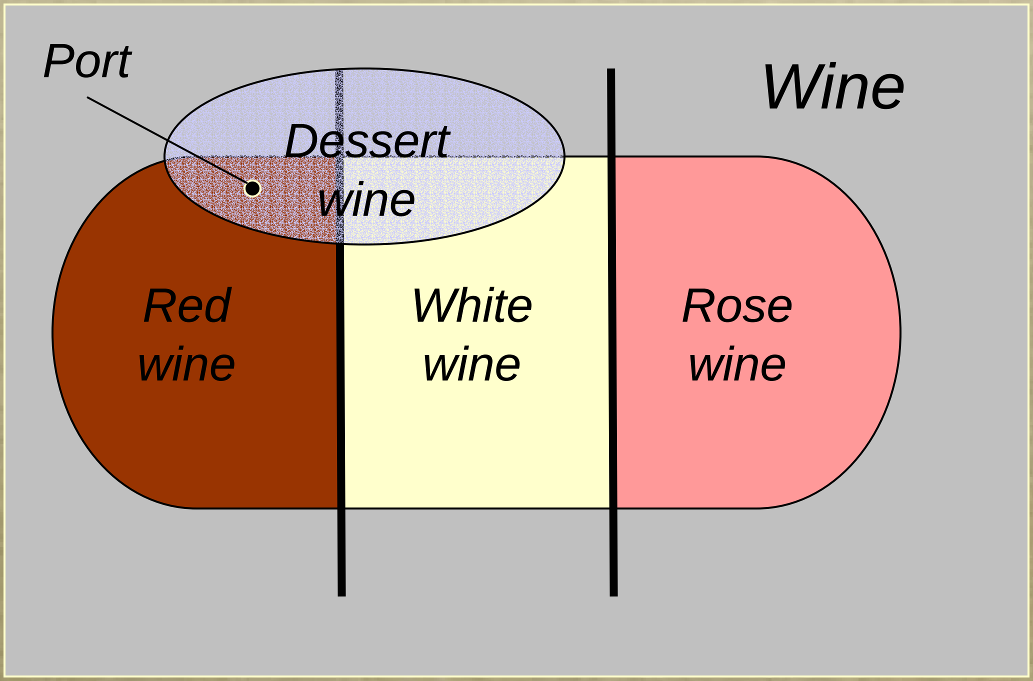
Avoiding class cycles



- *Danger of multiple inheritance: cycles in the class hierarchy*
- *Classes A, B, and C have equivalent sets of instances*
- *By many definitions, A, B, and C are thus equivalent*

Disjoint classes

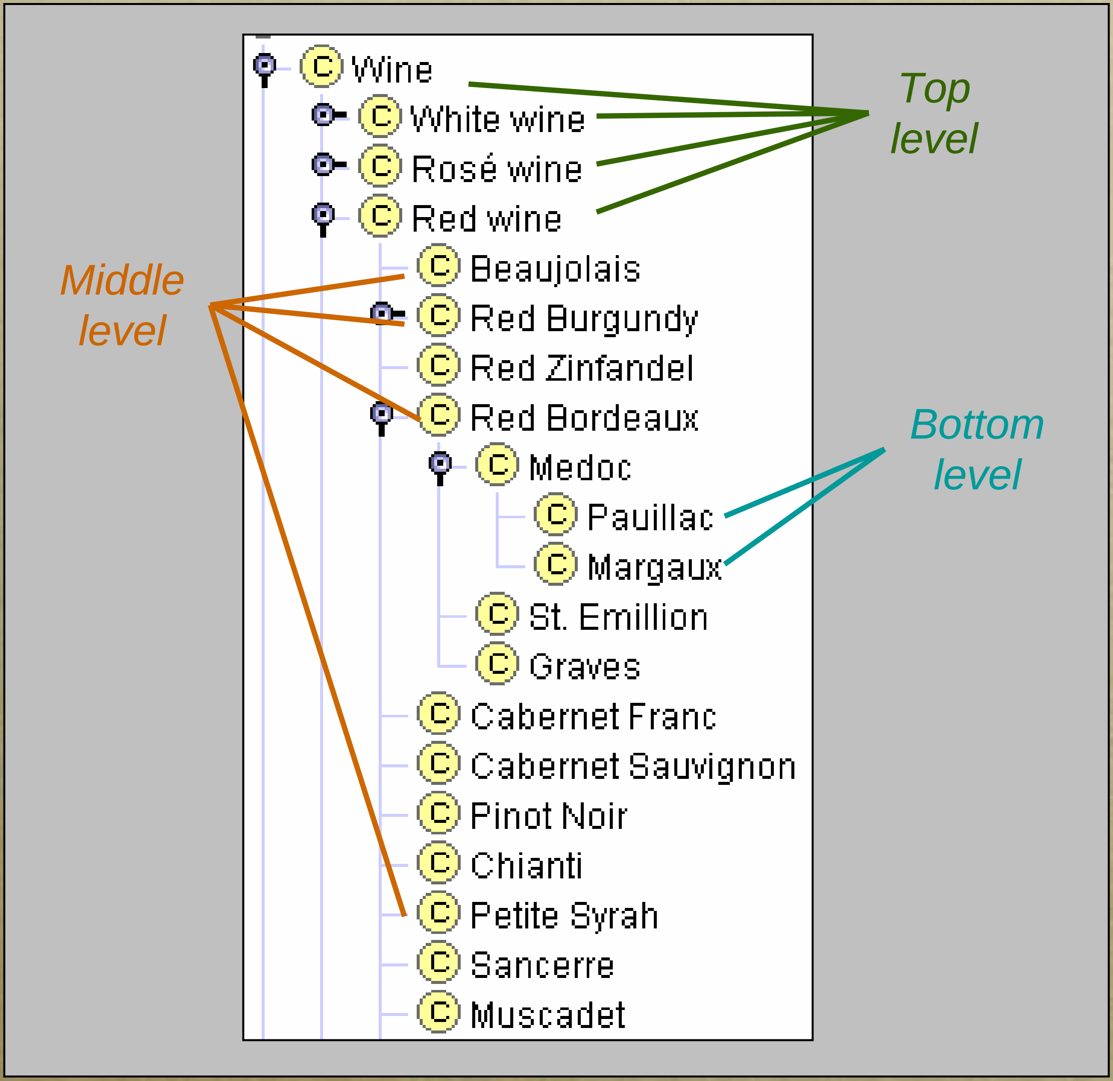
- *Classes are disjoint if they cannot have common instances*
- *Disjoint classes cannot have any common subclasses either*
  - *Red wine, White wine, Rosé wine are disjoint*
  - *Dessert wine and Red wine are not disjoint*



Levels in the class hierarchy

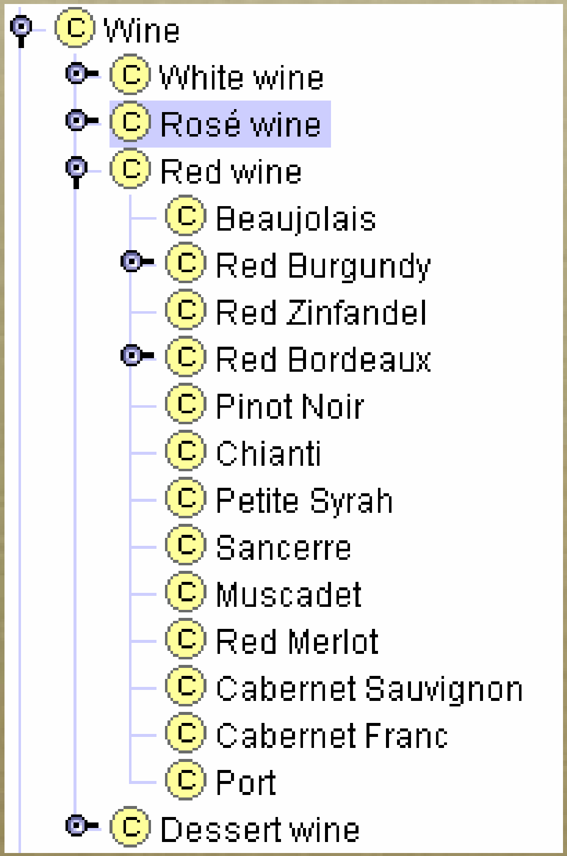
- *Different modes of the development*
  - *top-down - define the most general concepts first and then specialize them*
  - *bottom-up - define the most specific concepts and then organize them in more general classes*
  - *combination*

Levels in the class hierarchy



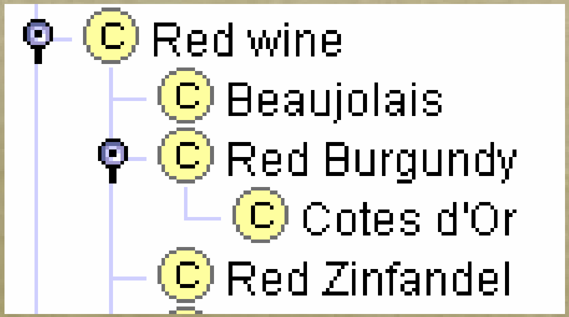
- Wine
  - White wine
  - Rosé wine
  - Red wine
    - Beaujolais
    - Red Burgundy
    - Red Zinfandel
    - Red Bordeaux
      - Medoc
        - Pauillac
        - Margaux
      - St. Emillion
      - Graves
    - Cabernet Franc
    - Cabernet Sauvignon
    - Pinot Noir
    - Chianti
    - Petite Syrah
    - Sancerre
    - Muscadet

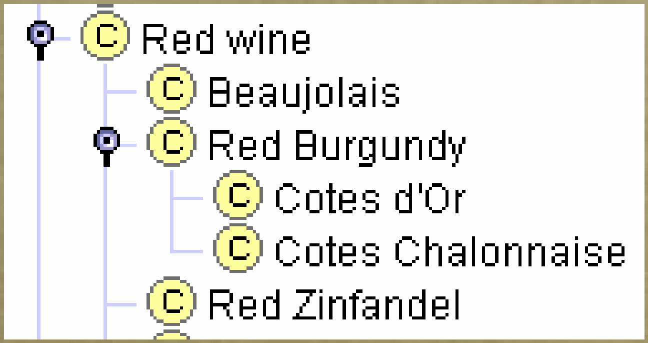
Siblings in the class hierarchy



- *All the siblings in the class hierarchy must be at the same level of generality*
- *Compare to section and subsections in a book*

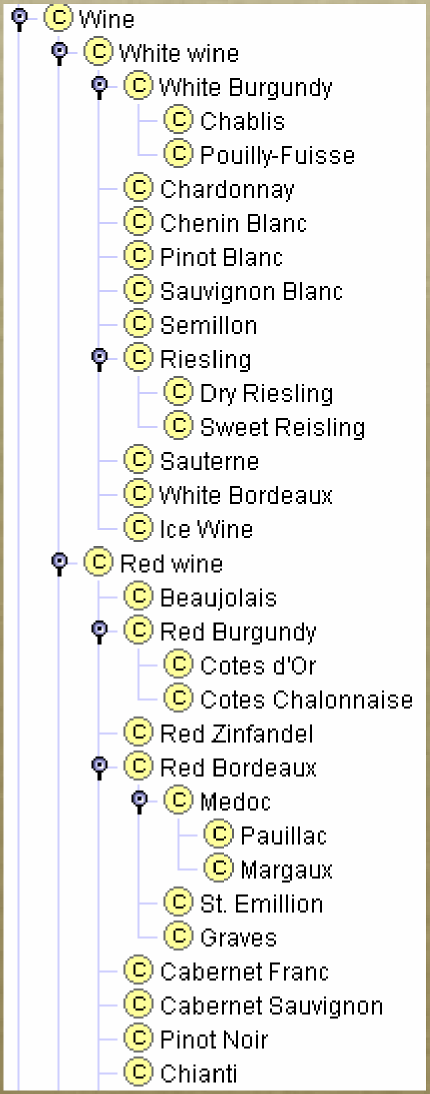
The perfect family size



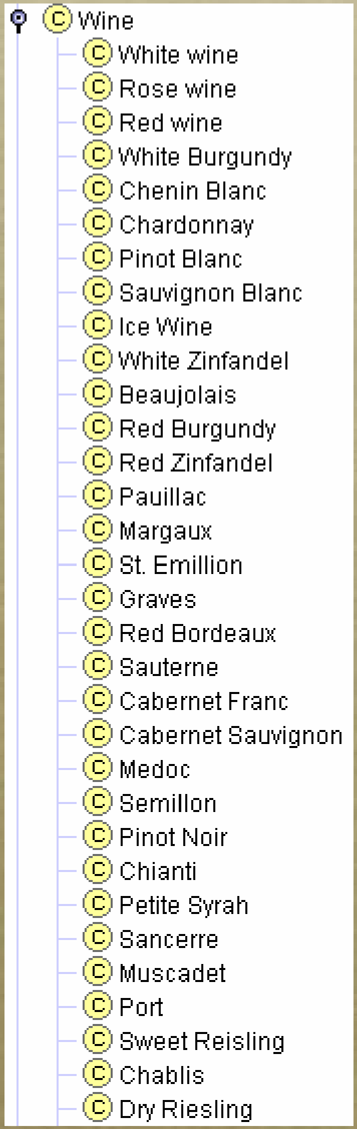


- *If a class has only one child, there may be a modeling problem*
- *If the only Red Burgundy we have is Côtes d’Or, why introduce the subhierarchy?*
- *Compare to bullets in a bulleted list*

The perfect family size (II)



- Wine
  - White wine
    - White Burgundy
      - Chablis
      - Pouilly-Fuisse
    - Chardonnay
    - Chenin Blanc
    - Pinot Blanc
    - Sauvignon Blanc
    - Semillon
    - Riesling
      - Dry Riesling
      - Sweet Reisling
    - Sauterne
    - White Bordeaux
    - Ice Wine
  - Red wine
    - Beaujolais
    - Red Burgundy
      - Cotes d'Or
      - Cotes Chalonnaise
    - Red Zinfandel
    - Red Bordeaux
      - Medoc
        - Pauillac
        - Margaux
      - St. Emillion
      - Graves
    - Cabernet Franc
    - Cabernet Sauvignon
    - Pinot Noir
    - Chianti



- Wine
  - White wine
  - Rose wine
  - Red wine
  - White Burgundy
  - Chenin Blanc
  - Chardonnay
  - Pinot Blanc
  - Sauvignon Blanc
  - Ice Wine
  - White Zinfandel
  - Beaujolais
  - Red Burgundy
  - Red Zinfandel
  - Pauillac
  - Margaux
  - St. Emillion
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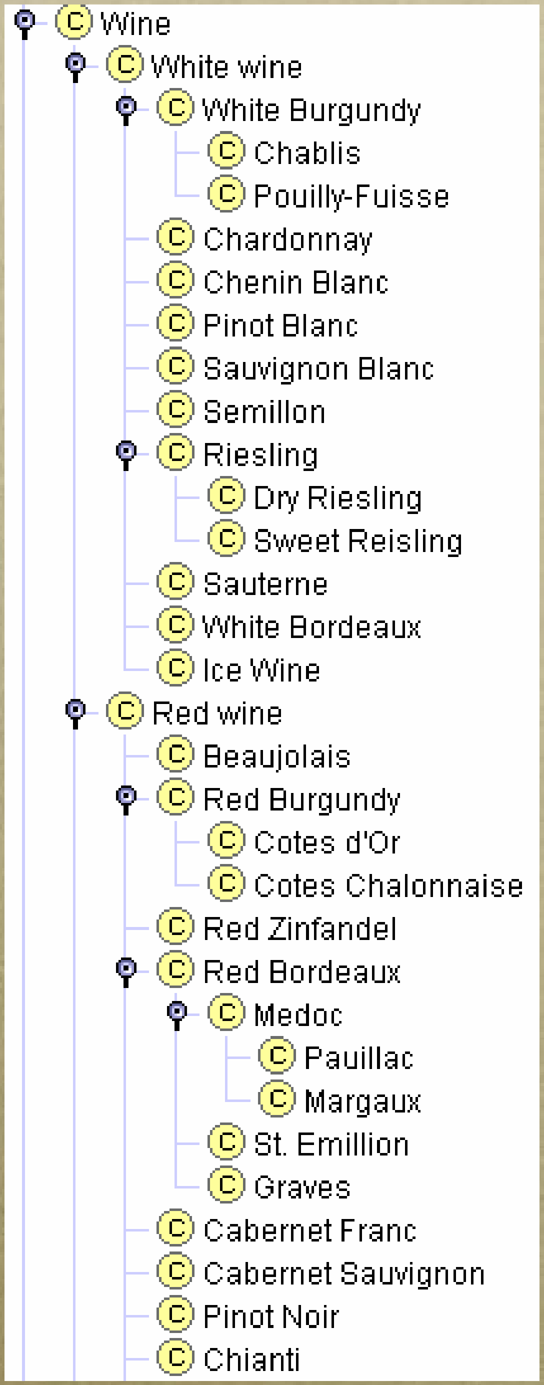
  - Cabernet Sauvignon
  - Medoc
  - Semillon
  - Pinot Noir
  - Chianti
  - Petite Syrah
  - Sancerre
  - Muscadet
  - Port
  - Sweet Reisling
  - Chablis
  - Dry Riesling

- *If a class has more than a dozen children, additional subcategories may be necessary*
- *However, if no natural classification exists, the long list may be more natural*

A completed hierarchy of wines



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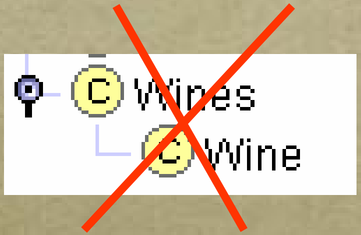
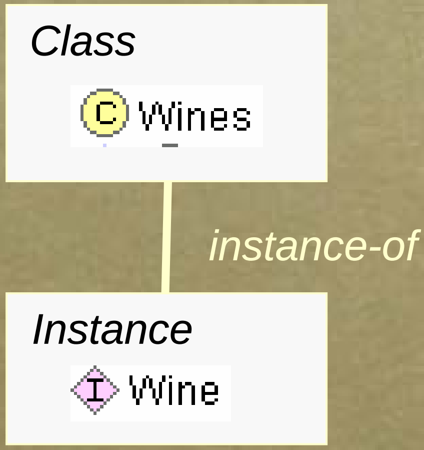
    - Chianti

Single and plural class names





- *A "wine" is not a kind-of "wines"*
- *A wine is an instance of the class Wines*
- *Class names should be either*
  - *all singular*
  - *all plural*

Classes and their names

- *Classes represent concepts in the domain, not their names*
- *The class name can change, but it will still refer to the same concept*
- *Synonym names for the same concept are not different classes*
    - *Many systems allow listing synonyms as part of the class definition*

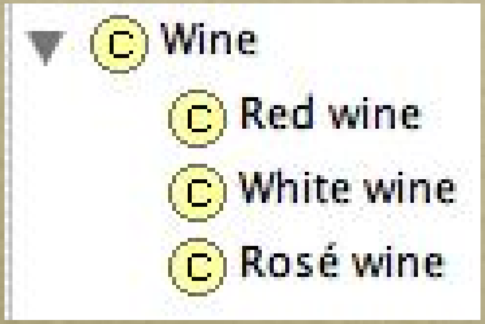
When to introduce a new class?

- *Subclasses of a class usually have*
  - *Additional properties*
  - *Additional slot restrictions*
  - *Participate in different relationships*
- *Subclasses of a class have*
  - *New slots*
  - *New facet values*

But

- *In terminological hierarchies, new classes do not have to introduce new properties*

A new class or a property value?



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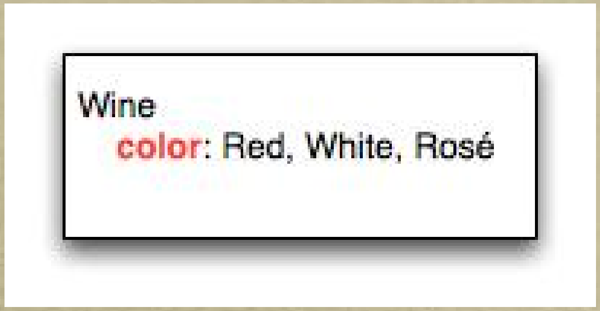
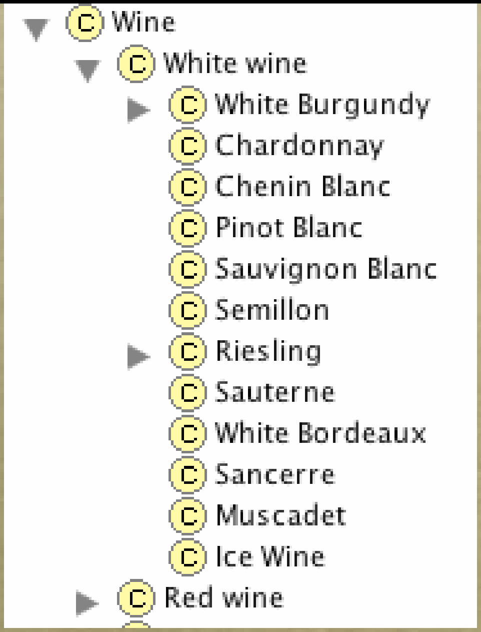


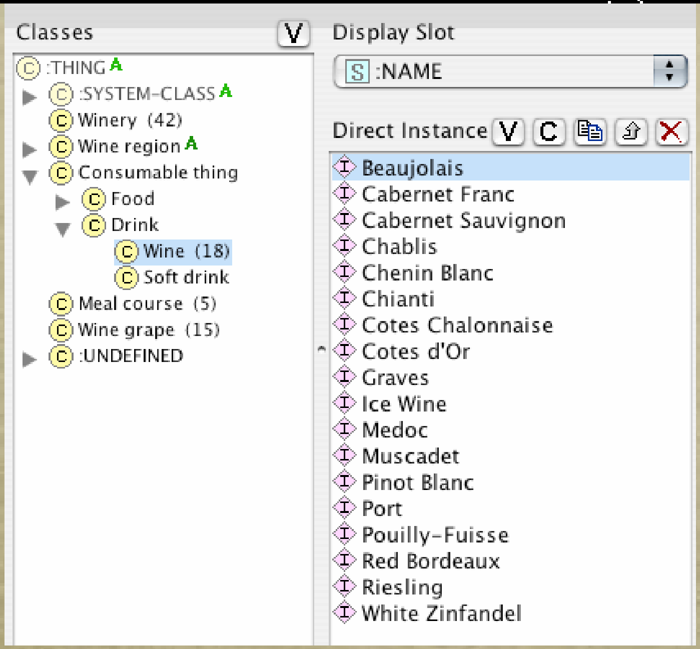
- *Do concepts with different slot values become restrictions for different slots?*
- *How important is the distinction for the domain?*
- *A class of an instance should not change often*

A class or an instance?



Wine
White wine
White Burgundy
Chardonnay
Chenin Blanc
Pinot Blanc
Sauvignon Blanc
Semillon
Riesling
Sauterne
White Bordeaux
Sancerre
Muscadet
Ice Wine
Red wine

OR



Classes
:THING
:SYSTEM-CLASS
Winery (42)
Wine region
Consumable thing
Food
Drink
Wine (18)
Soft drink
Meal course (5)
Wine grape (15)
:UNDEFINED

Display Slot: :NAME

Direct Instance
Beaujolais
Cabernet Franc
Cabernet Sauvignon
Chablis
Chenin Blanc
Chianti
Cotes Chalonnaise
Cotes d'Or
Graves
Ice Wine
Medoc
Muscadet
Pinot Blanc
Port
Pouilly-Fuisse
Red Bordeaux
Riesling
White Zinfandel

- *Individual instances are the most specific objects in an ontology*
- *If concepts form a natural hierarchy, represent them as classes*

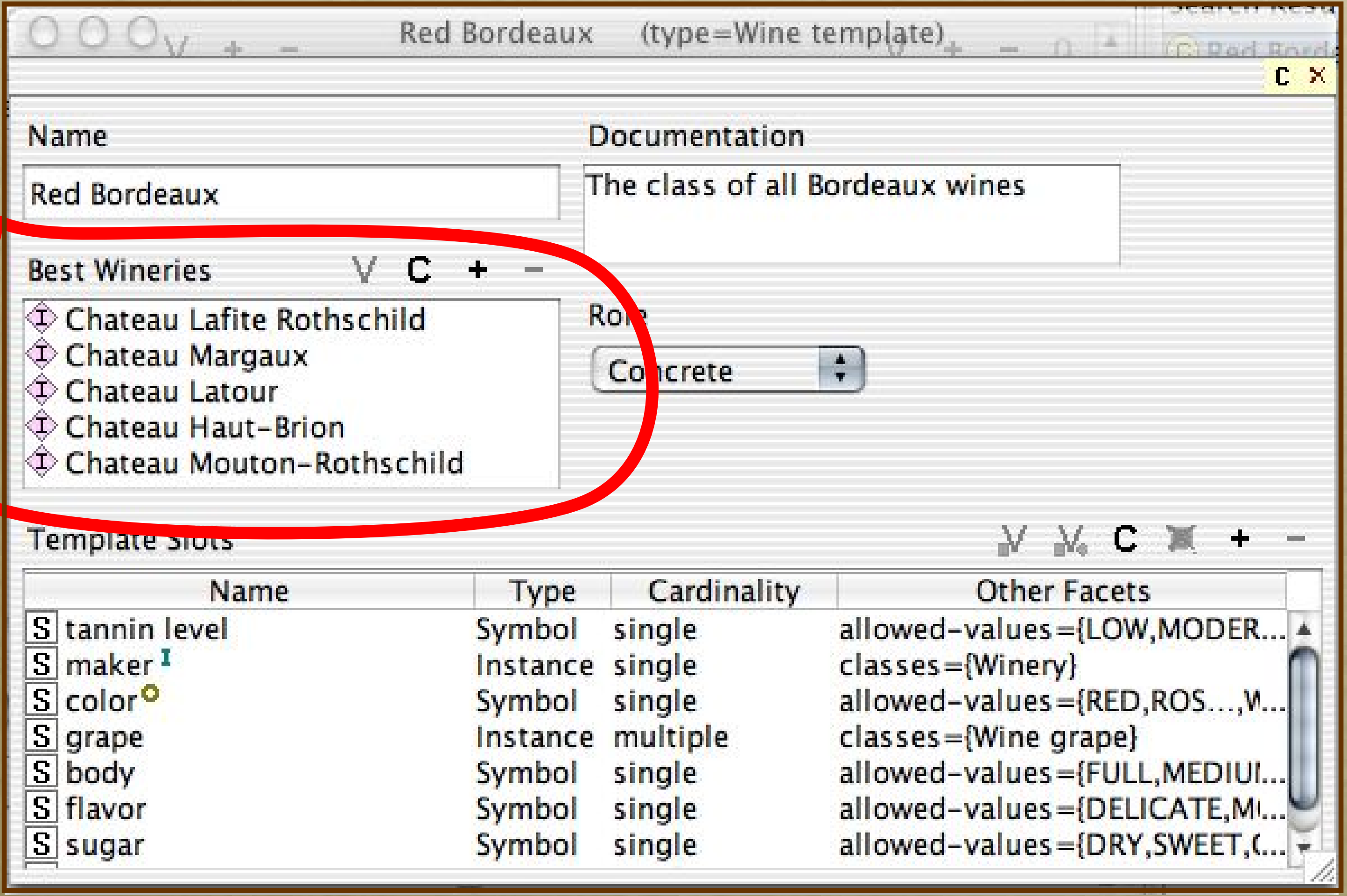
Metaclasses: Templates for class definitions

- *Metaclasses enable us to add attributes to class definitions*
- *By default, we have:*
  - *Class name*
  - *Documentation*
  - *Slots*
  - *...*

Metaclasses (II)

- *Additional attributes:*
  - *Synonyms*
  - *UMLS CUI*
  - *Latin name*
  - *Other class-level properties*

Best Wineries



Red Bordeaux (type=Wine template)

Name: Red Bordeaux

Documentation: The class of all Bordeaux wines

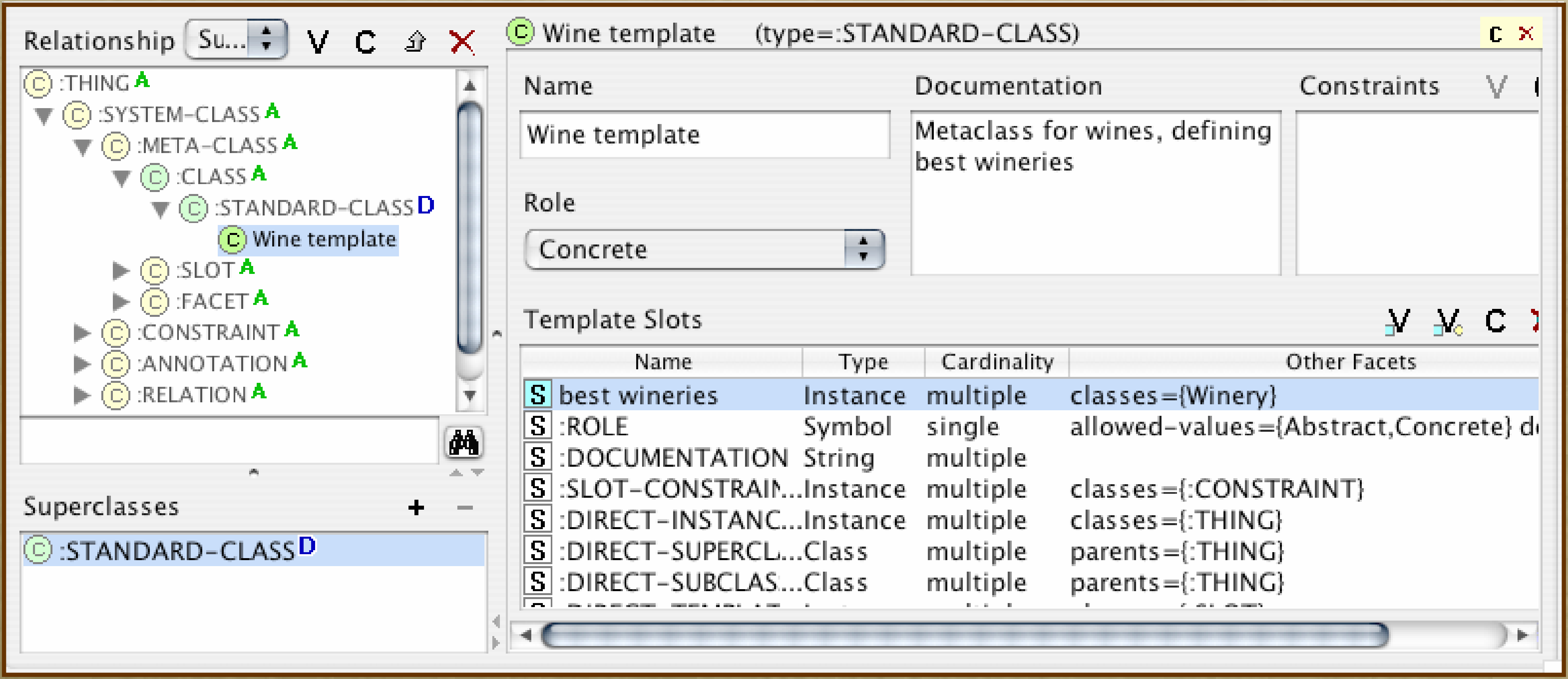
Best Wineries
- Chateau Lafite Rothschild
- Chateau Margaux
- Chateau Latour
- Chateau Haut-Brion
- Chateau Mouton-Rothschild

Role: Concrete

Template Slots

Name	Type	Cardinality	Other Facets
tannin level	Symbol	single	allowed-values={LOW,MODER...
maker	Instance	single	classes={Winery}
color	Symbol	single	allowed-values={RED,ROS...,W...
grape	Instance	multiple	classes={Wine grape}
body	Symbol	single	allowed-values={FULL,MEDIUI...
flavor	Symbol	single	allowed-values={DELICATE,M...
sugar	Symbol	single	allowed-values={DRY,SWEET,(...

Defining a metaclass



Wine template (type=:STANDARD-CLASS)

Name: Wine template

Role: Concrete

Documentation: Metaclass for wines, defining best wineries

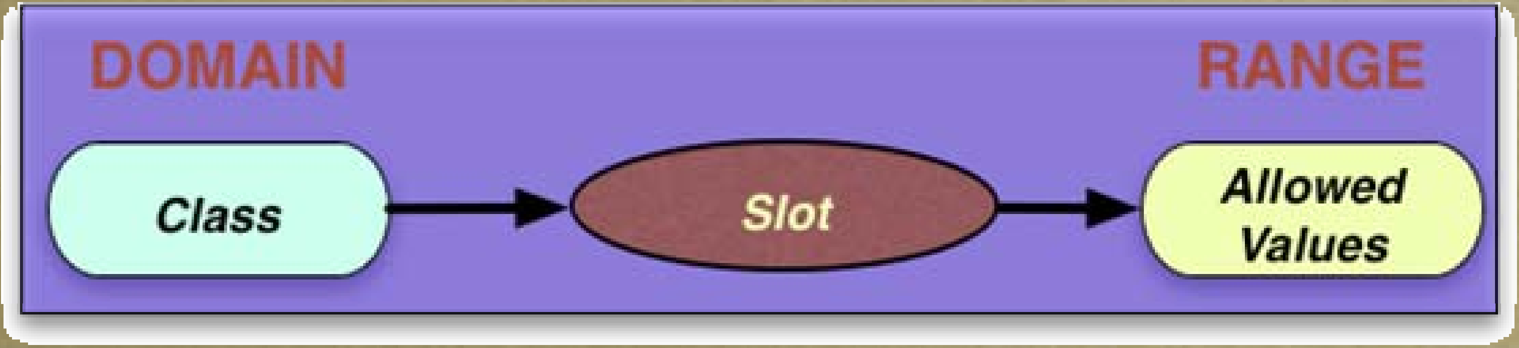
Constraints

Template Slots

Name	Type	Cardinality	Other Facets
best wineries	Instance	multiple	classes={Winery}
:ROLE	Symbol	single	allowed-values={Abstract,Concrete} d
:DOCUMENTATION	String	multiple	
:SLOT-CONSTRAIN...	Instance	multiple	classes={:CONSTRAINT}
:DIRECT-INSTANC...	Instance	multiple	classes={:THING}
:DIRECT-SUPERCL...	Class	multiple	parents={:THING}
:DIRECT-SUBCLAS...	Class	multiple	parents={:THING}

Domain and range of slot

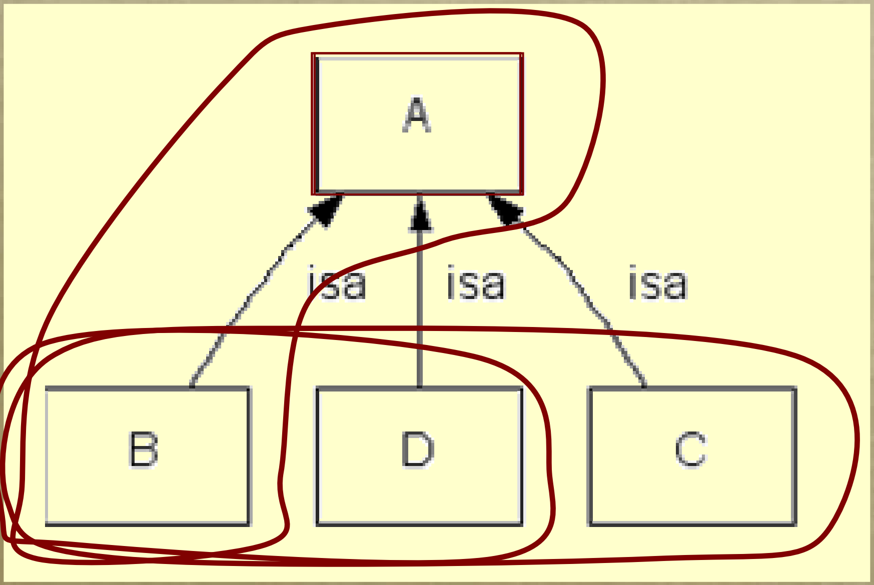
- *Domain of a slot – the class (or classes) that have the slot*
  - *More precisely: class (or classes) instances of which can have the slot*
- *Range of a slot – the class (or classes) to which slot values belong*



Back to slots: Allowed values

- *When defining a domain or range for a slot, find the most general class or classes*
- *Consider the produces slot for a Winery:*
  - *Range: Red ~~wine, White wine, Rosé wine~~*
  - *Range: Wine*
- *Consider the flavor slot*
  - *Domain: Red ~~wine, White wine, Rosé wine~~*
  - *Domain: Wine*

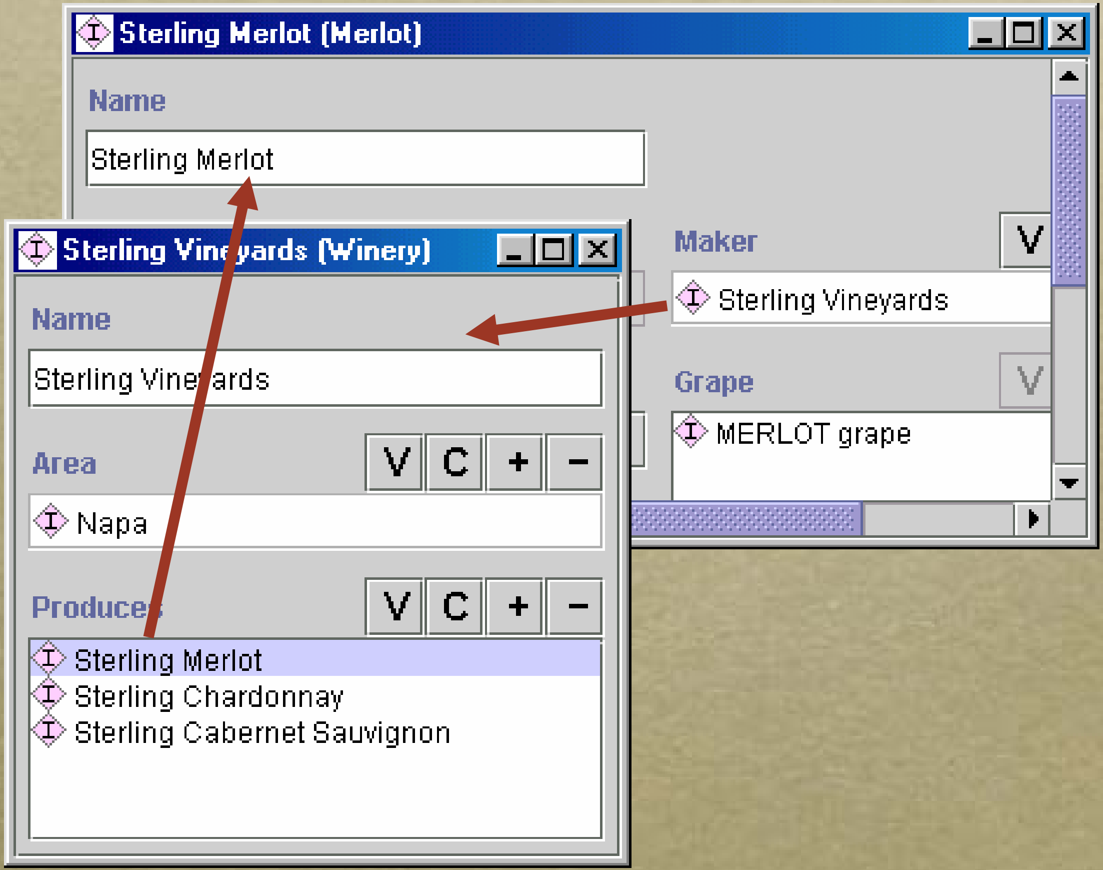
Defining domain and range



- *A class and a superclass – replace with the superclass*
- *All subclasses of a class – replace with the superclass*
- *Most subclasses of a class – consider replacing with the superclass*

Inverse slots

- *Maker and*
- *Producer*
- *are inverse slots*



Sterling Merlot (Merlot)

Name: Sterling Merlot

Maker: Sterling Vineyards

Grape: MERLOT grape

Sterling Vineyards (Winery)

Name: Sterling Vineyards

Area: Napa

Produces:
- Sterling Merlot
- Sterling Chardonnay
- Sterling Cabernet Sauvignon

Inverse slots (II)

- *Inverse slots contain redundant information, but*
  - *Allow acquisition of the information in either direction*
  - *Enable additional verification*
  - *Allow presentation of information in both directions*
- *The actual implementation differs from system to system*
  - *Are both values stored?*
  - *When are the inverse values filled in?*
  - *What happens if we change the link to an inverse slot?*

Default values

- *Default value – a value the slot gets when an instance is created*
- *A default value can be changed*
- *The default value is a common value for the slot, but is not a required value*
  - *For example, the default value for wine body can be FULL*

What’s in a name?

- *Define a naming convention for classes and slots and adhere to it*
- *Features of an ontology tool to consider:*
  - *Can classes and slots have the same names?*
  - *Is the system case-sensitive?*
  - *What delimiters are allowed?*

What's in a name? (II)

- *Capitalization and delimiters*
  - *Use spaces: Meal course*
  - *Run words together: MealCourse*
  - *Use underscore or dash: Meal_Course*
- *Singular or plural*
  - *Be consistent*
- *Prefix and suffix conventions*
  - *Common for slots: has-maker, has-winery*
  - *Wine rather than Wine class*
  - *Consistency: if Red **wine**, then White **wine***

Limiting the scope

- *An ontology should not contain all the possible information about the domain*
  - *No need to specialize or generalize more than the application requires*
  - *No need to include all possible properties of a class*
    - *Only the most salient properties*
    - *Only the properties that the applications require*

Limiting the scope (II)

- *Ontology of wine, food, and their pairings probably will not include*
  - *Bottle size*
  - *Label color*
  - *My favorite food and wine*
- *An ontology of biological experiments will contain*
  - *Biological organism*
  - *Experimenter*
- *Is the class Experimenter a subclass of Biological organism?*