DAMA-MN, 2005/6

35START

Subtypes & Supertypes

The Data Modeler's most Valuable Construct

©Gordon C. Everest
Professor Emeritus, Carlson School of Management
University of Minnesota
Community Faculty, MetroState

Advanced Database Design

431START

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7. Sub/Super Types

- **“Abstractions” & Collections**
- **Attribute and Relationship Generalization**
- **Subtypes and Supertypes (Entity Generalization)**
  - **Underlying assumptions; conditions**
  - **Generalization vs. Specialization**
  - **Graphical representations**
- **Constraints**
- **Subtype Definition - distinguishing attribute**
- **Sub/SuperType Hierarchy/Lattice**
  - **The Universal Relation**
- **Inheritance (single; multiple) & Reuse**
- **Mapping to Tables**

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Carlson School of Management
University of Minnesota

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"Abstractions" & Collections

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Focusing on *selected* properties of objects

-Batini, Ceri, & Navathe
- Smith & Smith (1977)
- Len Silverston
- Steve Hoberman
- David Hay

"Abstractions": (used in a different sense here)

- **CLASSIFICATION ("Member-of")**
  - Forming Types - entity sets/populations, domains
- **AGGREGATION ("Part-of")**
  - Building an entity record with descriptors (clustering attributes)
  - **COMPOSITION** (stronger "Part of" - no independent existence)
- **GENERALIZATION/SPECIALIZATION ("Is-a")**
  - Forming subtypes/supertypes, population subsets

Collections: (assumes homogeneous members)

- **SET – no duplicates and no order**
- **BAG – counting duplicates**
- **SEQUENCE – order matters**
- **…**

Omitting vs. Hiding Detail

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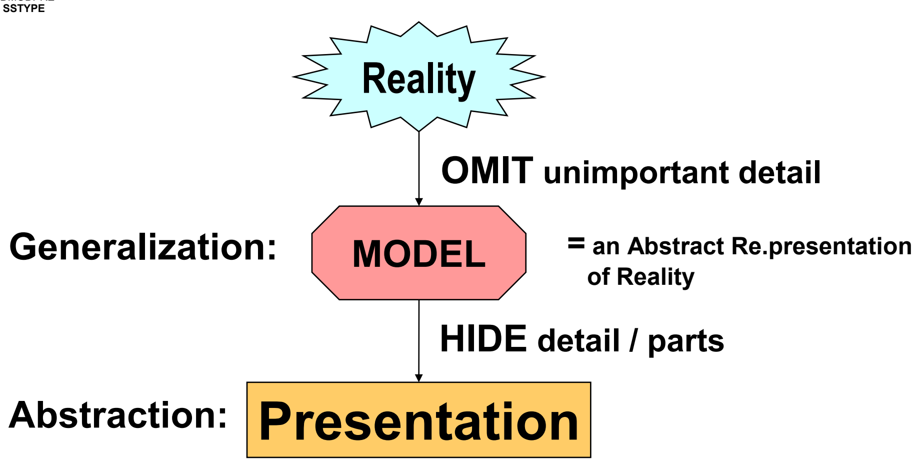

"There is no abstract art. You must always start with something. Afterward you can remove all traces of reality." **-- Pablo Picasso**

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Generalization

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- Recognizing commonalities (+valued, -cost)
- Moving "up" to a higher, more inclusive, more generic, more "abstract" view

TYPES:

- Attribute
  - constrained by Entity Generalization
  - often a prelude to Entity Generalization
- Entity
  - represented using subtypes/supertypes
  - implications for placement and naming of attributes and relationships
- Relationship

Attribute Generalization Examples

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Steve Hoberman, *Data Modeler's Workbench*

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- For a Tuxedo Rental shop, store Customer attributes:
  - Waist size
  - Leg length
  - Neck size
  - Arm length
  - Shoulder width

=> Later add Shoe size.

What does that do to your database schema?
How might you solve the problem?
How does referential integrity become important here?
What is the down side of this schema redesign?

Similarly for Phone numbers:
Problems:
- Handling international numbers
- Handling other contact information, e.g. email

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Attribute Generalization Example

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Steve Hoberman, *Data Modeler's Workbench*

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Given the following three entity type populations:

What do you observe?

CUSTOMER
- First name
- Last name
- Address line
- City
- State
- Zip code
- Phone number
- Fax number
- Tax id
- First order date
- DUNS #

SUPPLIER
- Company name
- Contact first name
- Contact last name
- Address line
- City
- State
- Zip code
- Phone number
- Cell Phone Number
- Fax number
- Credit Rating
- First PO Date
- DUNS #

ASSOCIATE (Employee)
- First name
- Last name
- Address line
- City
- State
- Zip code
- Phone number
- Pager number
- Social Security #
- Email address
- Hire date
- Clock #

An ASSOCIATE can be assigned to several CUSTOMERs, and manage the relationship with many SUPPLIERs.
A CUSTOMER or SUPPLIER can contact multiple ASSOCIATES.

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Attribute Generalization - Financial

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Suppose you saw a table defined like this:

How many rows would it have?

What would YOU want to do?

FINANCIAL DATA:

Dept	Year	Qtr	Bud/Act	Category	Amount

Classic Fact Table for a Dimensional Model!

How many rows would this table have?

FINANCIAL DATA:
*Dept
*Year
Qtr1 Budget Material Amount
Qtr2 Budget Material Amount
Qtr3 Budget Material Amount
Qtr4 Budget Material Amount
Qtr1 Budget Labor Amount
Qtr2 Budget Labor Amount
Qtr3 Budget Labor Amount
Qtr4 Budget Labor Amount
Qtr1 Budget Capital Amount
Qtr2 Budget Capital Amount
Qtr3 Budget Capital Amount
Qtr4 Budget Capital Amount
Qtr1 Actual Material Amount
Qtr2 Actual Material Amount
Qtr3 Actual Material Amount
Qtr4 Actual Material Amount
Qtr1 Actual Labor Amount
Qtr2 Actual Labor Amount
Qtr3 Actual Labor Amount
Qtr4 Actual Labor Amount
Qtr1 Actual Capital Amount
Qtr2 Actual Capital Amount
Qtr3 Actual Capital Amount
Qtr4 Actual Capital Amount

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Extreme Attribute Generalization

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ENTITY
*EntityID
EntityName

ATTRIBUTE
*EntityID
*AttributeName
AttributeValue

ATTRIBUTE
*EntityID
*Name
Value
Type
Size
Precision
Units
LastUpdate
Source
Confidence
...

What is lost here?

How many rows?

What is hard?

What else might be of interest about an attribute?

What is easy?

The Power of Generalization Thinking!

If find you are mixing value domains, you may have generalized too much.

Relationship Generalization

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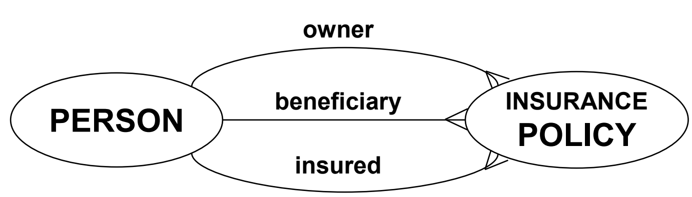
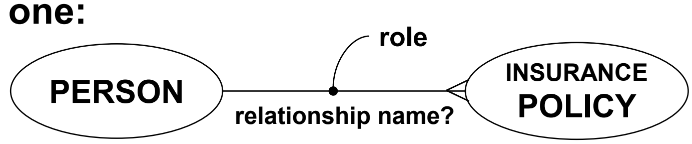
G. Simsion, *DM Essentials*, 2005, p.140.

Reducing multiple relationships:



to one:



NOTE: We have already generalized the individual roles into a Person entity.

Where would you store the 'role' attribute?

How many foreign keys are stored? Where?

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Model "Family Trees"

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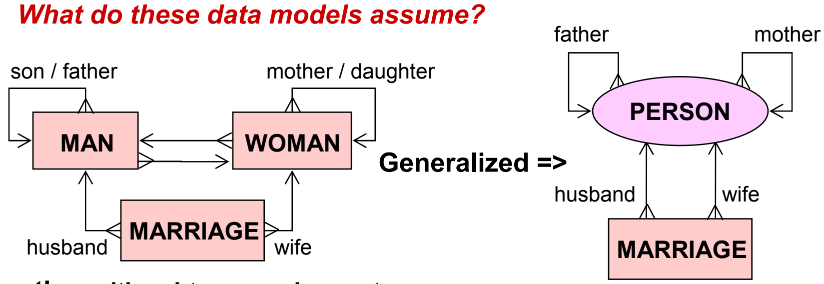
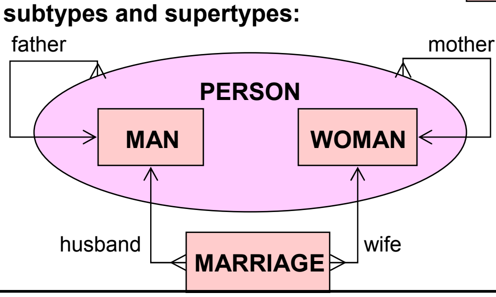
Graeme Simsion, *DM Essentials*, 2005

11 **Fathers, Mothers, their Marriages, and Children:**

What do these data models assume?



Together with subtypes and supertypes:



... leaving open the question of where the Tables will be built.

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Generalization: Pros & Cons

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- \+ **Fewer entities and relationships (simpler?)**
- \+ **Greater flexibility to incorporate extensions**
- \+ **Greater long-term stability of the model**
- \+ **Looking for commonalities -> greater understanding**
- \+ **handle special treatment of subsets**

- – **Hides business vocabulary**
  - – **business terms not in schema names but in attribute values**
- – **harder to express and enforce business rules or constraints. Most become conditional on the specialized subtype.**
- – **Problem defining the identifiers (Ref. modes)**
- – **queries are more difficult to formulate and less efficient to execute (more JOINs).**
  - – **e.g., "FIND Customers WHERE Waist = 42" - no longer works**

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Discerning Inter-Entity Relationships

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PERSON	ORGANIZATION
EMPLOYEE	SHAREHOLDER
CUSTOMER	VENDOR

Construct a high-level, conceptual data model.

Problems?
Observations?

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A Fundamental Assumption in a Data Model Diagram

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- **The main construct is an Entity.**
- **Each labeled box/circle represents an Entity Type**
  - **a Defined Structure (a schema template)**
  - **a Population of Instances**
- **Grouping Instances into Types is essentially Arbitrary.**
  - **The world isn't naturally that way; the designer imposes a view**
- **All Entity Type Populations are strictly Disjoint (mutually exclusive; or non-overlapping).**
  - **At least that is the system's assumption, thus each file/table has its own set of records/tuples.**

Is this always true?

***What about*: EMPLOYEE SHAREHOLDER**

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Using Subtypes and Supertypes

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Smith & Smith, *ACM TODS*, 1977/6.

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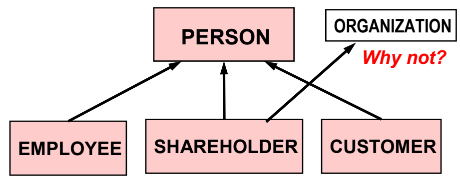
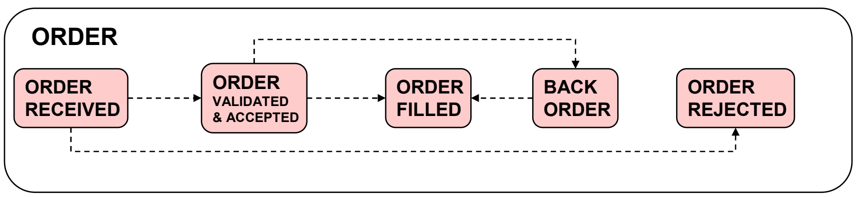
- **Subtypes and Supertypes** allow us to **formally represent overlapping populations**
  - Every member of a subtype population ***is-a*** member of its supertype population(s).

so we can model:

- different ***roles*** played by members of a common population, e.g.:
  - role determines the attributes



- different ***states*** of an entity (over time), e.g.:



Subtype-Supertype "Relationship"

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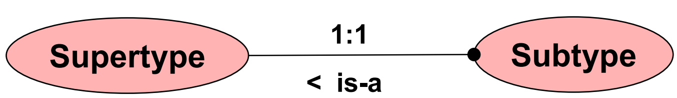
- Tempting to call it a "Relationship"



- pop(subtype) $\subseteq$ pop(supertype)
- AND the related members in the two sets are the *same* instance
  - that is what makes it different from relationships in a traditional ER/Relational data model, where the entity type populations are (assumed) disjoint!

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Generalization / Specialization

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Forming Entity Types

- **Fundamentally an "arbitrary" choice made by the DB Designer**
- **Recognizing when to use Subtypes and Supertypes**
- **Think about the entity *populations* you are modeling**

Two basic and distinct situations:

- **Generalization: (bottom-up - from several to a common supertype)**
  - **When you observe commonalities (e.g., common attributes*) across multiple entity populations.**
    - the members may actually be from the same population, the same type of 'thing', so define a common supertype.
- **Specialization: (top-down - from one to subtypes)**
  - **When there is something special about a subset of a population**
    - **They have some unique attributes***
    - **You want to treat them differently**
      - **e.g., Apply a constraint, or have some attributes mandatory**

***NOTE: speaking of attributes in ORM, means roles in relationships with other objects.**

Subtypes and Supertypes

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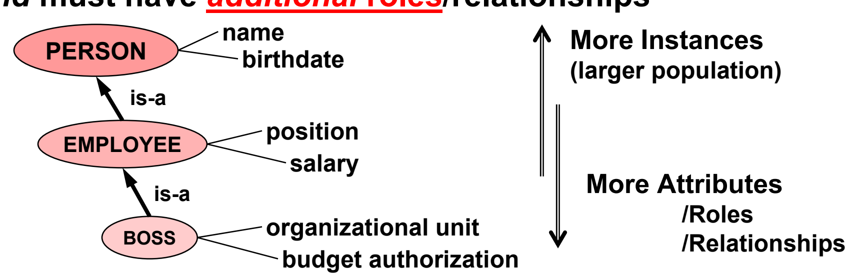
TWO CONDITIONS MUST *ALWAYS* BE TRUE:

- **each subtype population must be a *subset* (potentially) of each of its supertype populations**
  i.e., each instance of the subtype is in every supertype population
- **each subtype inherits *all* the roles of its supertypes *and* must have *additional roles*/relationships**



If either condition is NOT true,
no reason to call out the subtype in a separate definition.

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Diagramming Subtypes and Supertypes

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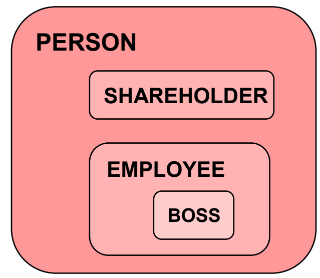
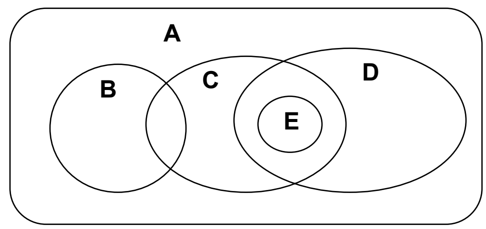
19 Two Basic Representations:

1. **NESTED (Euler Diagram)**
   - **+ Intuitive - visually shows inclusion**
   - **+ Clean and Compact**
   - **– Only good for simple cases**
   - **– generally assumed disjoint**
   - **– Not good for complex cases - difficult to represent both exclusive and overlapping subtypes (like a Venn Diagram):**





Diagramming Subtypes and Supertypes

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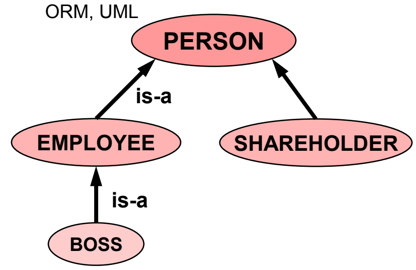
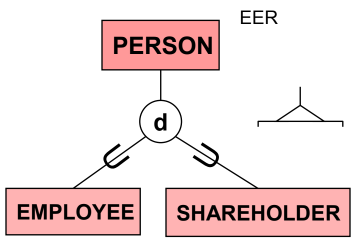
20 Two Basic Representations:

2. **SEPARATED**
   - **+ More common**
   - **+ Easier to show constraints and multiple supertypes for more complex cases.**
   - **– not visually intuitive**
   - **– confusion with "relationship"**
   - **– Adds more "clutter"**

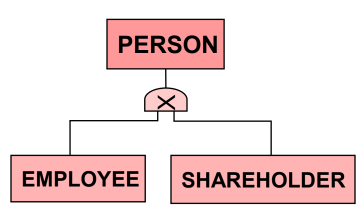
ORM, UML



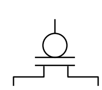
EER



IE



IDEF1X



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Diagramming Exercise

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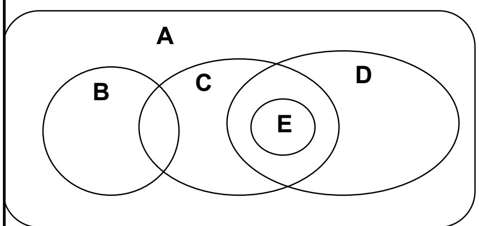
- **Convert the following Nested diagram into a Separated S/Stype diagram:**



How to model 'E' ?

Any constraints required?

Subtype / Supertype Constraints

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IN GENERAL, WITHOUT CONSTRAINTS, ASSUME:

- **overlapping subtype populations**
  - else **Disjoint**, so apply **Exclusion** constraint:
- **non-exhaustive (Partial) on the supertype,** i.e., a supertype instance need not be in any subtype
  - else **Mandatory/Totality/Dependency** constraint

=> Declare constraints on the more restrictive cases

- **Some systems allow only Disjoint and Total**
  - **it is possible to model Overlapping, even if the system only allows Disjoint subtypes.**
- **Some systems make Disjoint and Total the defaults**

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Diagramming S/Stype Constraints

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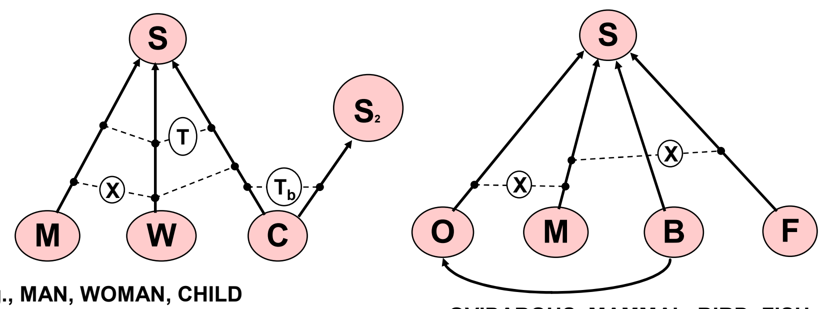
CONSTRAINTS (3 cases):

1. **Exclusive** or **disjoint *subtypes* – X**
2. **Exhaustive** or **Total on the *supertype* – T**
3. **Exhaustive** or **Total on the *subtype* – T_b**



e.g., MAN, WOMAN, CHILD

e.g., OVIPAROUS, MAMMAL, BIRD, FISH

S/Stype Constraints - Other Notations

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	Exclusive or disjoint	overlapping	Exhaustive or Total	Partial
NIAM	X		T	
ORM*	X	(default)	•	(default)
EER				
IE	d	o		
UML	(explicit English labels on the S/Stype arcs)			
ODL				
IDEF1X				
***combined**	X			

NOTE: No modeling schemes or systems recognize totality on the subtype.

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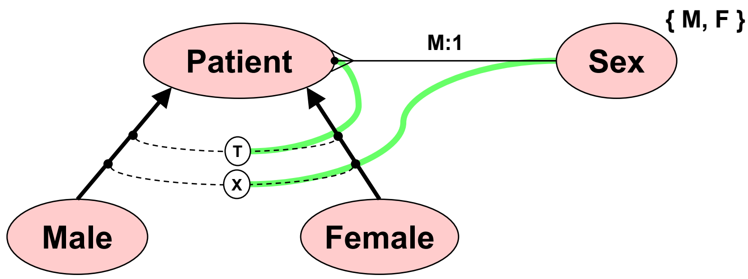
"Well-Defined" Subtypes

- **based on an attribute of the supertype**
  - **called the "distinguishing" attribute**
- **characteristics of the relationship determine the constraints on the subtypes**
  - **mandatory attribute => exhaustive/totality constraint**
  - **single-valued attribute => exclusive subtypes constraint**



- ***What if an optional attribute?***
- ***What if a multi-valued attribute (M:N relationship)?***

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Subtype Definition

Attribute-Defined Subtype (Intentional Set)

- **a rule for including a Supertype instance in the Subtype**
- **Defined in terms of the values of a supertype attribute**
- **in general, a Boolean expression on attribute(s) of the supertype**
- **can be considered a *constraint* rule on subset membership**
- **there are many possible subgroupings (specializations) of an entity type based on the values of its attributes, so find those that matter.**
- **it is not always possible to define the rules for membership in a subtype, hence:**

User-Defined Subtype (Extensional Set)

- **inclusion determined by "existence" in the set; membership is manual, the system cannot automate or validate membership.**
- **Some systems *require* subtype definitions such as *VisioEA* (but... as free-form text!)**
- **Can always come up with an artificial distinguishing attribute**

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MISQ Subscription Database

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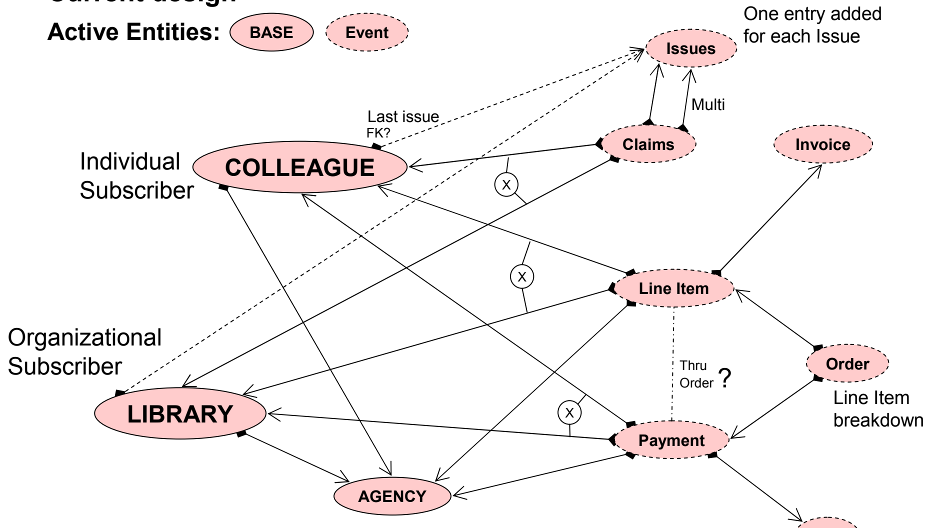
Current design



What commonalities do you observe?

Supertype example - Subscription

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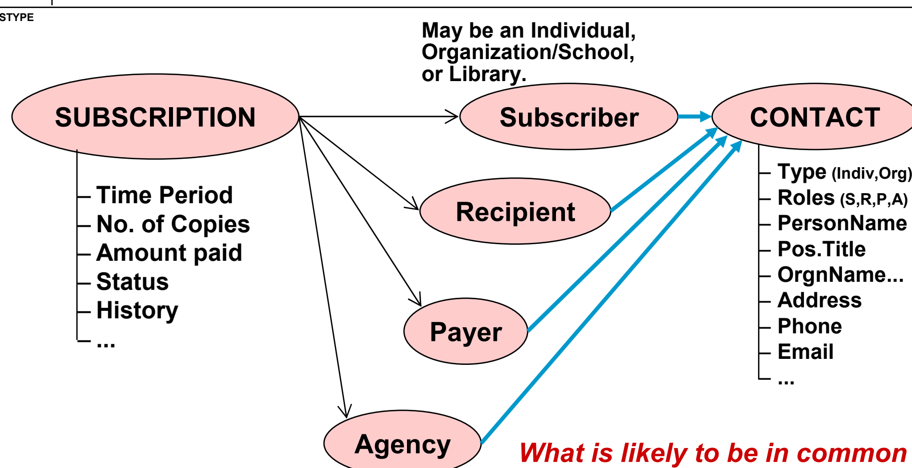

What is likely to be in common across these parties?

Who 'owns' the Subscription? Faculty or the Dept/School that pays? Gift Subscription? Who gets the renewal notice?

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Subtype / Supertype Hierarchy (Lattice)

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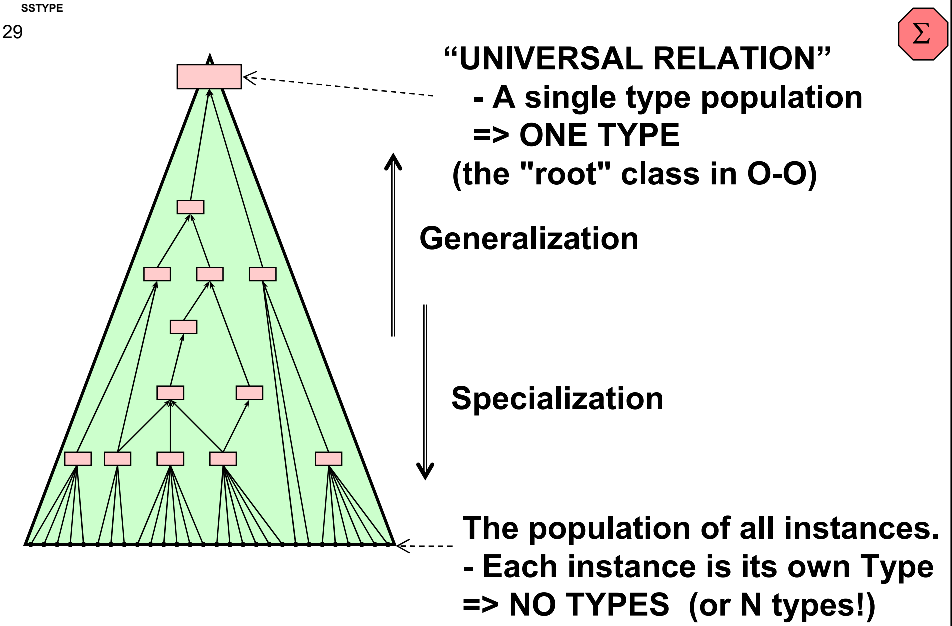

Sub/SuperType Hierarchy/Lattice - notes

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AT THE EXTREMES:

- a single supertype at the top is called the UNIVERSAL RELATION. If you built a single table for all the data in your organization:
  - *what would be the entity?*
  - *what would be the identifier?*
  - *what would be the attributes?*
  - *would all the attributes be relevant for each row?*
- at the bottom would be individual instances, each instance being its own type!
  - But sharing many attributes with other entities

The real art of database design is picking the appropriate entity types within the levels of the hierarchy.

- Allows the designer to defer choosing what tables to build

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Single vs. Multiple Inheritance

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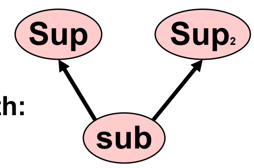
- **SINGLE - every subtype has only one supertype**

  => a strict Hierarchy of types
- **MULTIPLE supertypes for a (Shared) Subtype**
- **If multiple supertypes, they must converge on one population higher up = the root type**

  => a lattice.



so what is wrong/incomplete with:

- **no lattice if no overlapping subtypes**
- **it is possible to transform multiple inheritance to a generalization hierarchy by defining all possible combinations of subtypes**
- **each mini hierarchy or lattice has a root, all root objects are disjoint.**

Extreme Entity Generalization

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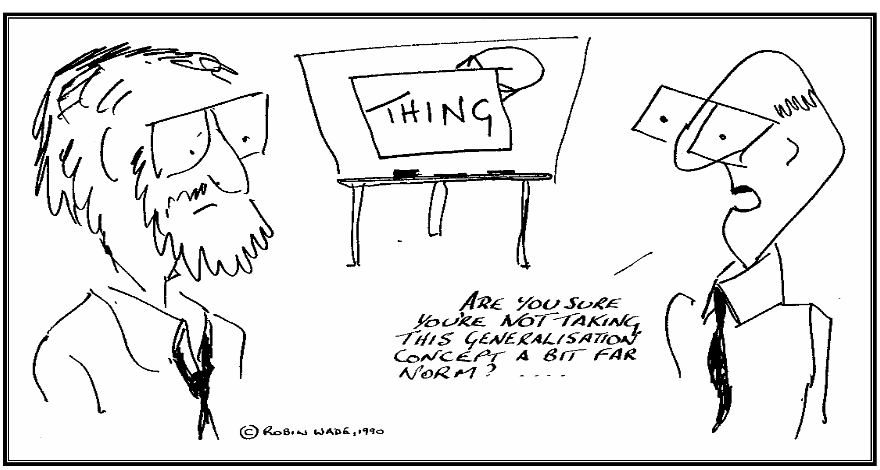

"The level of generalization is *critical*." **- Graeme Simsion**

***What is the* 'THING'?**

SIMSION & BOWLES ASSOCIATES

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Inheritance and Reuse

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DESIGN NOTION based on characteristics of populations:

- Multiple populations with some different characteristics sharing some common characteristics, … so define a supertype (generalization).
- Need for special treatment of a subset of a population … so define a subtype (specialization)
  - Subtype inherits common characteristics from its supertypes plus has some additional characteristics of interest

CONSTRUCTION - implementation efficiency => REUSE

- Inheritance of definitions of data and procedures
  - for efficiency of implementation

  SOLVING PROBLEMS:
  - overriding and blocking
  - static (copy at creation time only), vs. dynamic (maintain linkage to automatically inherit changes)
  - multiple inheritance => conflict, priority order

Comparing Modeling Schemes

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	ER/Rel (Chen)	EER (Teorey++)	ORM (Halpin)	UML (OMG)	ODL (ODMG)	SQL 1999
Class Hierarchy	X	Y	Y	Y	Y	Y
Disjoint*		Y	Y	default	only	only
Overlapping		default	default	Y	X	X
Total covering*		Y	Y	user-defined	on abstr.class	partly
Partial		Y	Y	Y (incomplete)	Y	Y
Attribute-defined discriminator		Y	'must' but…	limited (pseudo attrib)	X	X
Shared Subclasses (multiple inheritance)		Y	Y	Y	X	X

*the more restrictive case, calling for a constraint declaration.

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Mapping to (Relational) Tables

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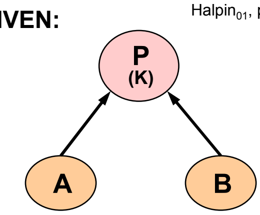
35 **THREE BASIC CHOICES:**

Halpin$_{01}$, p.426.

GIVEN:



- **Supertype only:**
  (Absorption - 'flatten' up)

  $\underline{K_P}$ D { P_i }... { A_i }... { B_i }...

- **Subtypes only:** **(not possible in VisioEA)**
  (Separation - 'flatten' down)

  $\underline{K_A}$ { P_i }... { A_i }...

  $\underline{K_B}$ { P_i }... { B_i }...

- **Both:**
  (Partition)

  $\underline{K_P}$ D { P_i }...

  $\underline{K_A}$ { A_i }...

  $\underline{K_B}$ { B_i }...

CONSIDER:
- **D = Distinguishing Attribute on P**
  (optional)
  (single-valued?)
- **Exclusive: on A & B**
  - A & B overlapping
- **Exhaustive (Total): P in neither A or B**

PROBLEMS:
- **Redundancy**
- **Incomplete**
- **Querying**

Inheritance - Three Kinds:

OODBMS

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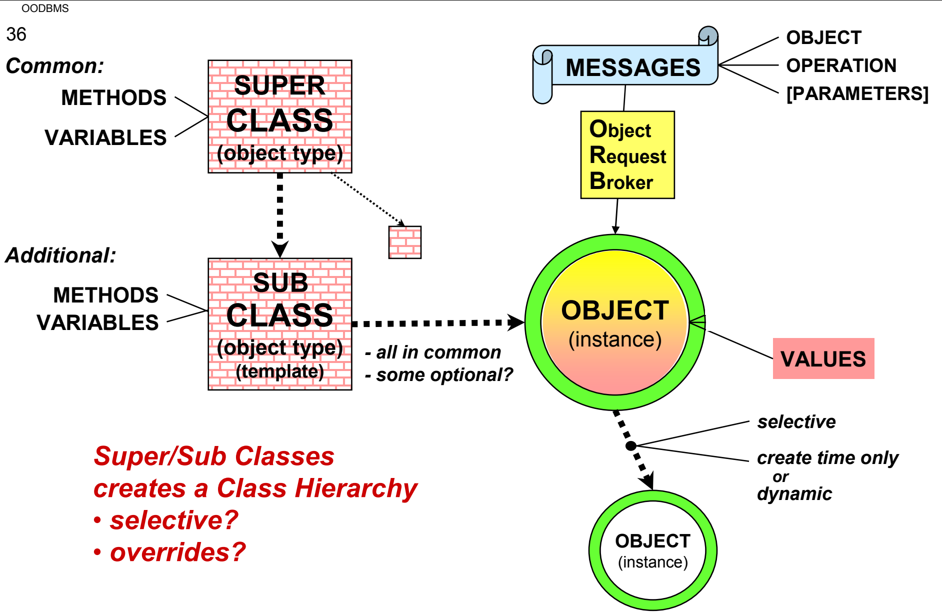

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Benefits of Subtype/Supertype

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G. Simsion, *DM Essentials*, 2005, p.128ff.

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- **Consciously and Creatively think...**
  - commonalities => generalization to supertype
  - special cases => specialization to subtypes
- **Generalization can reveal common patterns for reuse.**
- **Abstraction for presentation, collapse the subtypes into their supertypes**
  - **equivalent of "leveling" in process/DFD models**
- **Use subtyping to aid human understanding with no intention of implementing as separate tables.**
- **Can approach design top-down, bottom-up, or middle-out**
- **Explicit representation of multiple table designs, thus deferring the choice for later implementation.**

References

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- **John SMITH and Diane P. SMITH, "Database Abstractions: Aggregation and Generalization,"** ***ACM TODS*****, (2:2) 1977. -classic**
- **Chris J. DATE, "Subtypes and Supertypes: Setting the Scene,"** ***Database Programming & Design*****, 1999 February.**
- **Terry HALPIN,** ***Information Modeling and Relational Databases*****, Morgan Kaufmann, 2001, in ORM context.**
- **Graeme C. SIMSION and Graham C. WITT,** ***Data Modeling Essentials*****, 3e, Morgan Kaufmann, 2005, chap. 4.**
- **Ramez ELMASRI and Shamkant NAVATHE,** ***Fundamentals of Database Systems*****, 3e, Addison-Wesley, 2000, chapter 4 - academic, theoretical.**
- **Steve HOBERMAN,** ***Data Modeler's Workbench*****, Wiley, 2002, chapter 9 - practical with examples.**
- **Susanne W. DIETRICH and Susan D. URBAN,** ***An Advanced Course in Database Systems - Beyond Relational Databases*****, Prentice Hall, 2005.**

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