COMP219:
Artificial Intelligence

Lecture 17: Semantic Networks

Overview

- Last time
  - Rules as a KR scheme; forward vs backward chaining
- Today
  - Another approach to knowledge representation
    - *Structured objects: semantic nets*
      - Notation
      - Extended example
- Learning outcomes covered today:

  Distinguish the characteristics, and advantages and disadvantages, of the major knowledge representation paradigms that have been used in AI, such as production rules, semantic networks, propositional logic and first-order logic;

  Solve simple knowledge-based problems using the AI representations studied;

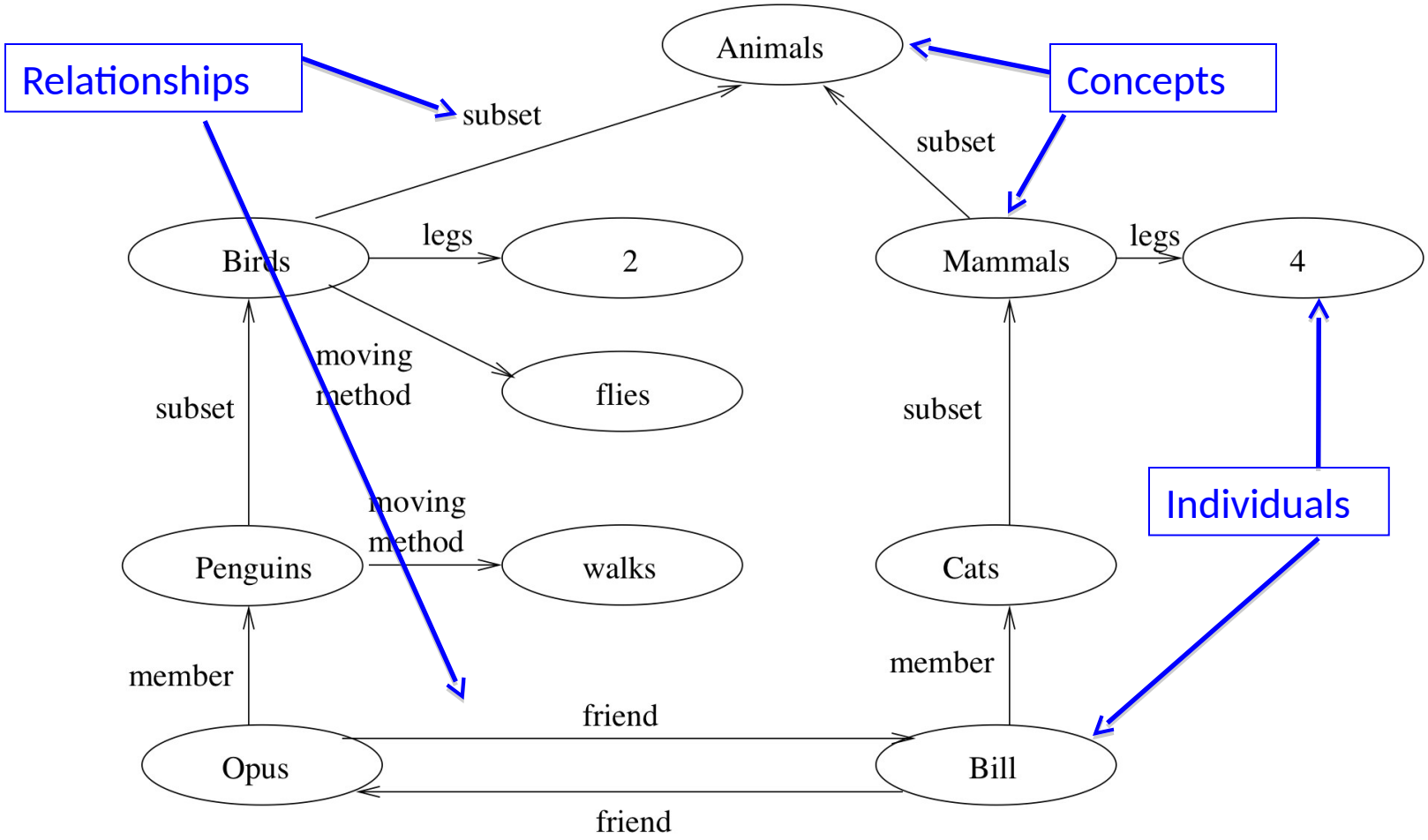
Structured Objects

- Structured objects are
  - Knowledge representation formalisms whose components are essentially similar to the nodes and arcs found in graphs
  - In contrast to production rules and formal logic
  - An attempt to incorporate certain desirable features of human memory organisation (association) into knowledge representations

Semantic Networks

- Developed by Quillian in 1968, as a model for human memory
  - *semantic memory*
- Models the "associations" between ideas and concepts that people maintain
- Semantic net is a *labelled graph*
  - nodes in graph represent *objects*, *concepts*, or *situations/events*
  - arcs in graph represent *relationships* between these things

Semantic Networks

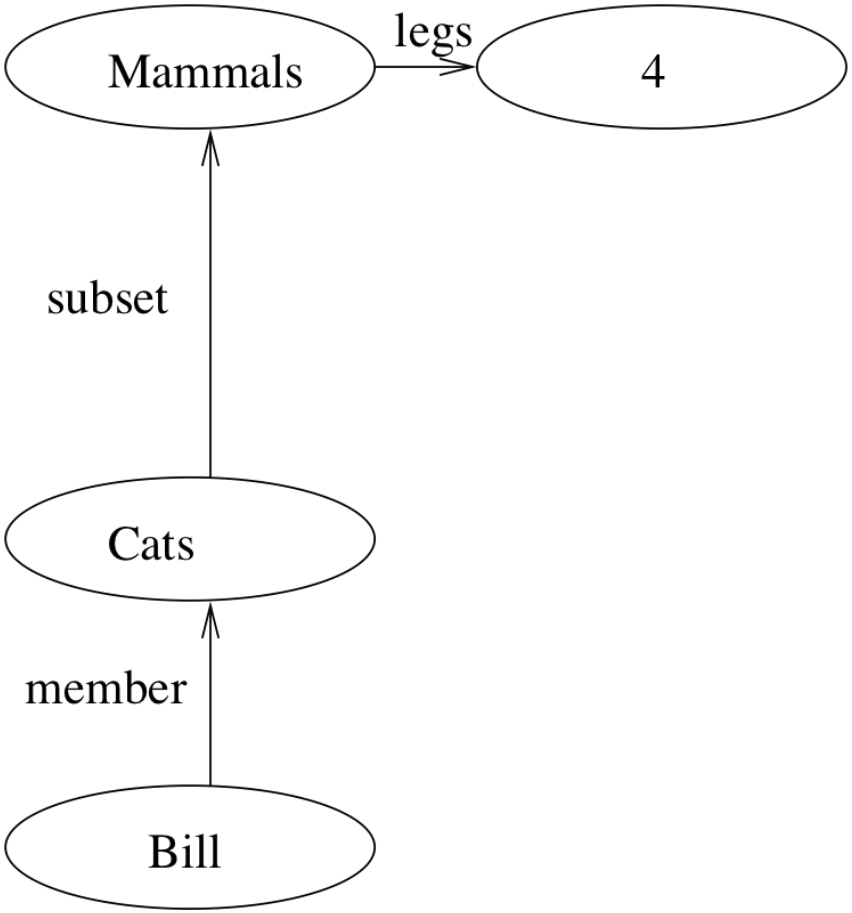


Important Arc Types

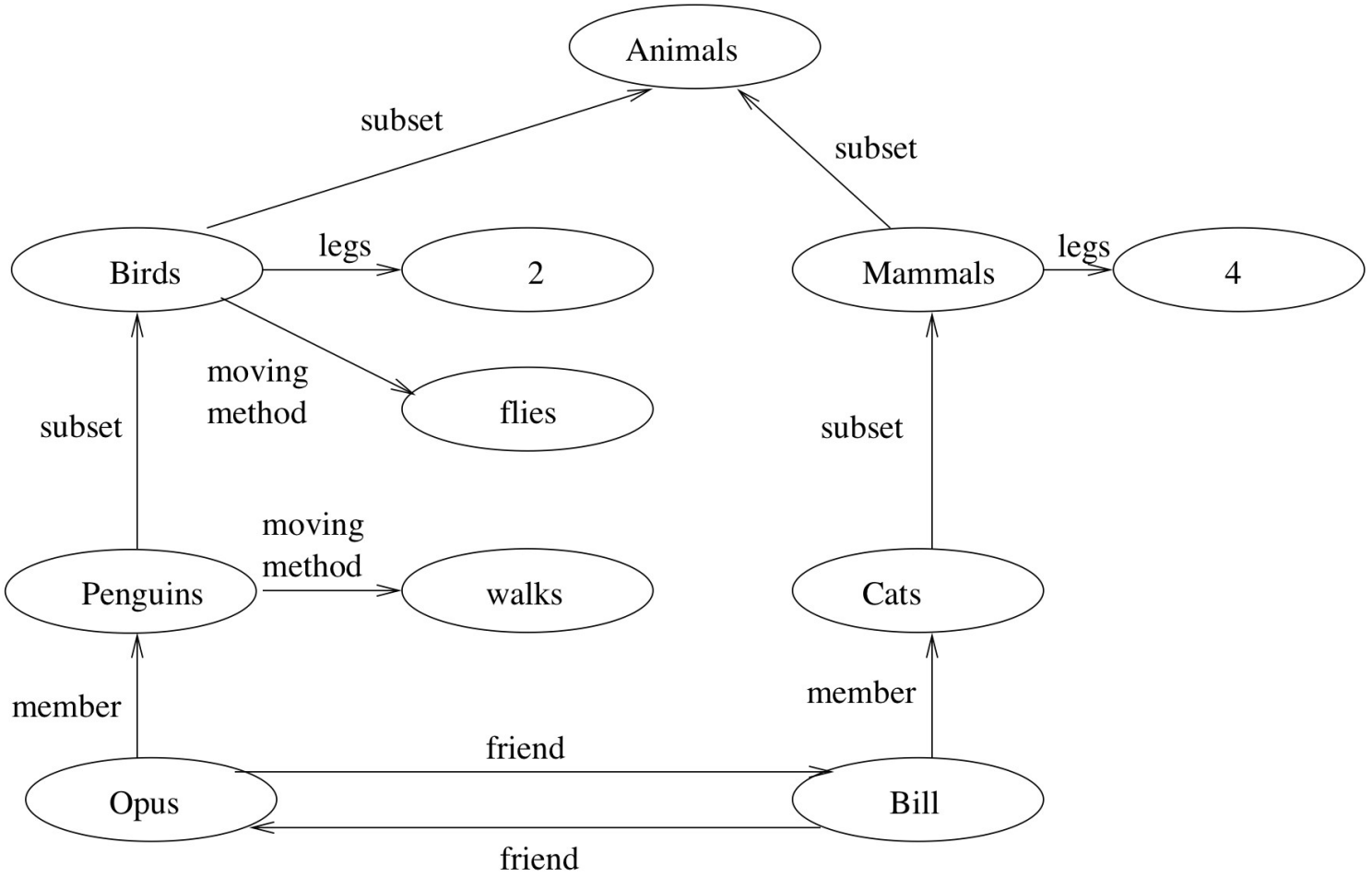
- Subset
  - X is a kind of Y
  - Penguin subset Bird: Concept to Concept
- Member
  - X is a Y: X is an instance of Y
  - Opus member Penguin: Individual to Concept
- R-relation
  - X relation-name Y
  - Opus is a friend of Bill; Lou is a parent of Ian Individual to Individual

Inheritance

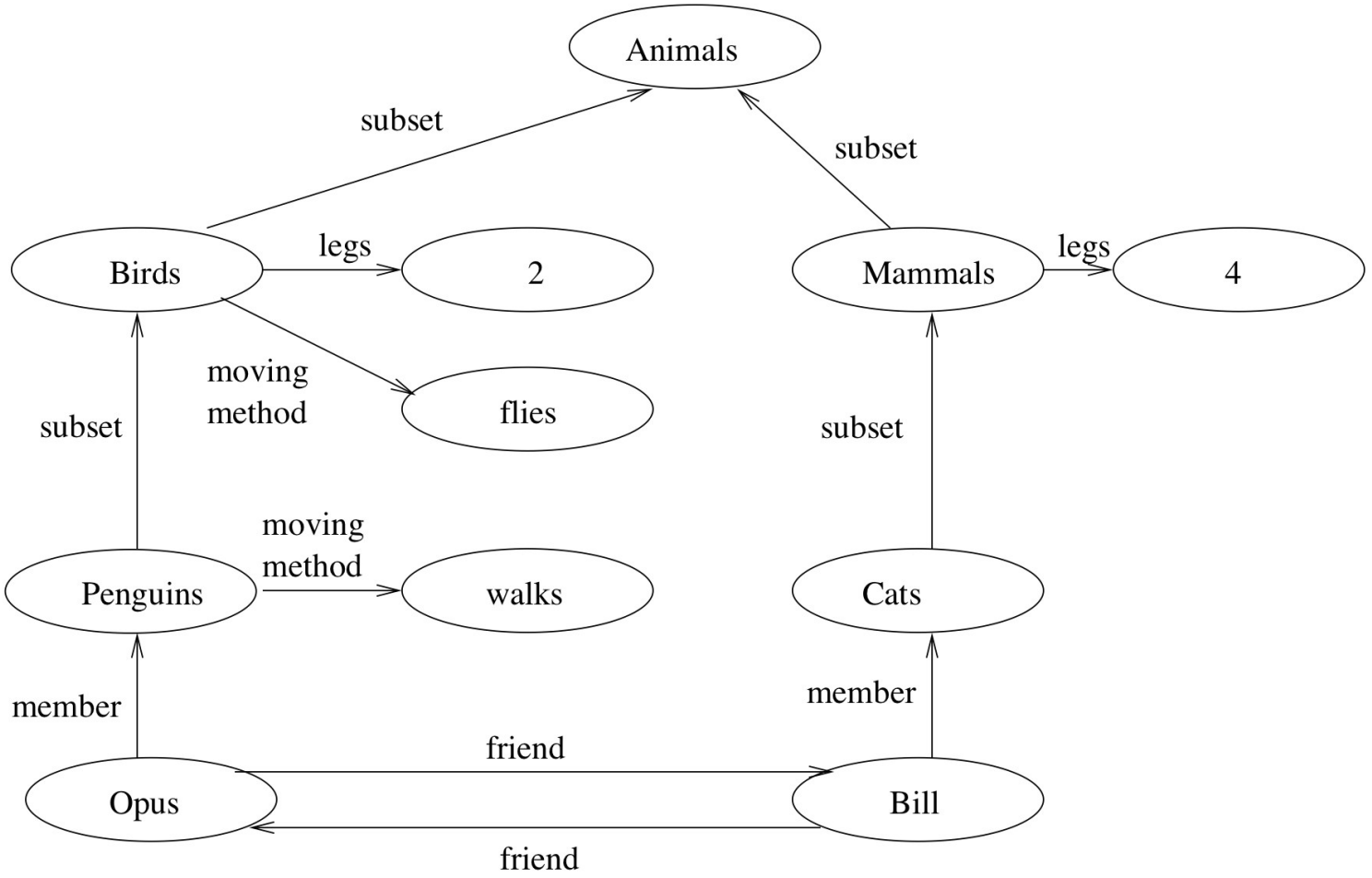
- Inheritance is one of the main kinds of reasoning done in semantic nets
- The subset relation is often used to link a class and its superclass
- Some links (e.g. legs) are inherited along subset paths
- The semantics of a semantic net can be relatively informal or very formal
- Often defined at the implementation level



Example

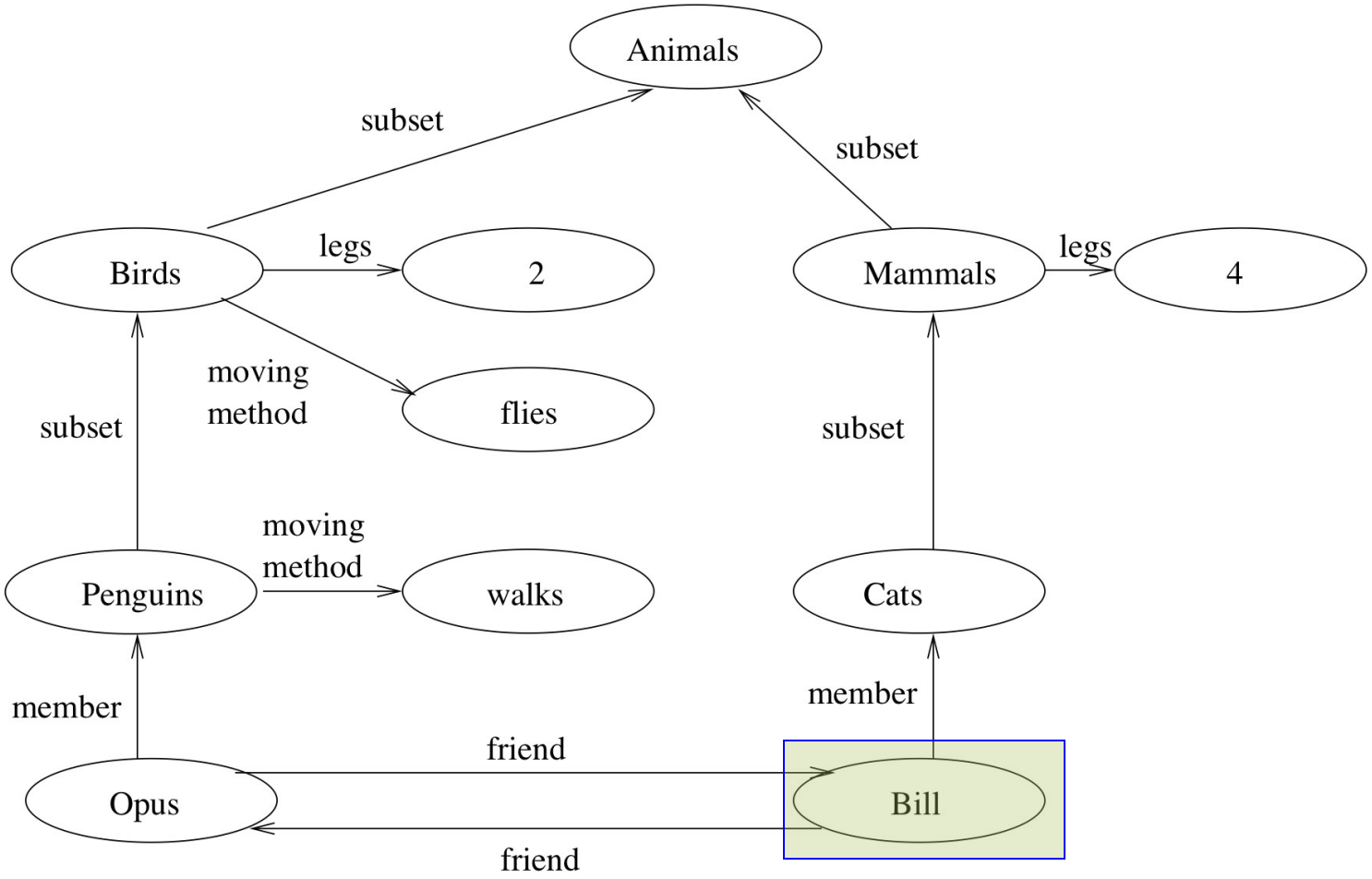

Animals
subset
subset
Birds
legs
2
Mammals
legs
4
moving
method
flies
subset
subset
moving
method
Penguins
walks
Cats
member
member
friend
Opus
Bill
friend

Example



Bill has four legs

Example



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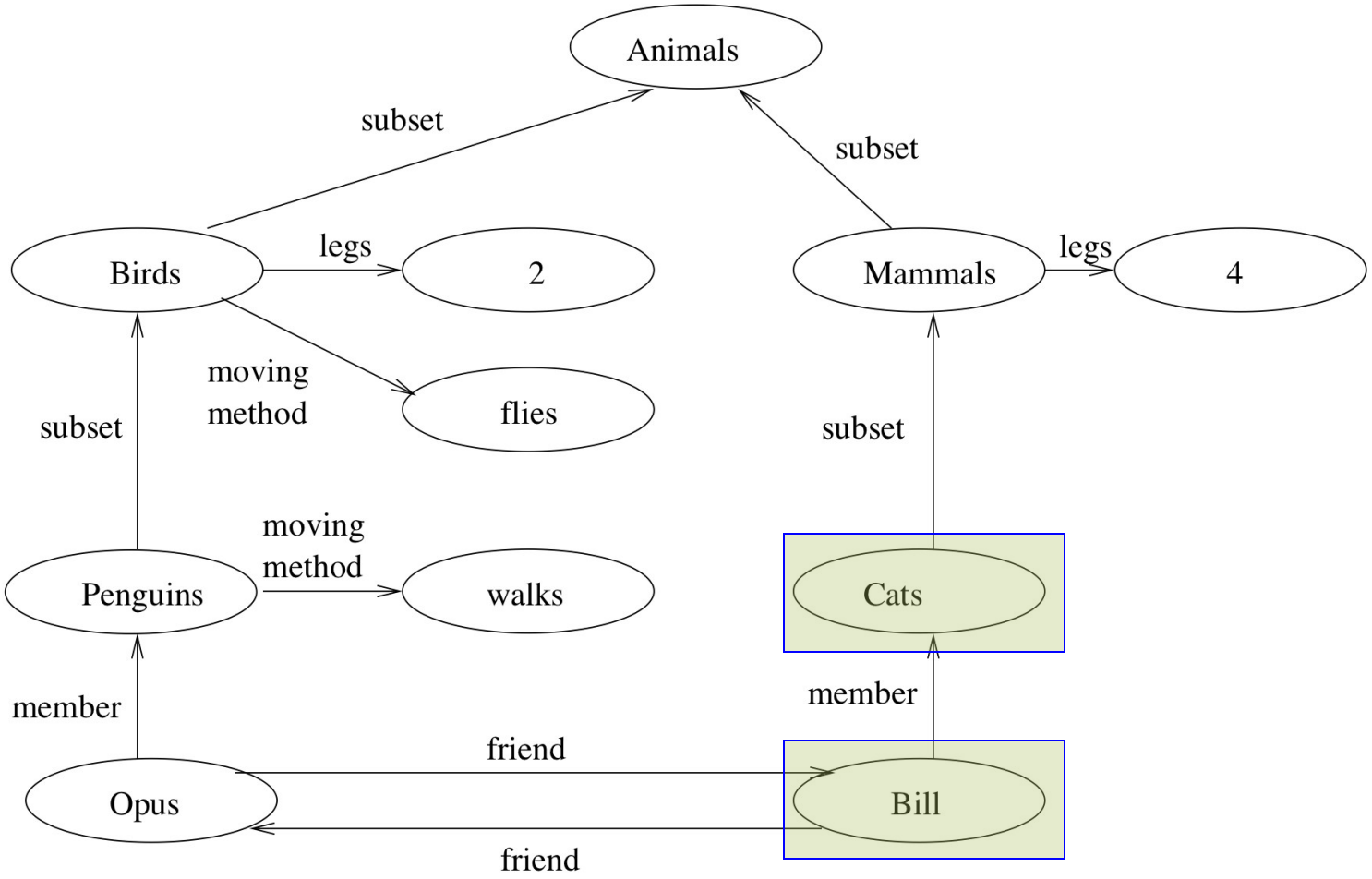
Example



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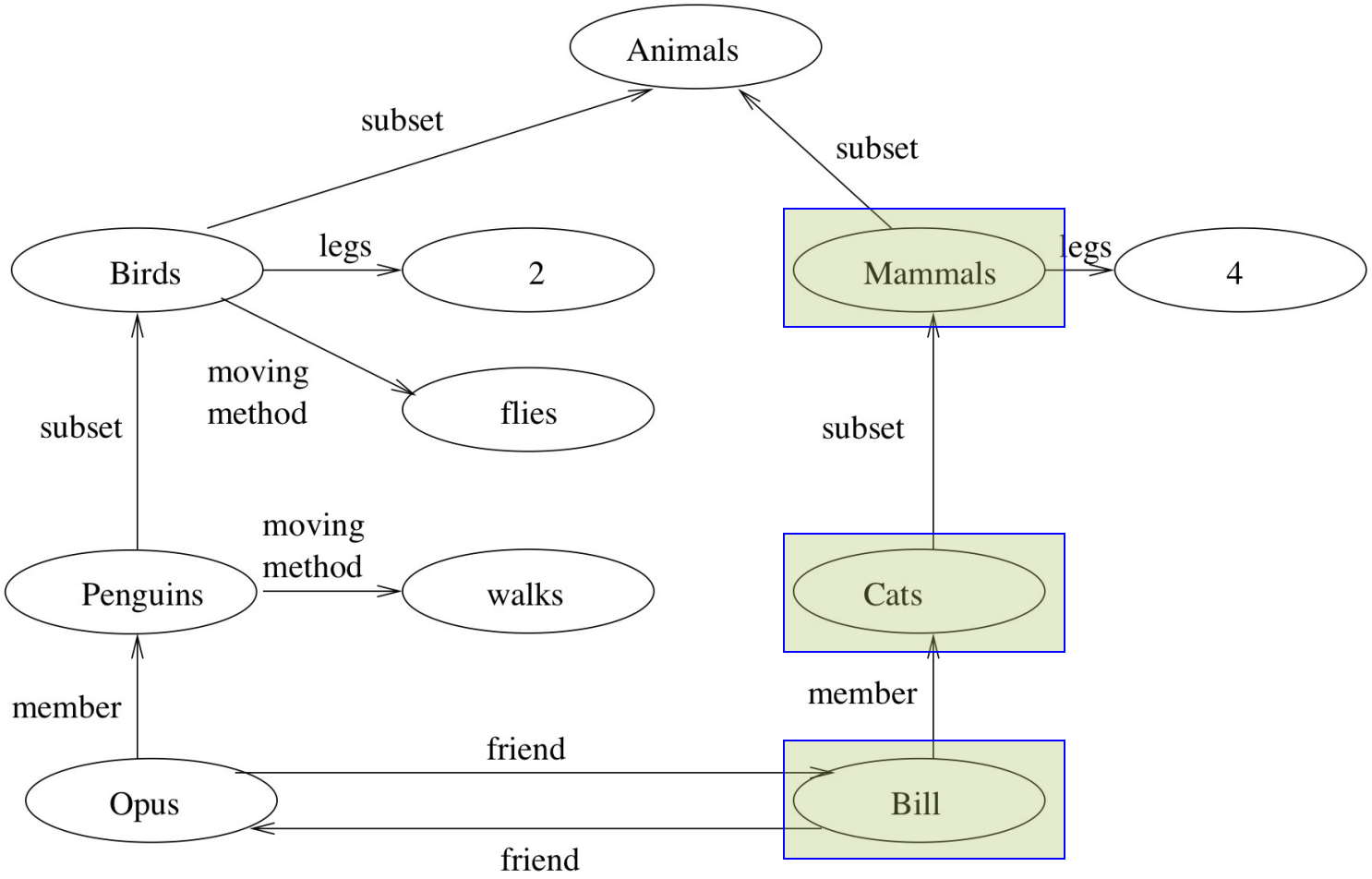
Example



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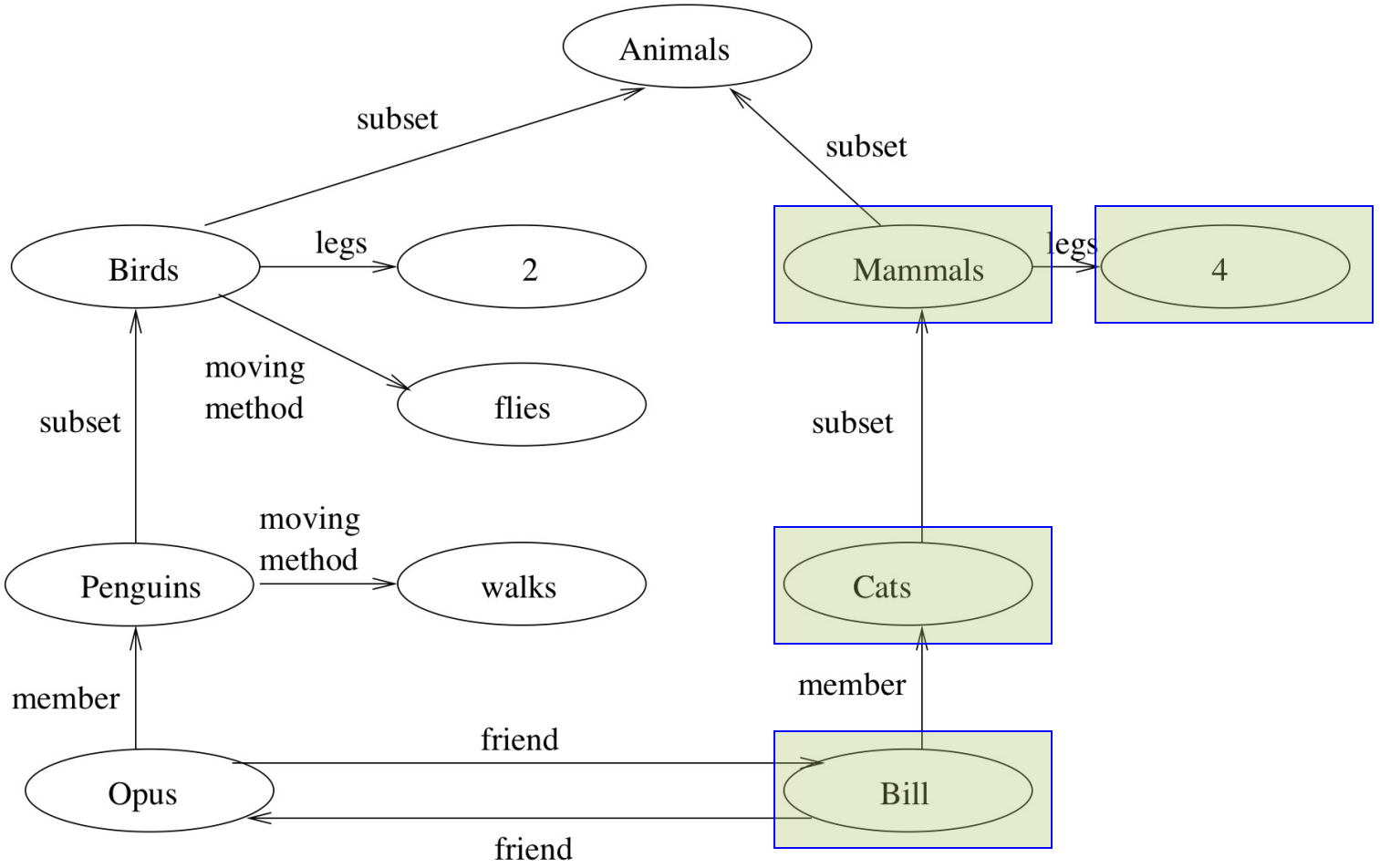
Example



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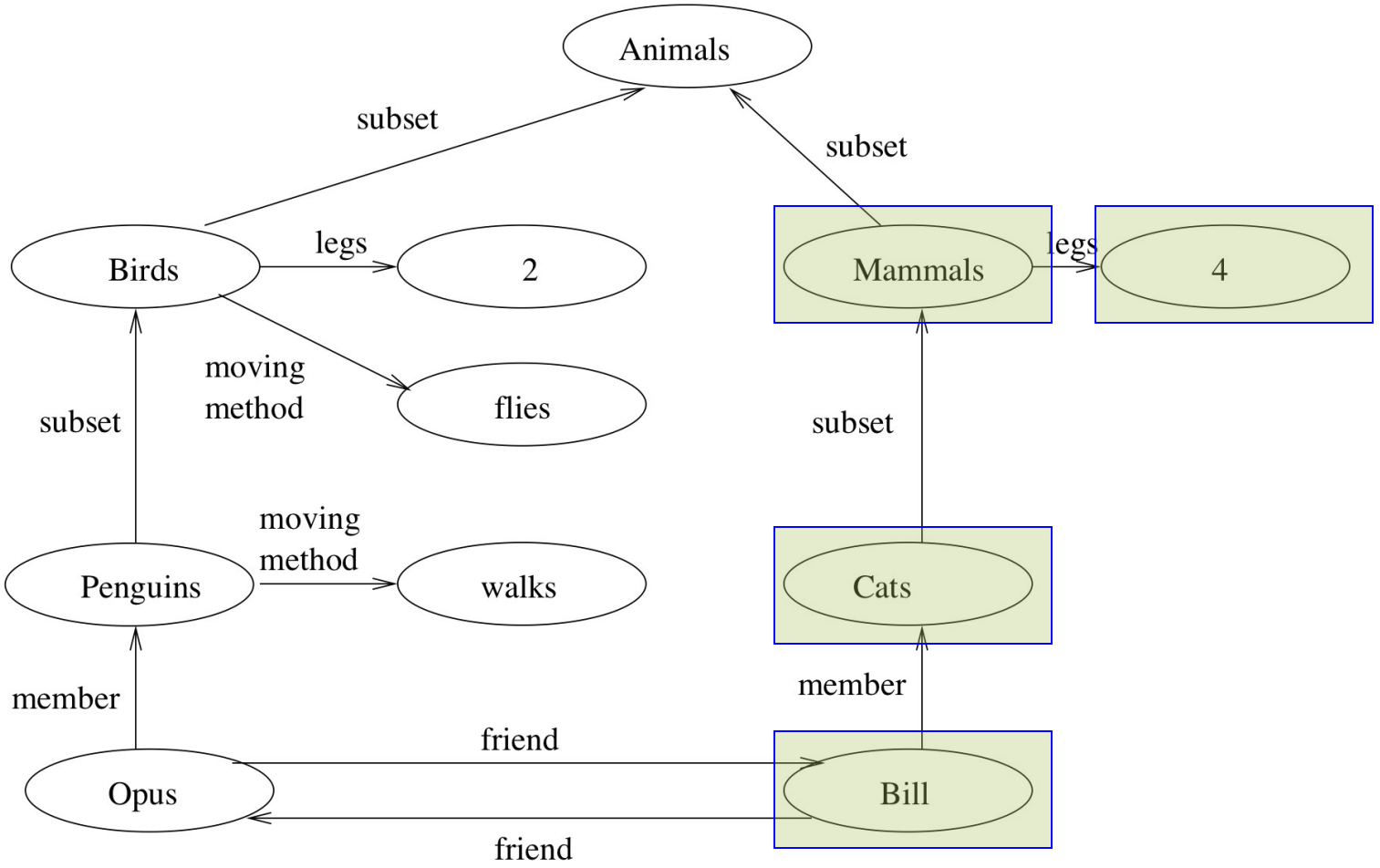
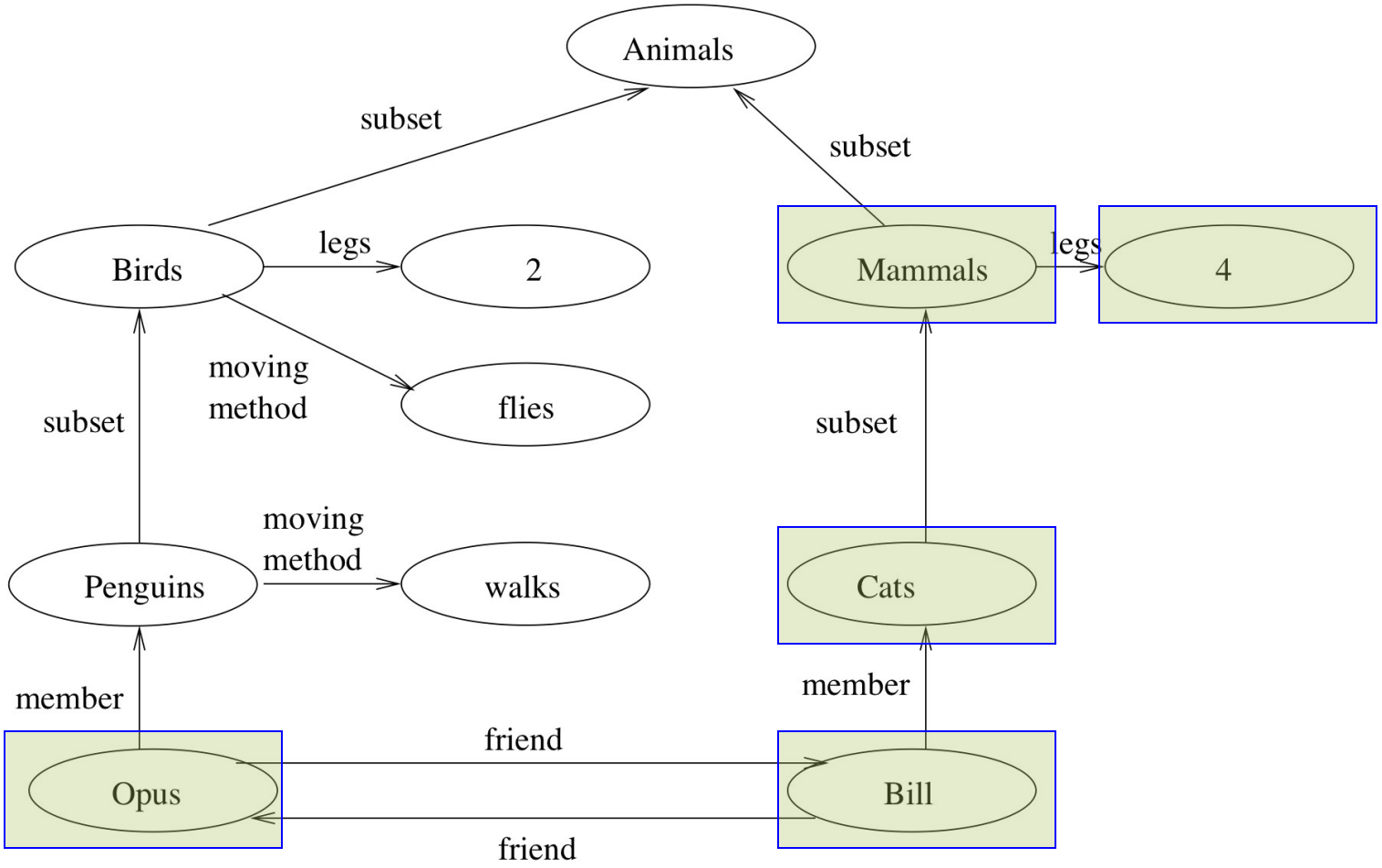
Example



Bill has four legs

Opus is a Bird

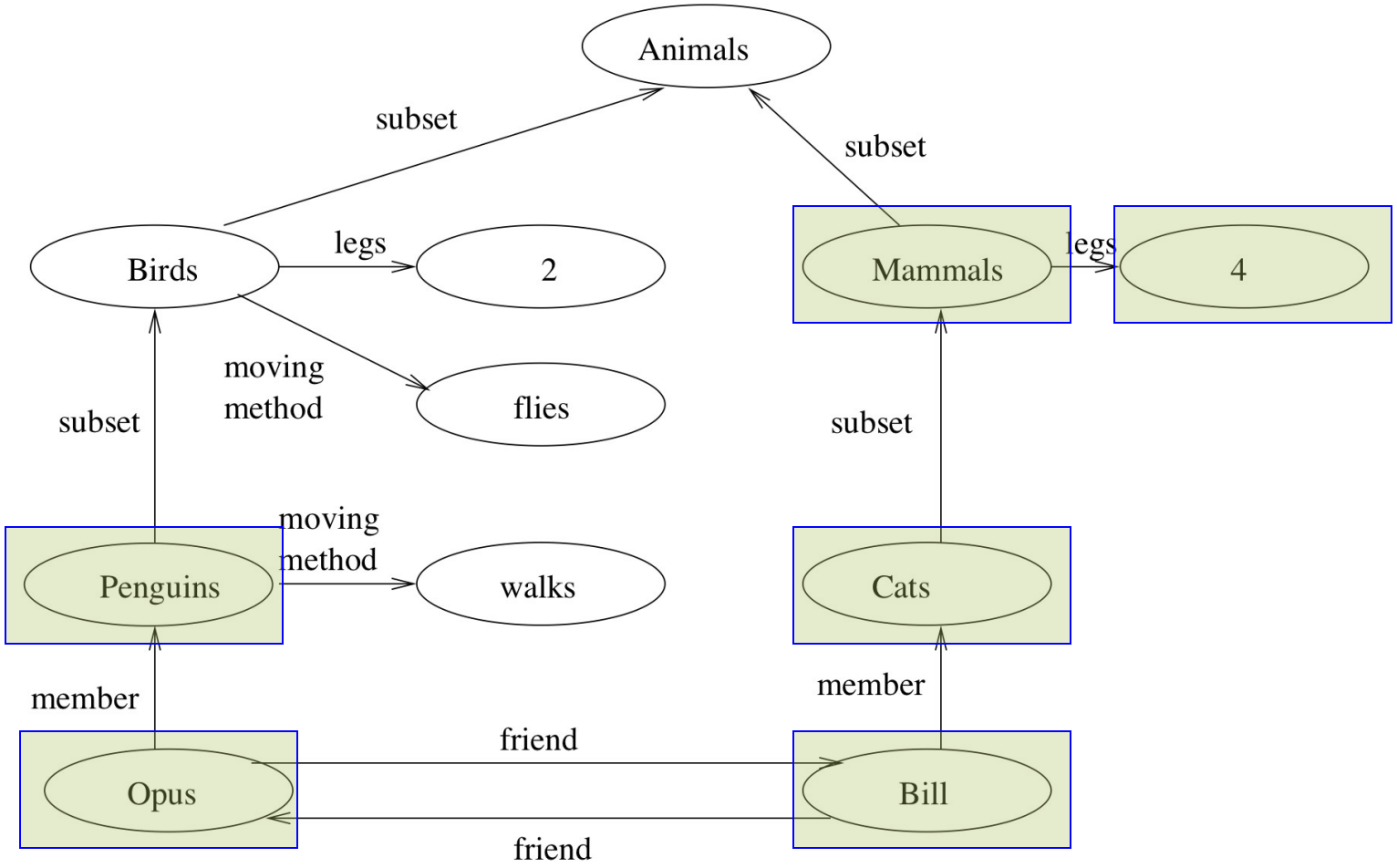
Example



Bill has four legs

Opus is a Bird

Example



Bill has four legs

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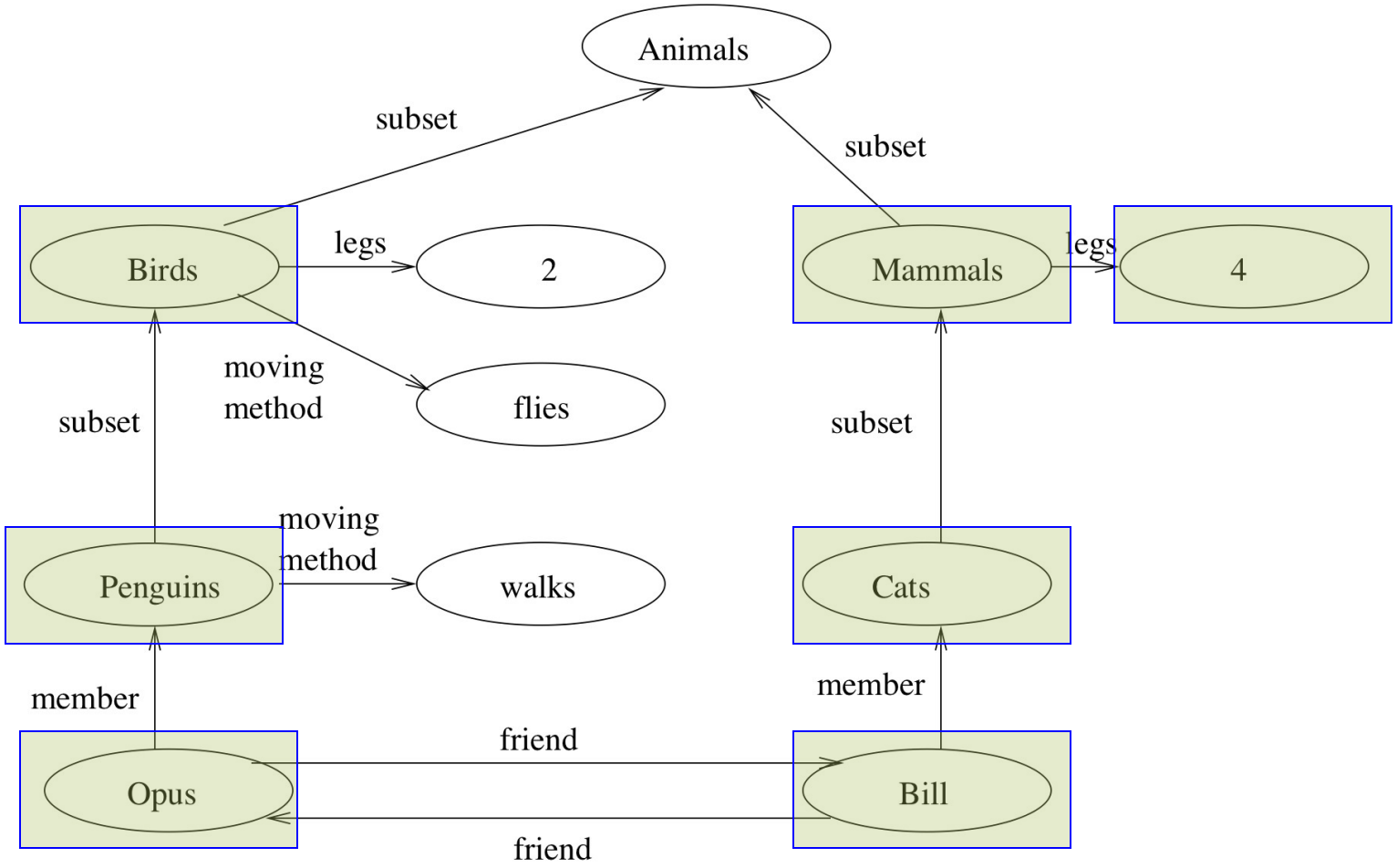
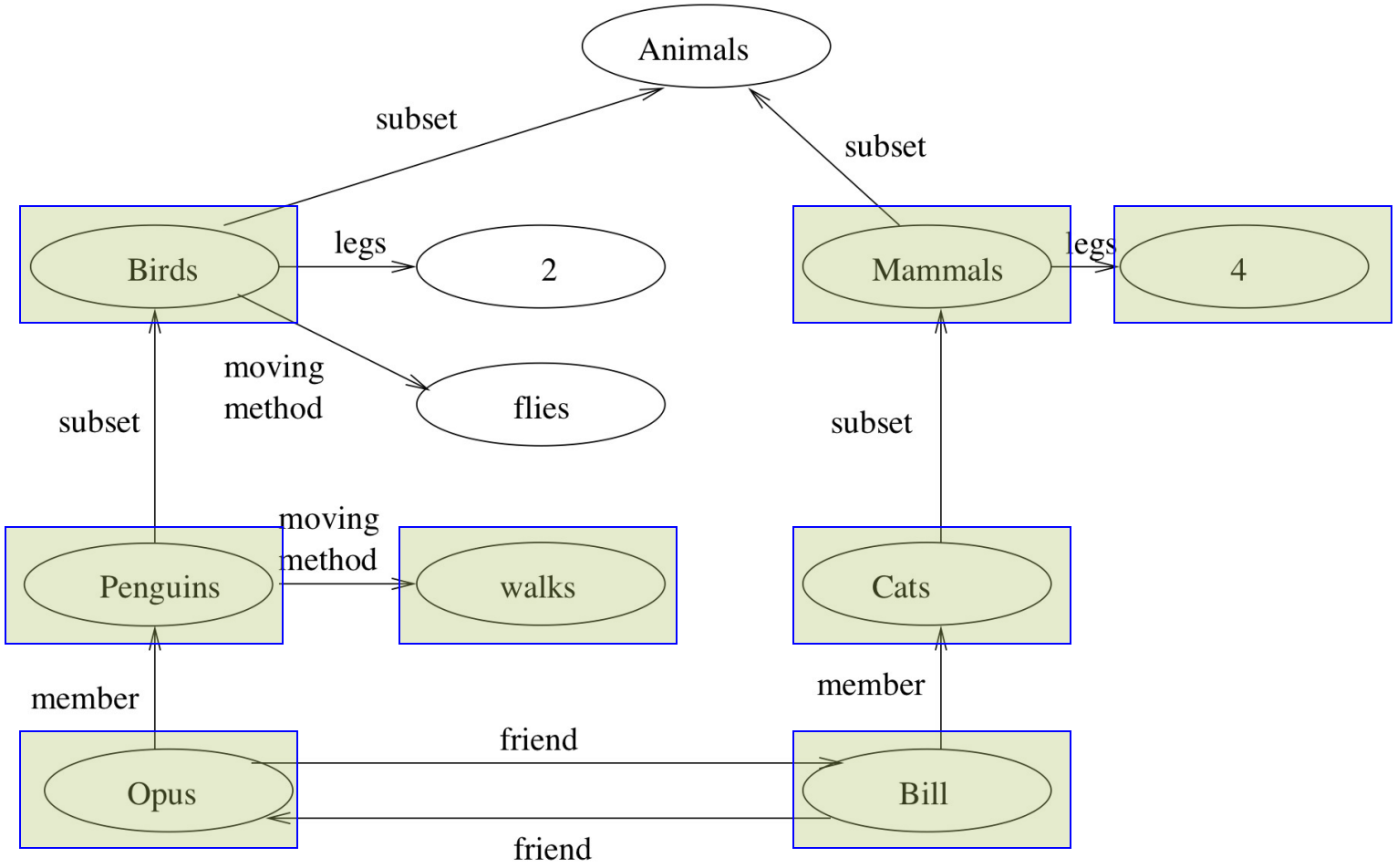


Bill has four legs

Opus is a Bird

Example



Bill has four legs

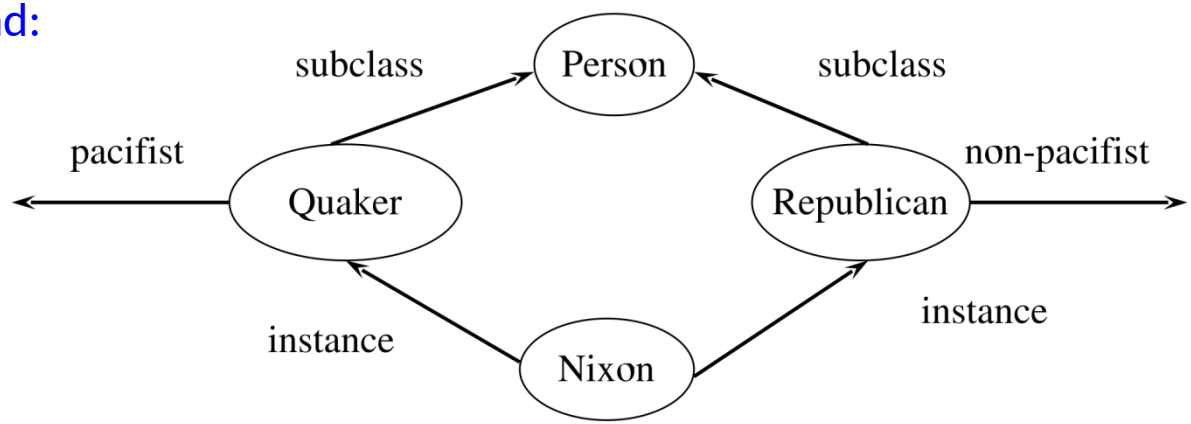
Opus is a Bird

Opus walks

Multiple Inheritance

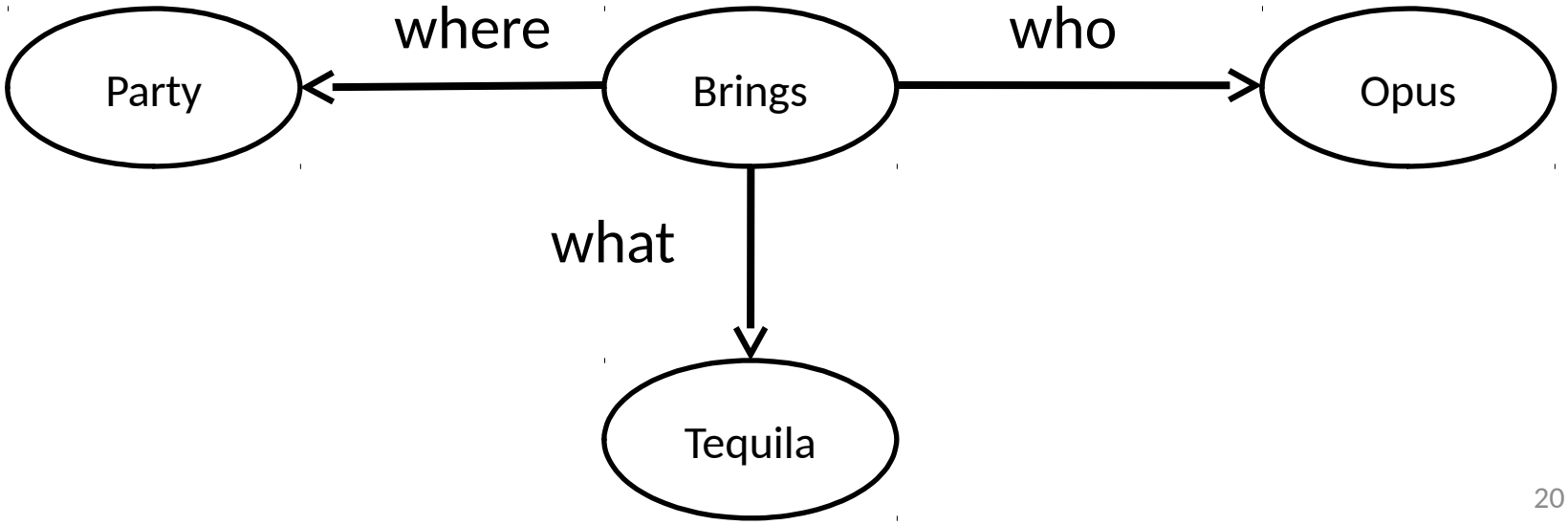
- A node can have any number of superclasses that contain it, enabling a node to inherit properties from multiple parent nodes and their ancestors in the network. It can cause conflicting inheritance

Nixon Diamond:



Problems with Semantic Nets

- Binary relations are easy to represent
- Others are harder
- Example: “Opus brings tequila to the party”



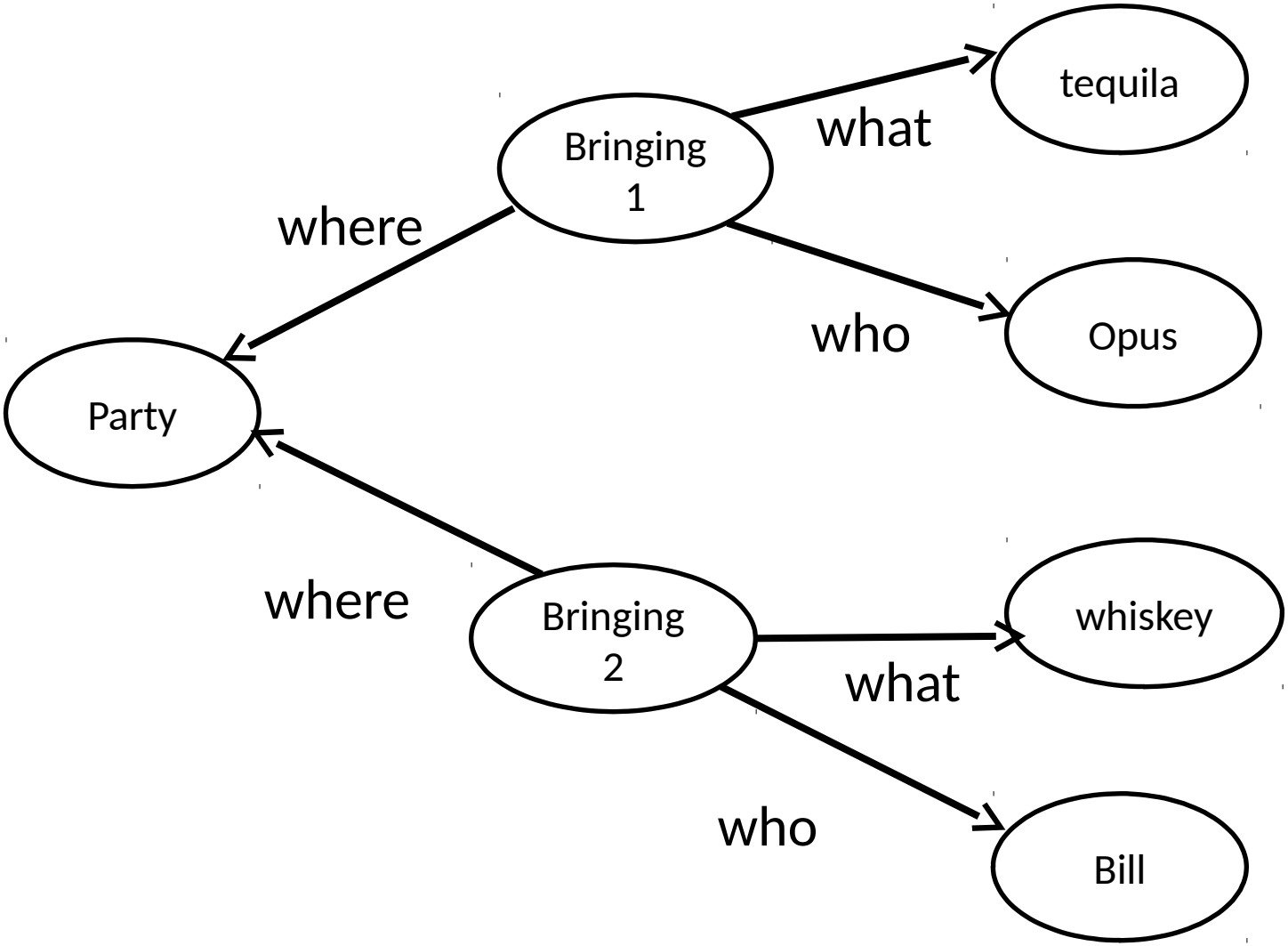
Exercise

- Suppose we have the information “Bill brings whiskey to the party”.
- How could we extend the semantic network to include this information?
- Can you see any problems with the reasoning in the example once we introduce this information?

Binary Relations

- Any relation can be rewritten as a set of binary relations
- Bringing-1(Opus,tequilla,party)
- Bringing-2(Bill,whiskey,party)
- Make the event a thing and make one binary relation ***per role***
  - who(bringing-1,Opus); who(bringing-2,Bill)
  - what(bringing-1,tequila); what(bringing-2,whiskey)
  - where(bringing-1,party); where(bringing-2,party)

Now we can see who brought what



Other Problems are Harder

- Negation
  - Opus and Dirk are not friends
    - Can just assume an absence of a link
- Cancellation
  - Property inherited from a distant superclass cancelled at a lower level
    - Birds fly, penguins don't
- Disjunction
  - Opus either drinks tea or coffee
- Quantification
  - "every dog has bitten a postman"
  - "every dog has bitten every postman"

Advantages of Semantic Nets

- Easy to visualise
- Flexible: relationships can be arbitrarily defined by the knowledge engineer
- Formal definitions of semantic networks have been developed
- Related knowledge is easily clustered
- Efficient in space requirements
- Objects represented only once
- Inference reduced to search

Disadvantages of Semantic Nets

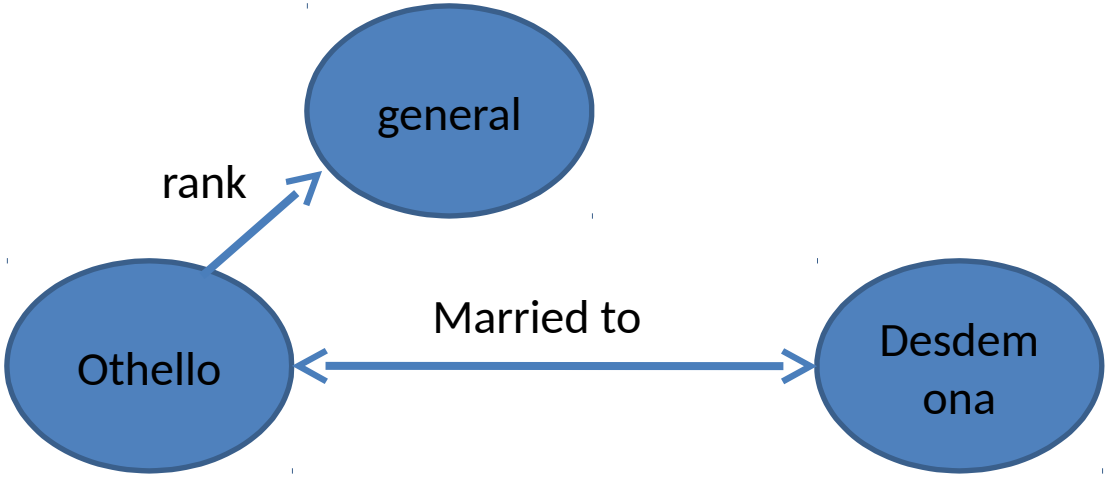
- Inheritance (particularly from multiple sources and when exceptions in inheritance are required) can cause problems
- Facts placed inappropriately cause problems
- No standards about node and arc values
- Limited expressiveness: may require a number of specially coded procedures
- The above problems make it difficult to
  - verify and validate the systems
  - share knowledge
  - reuse knowledge
  - acquire knowledge methodically

wikipedia

The Story of Othello

- Othello was a general who was married to Desdemona
- Iago was a captain who was married to Emilia; he hated Othello
- Iago told Othello lies about Desdemona
- Othello killed Desdemona with a pillow. He felt remorse and killed himself with a dagger

Othello was a general who was married to Desdemona



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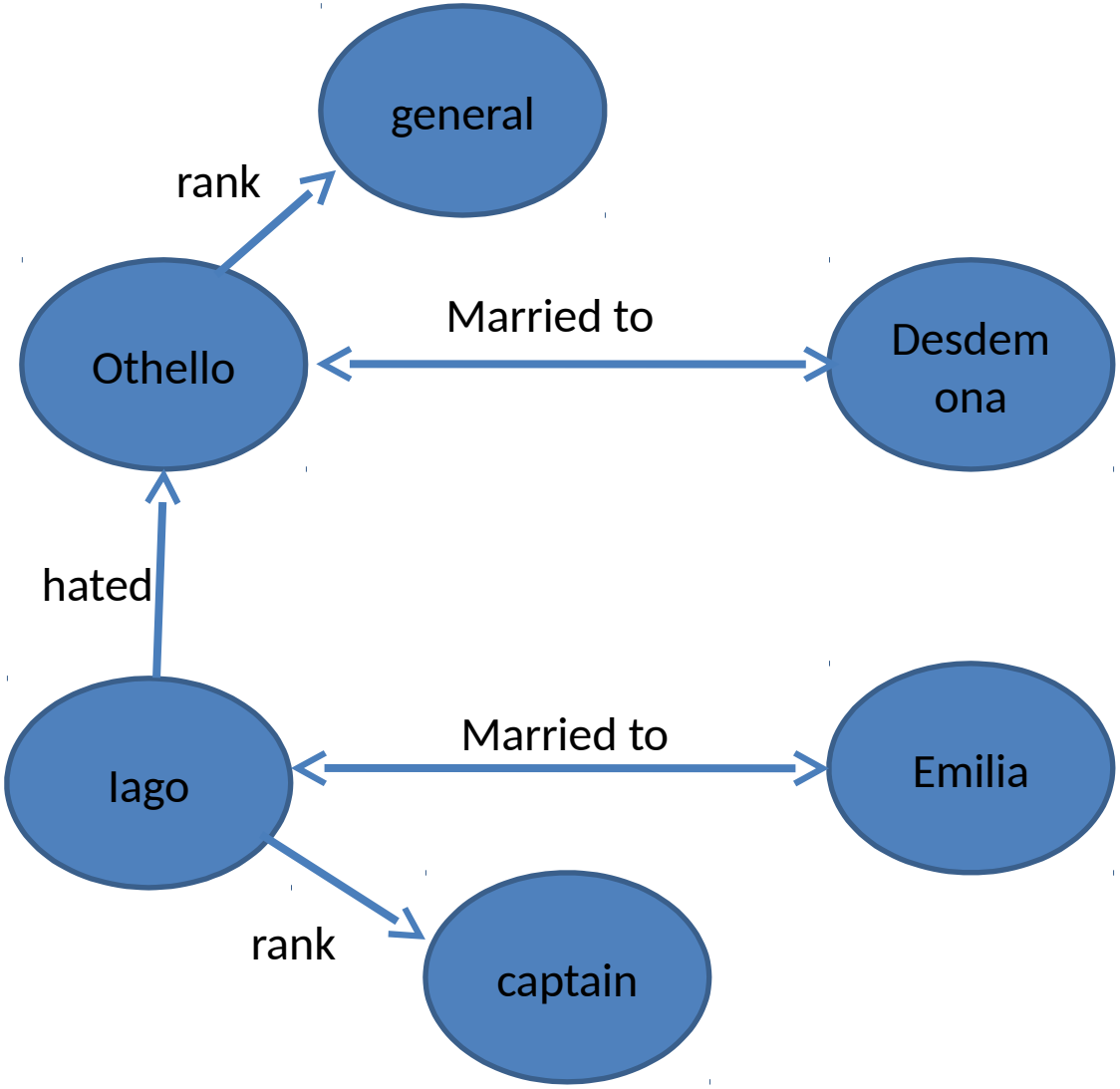
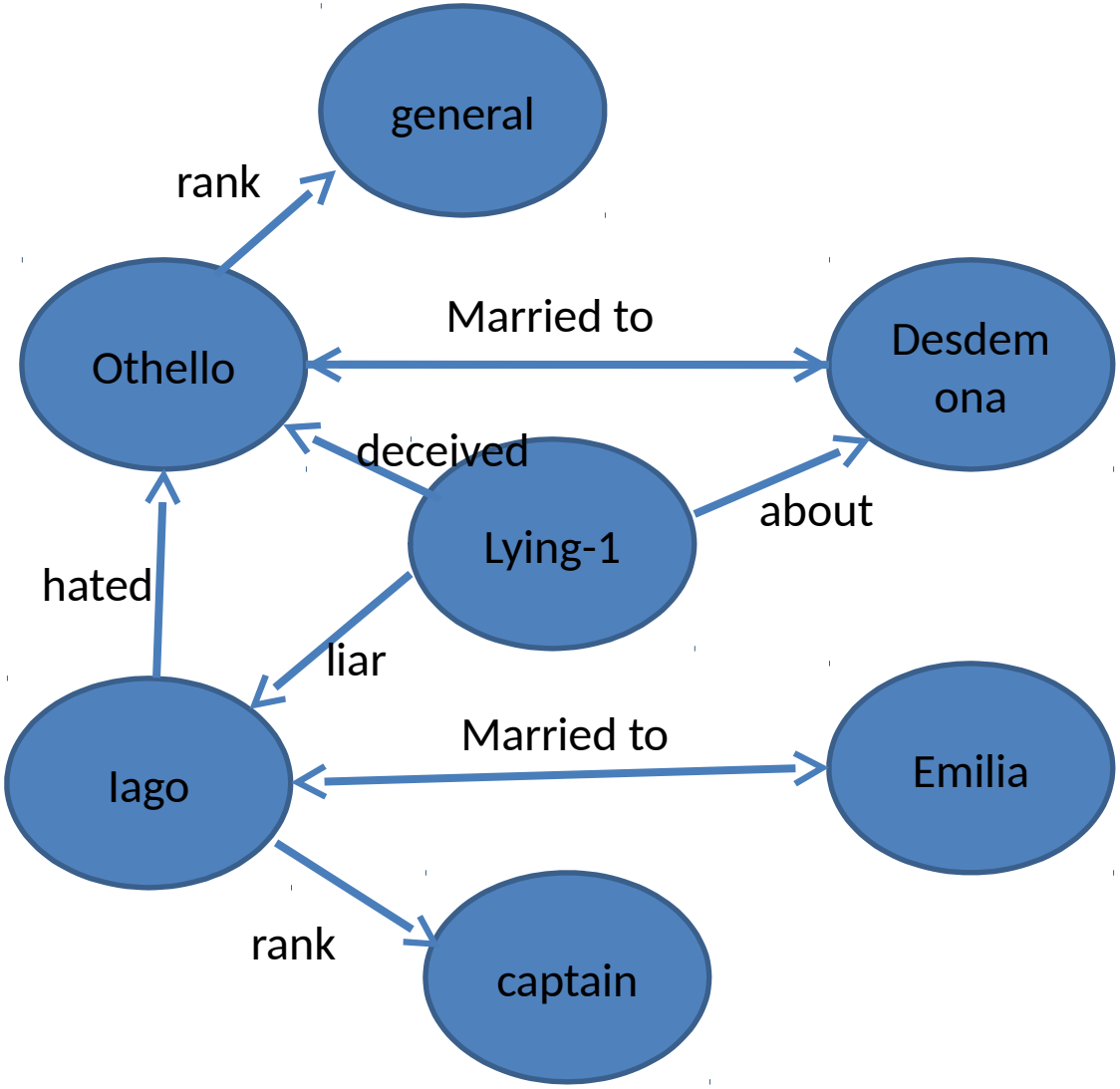
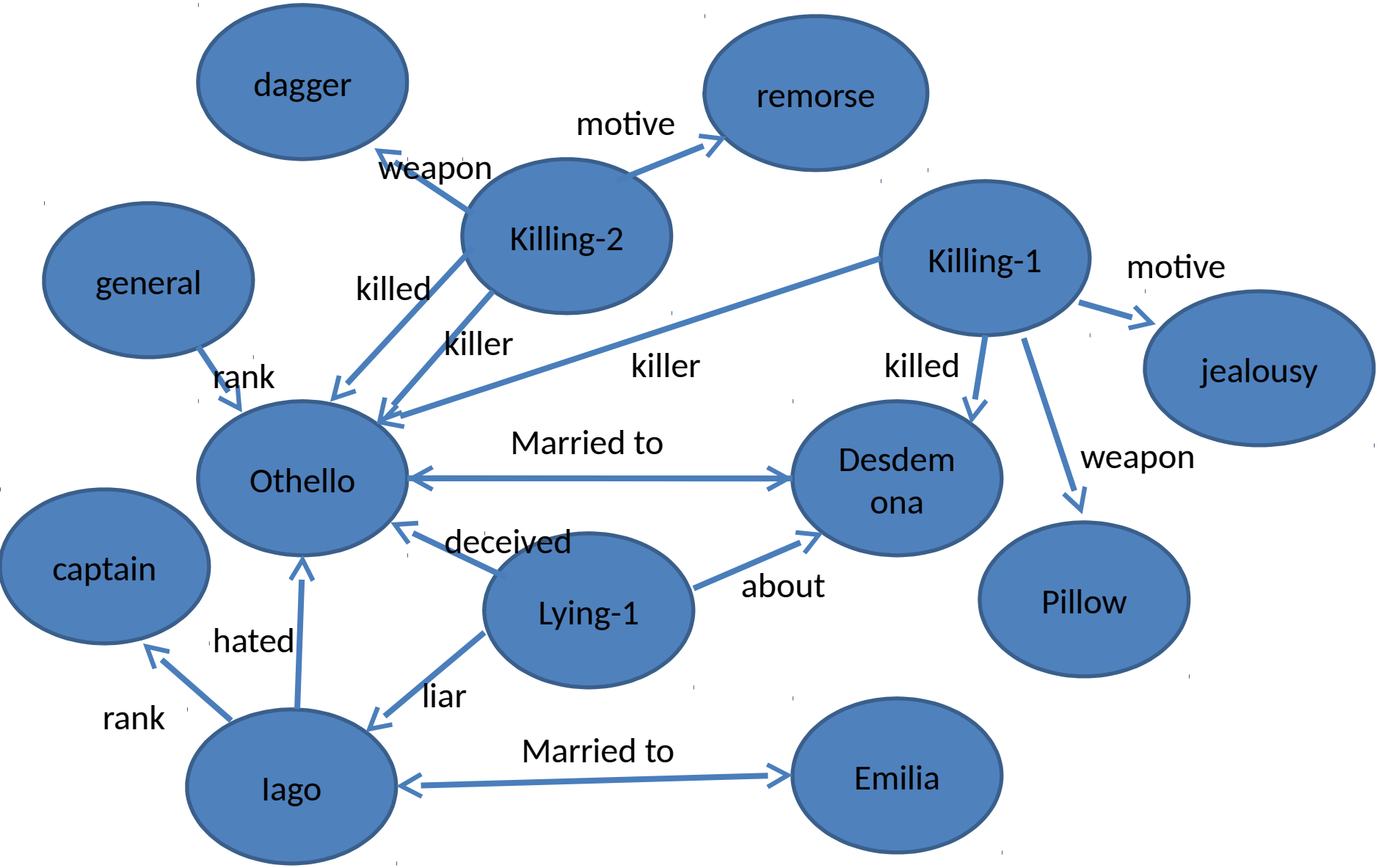


Iago told Othello lies about Desdemona





Othello killed Desdemona with a pillow. He felt remorse and killed himself with a dagger

Prolog – Organised by Relations

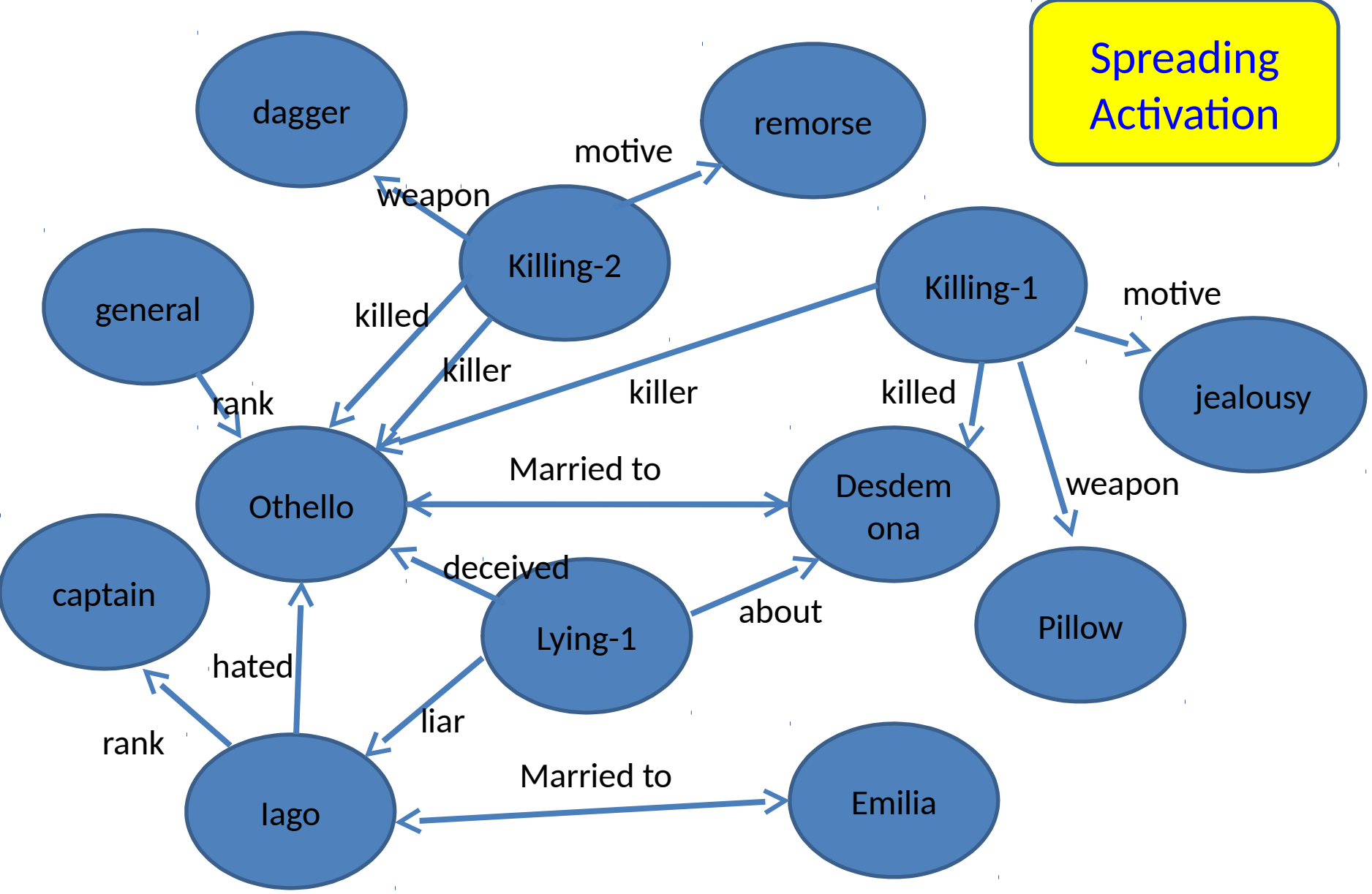
```
marriedTo(Husband,Wife).
marriedTo(X,Y):-marriedTo(Y,X).
rank(Soldier,Rank).
male(Person).
alive(Person).
killing(Killer,Killed,Weapon,Motive).
motiveForKilling(Person,Motive):-
    killing(Person,_,_,Motive).
```

And so on…

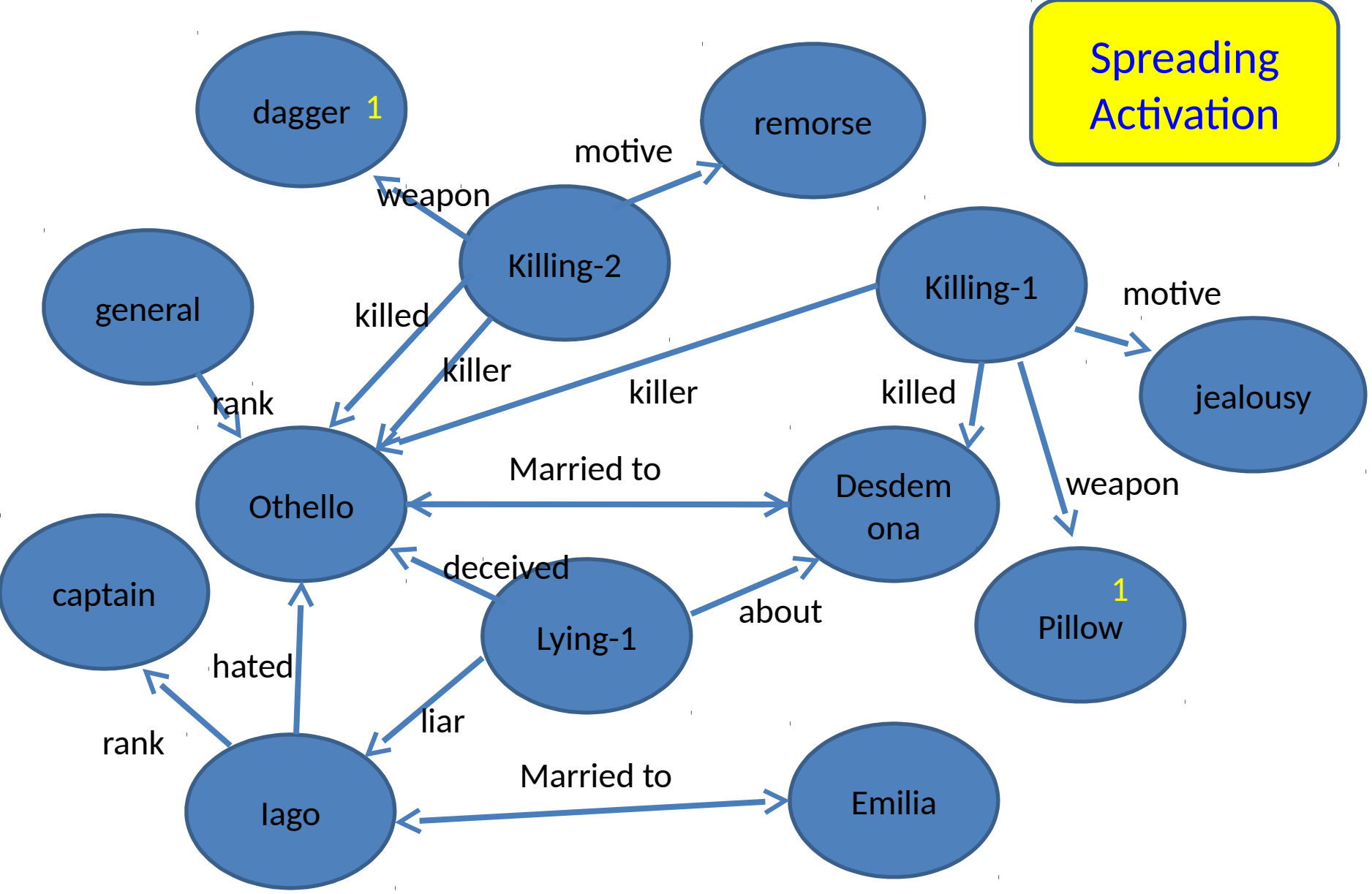
Manipulating the Knowledge

- So far we have represented the knowledge in a variety of ways
- We also need to manipulate the knowledge
- This can be done in a variety of ways

Spreading Activation



What do the pillow and the dagger have in common?



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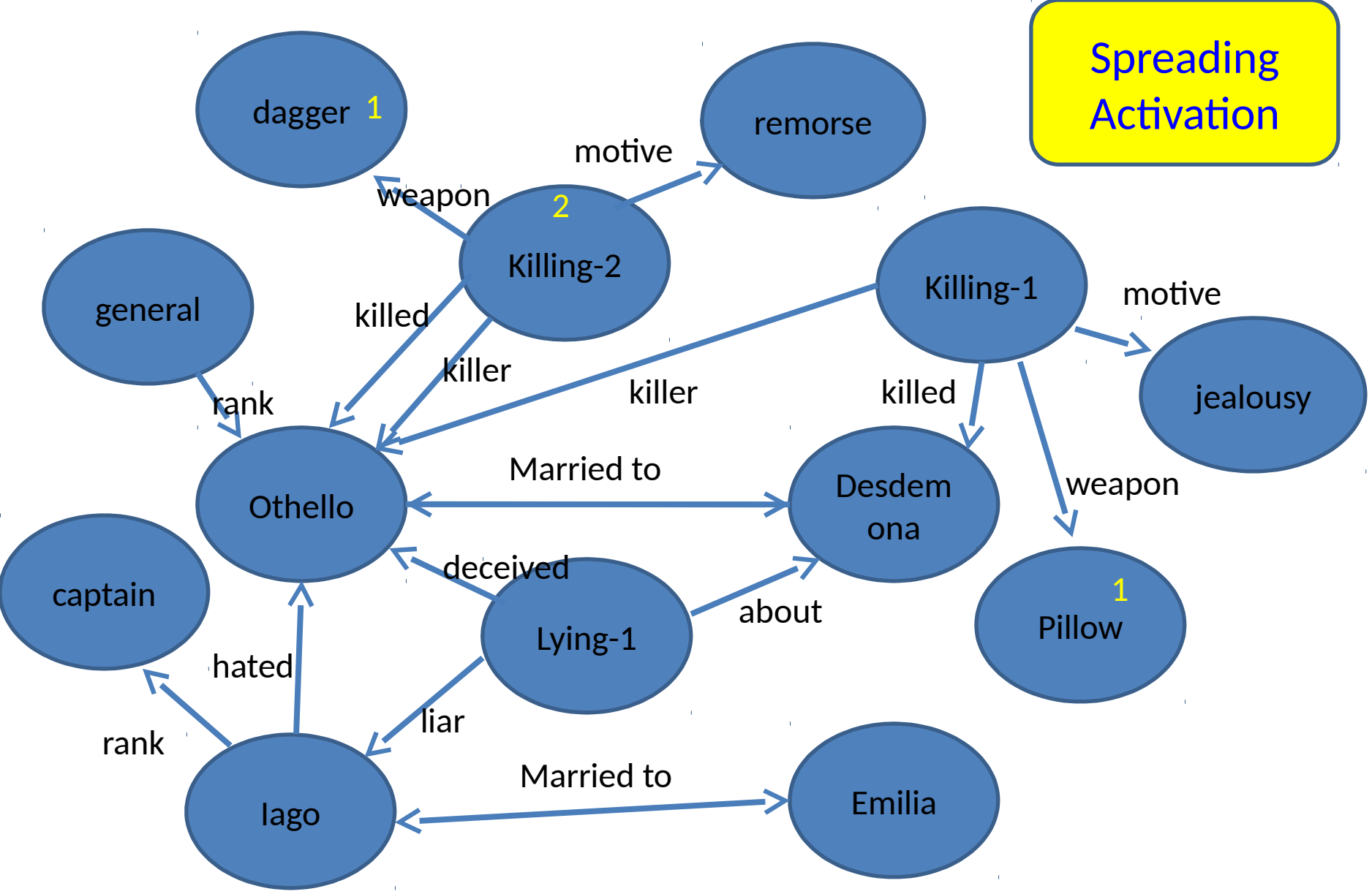

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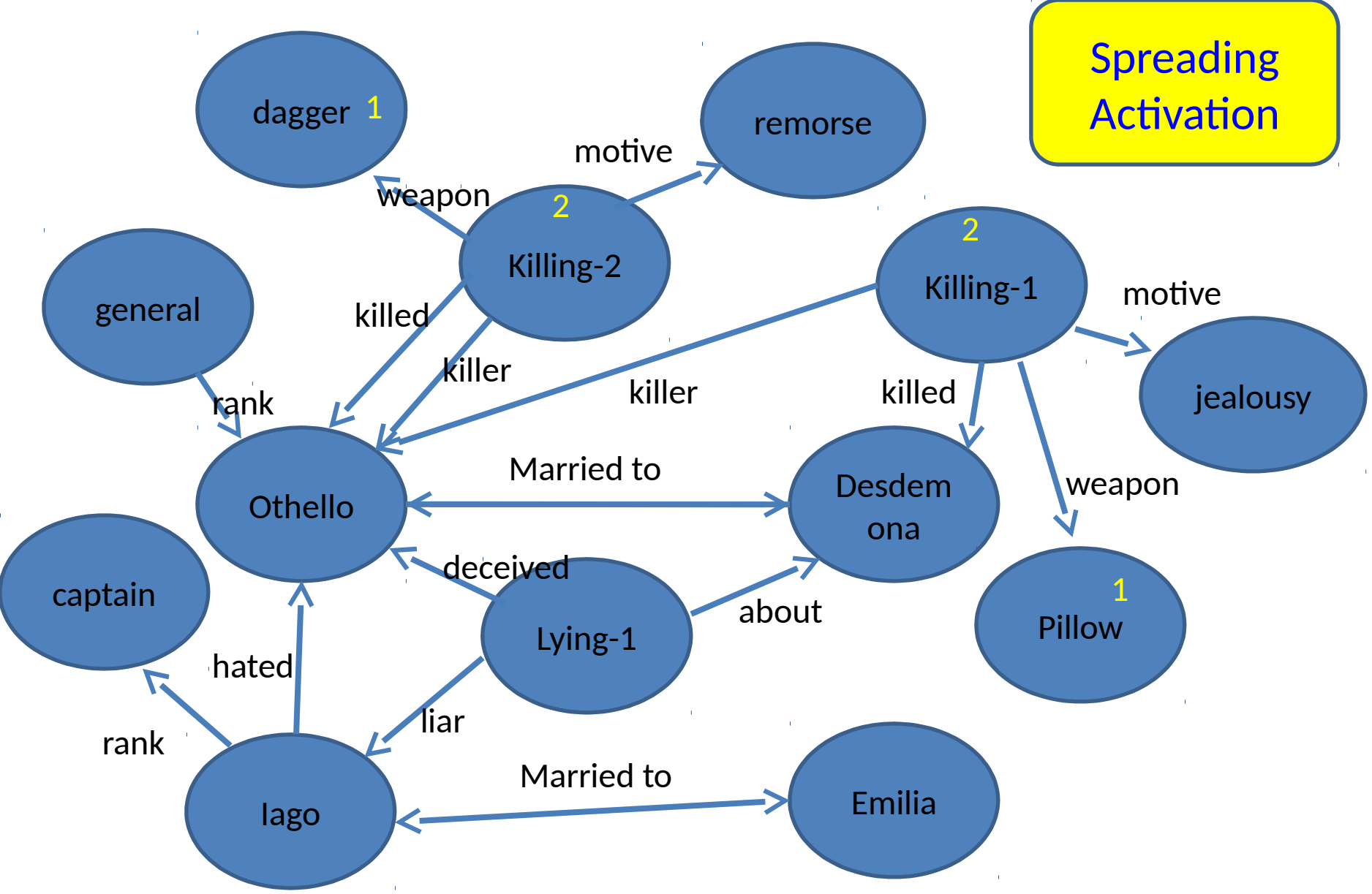

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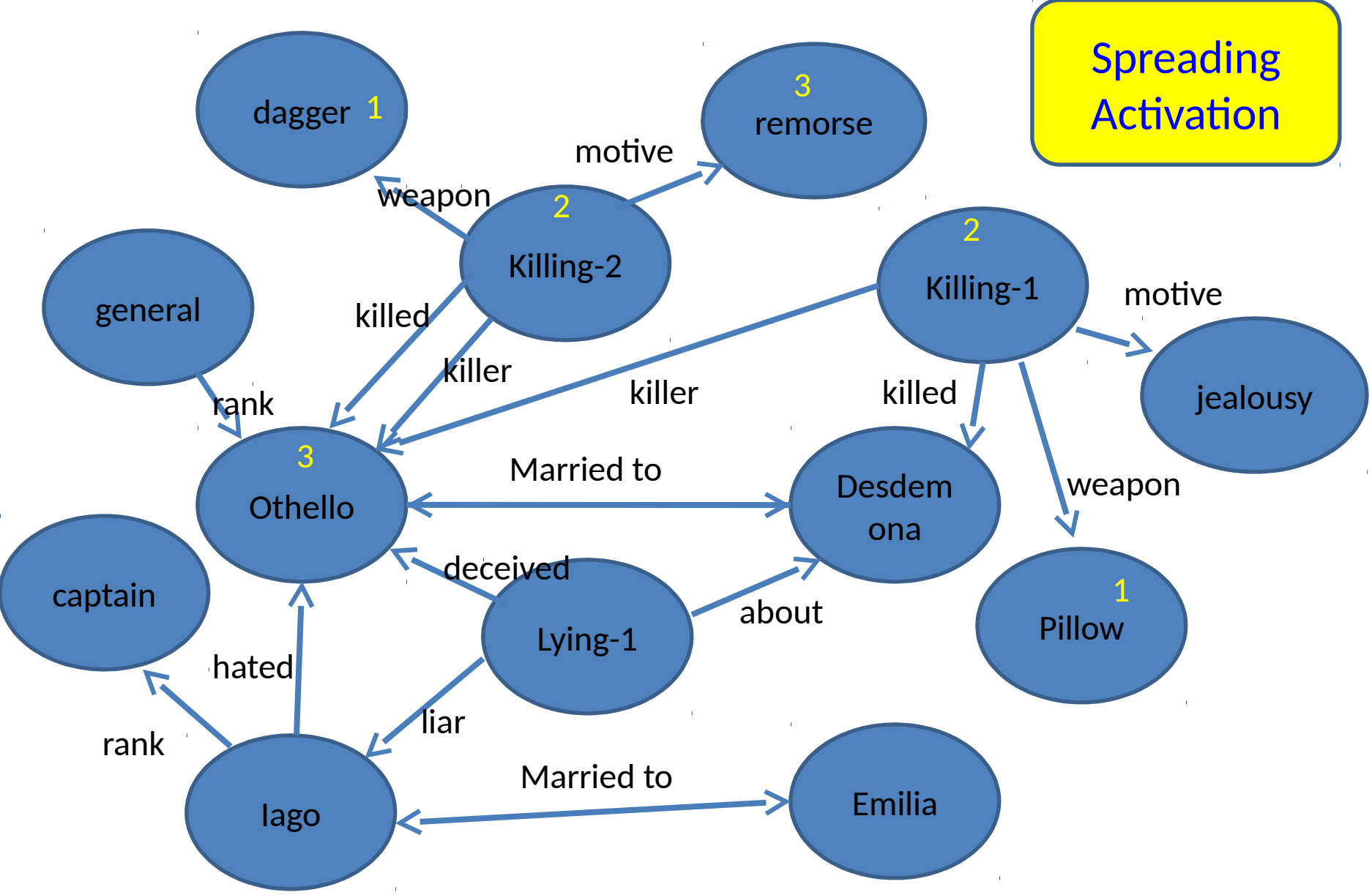

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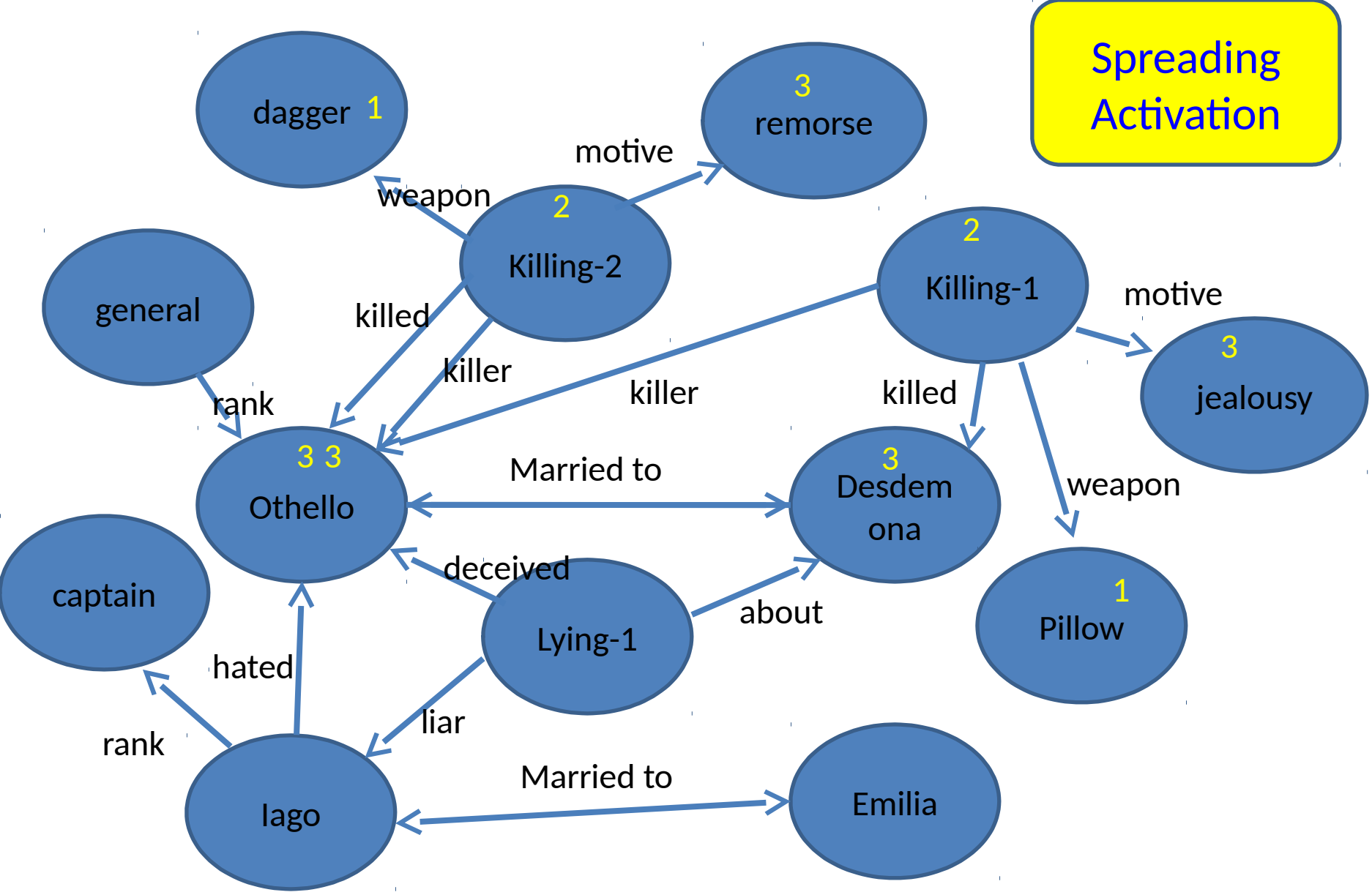
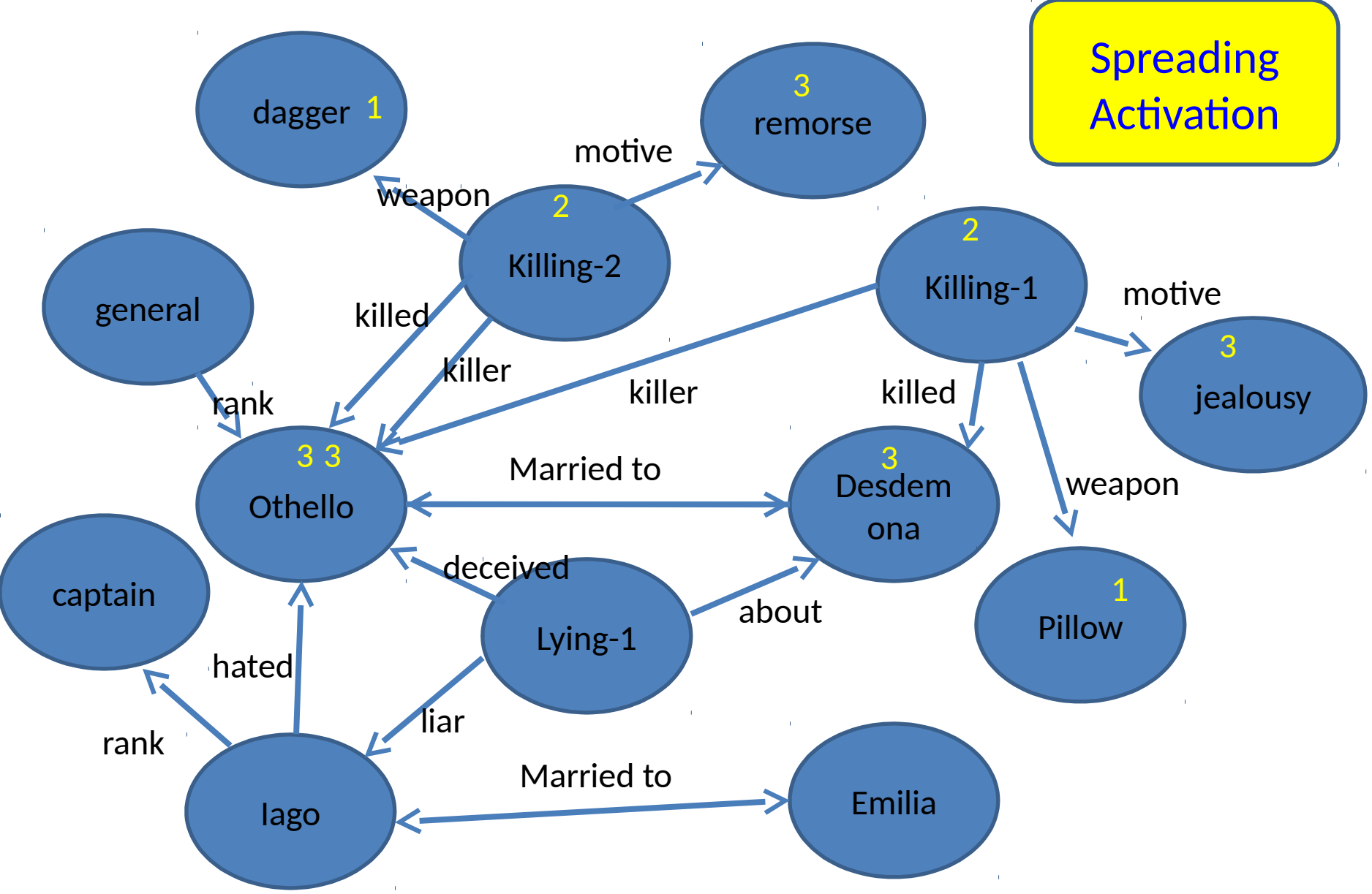


What do the pillow and the dagger have in common?



What do the pillow and the dagger have in common?

Weapons used by Othello in killings

Using Rules

```
IF (?X is-a killing) AND (?X killed ?Y) THEN
   REMOVE (?Y alive T) AND
   ADD (?Y alive F).
IF create(killing, ?X, ?Y) THEN
   execute(?X.weapon) AND
   execute(?X.motive) AND
   put(?Y.alive,F).
```

- Or we can use clauses for Prolog

```
alive(X,false):-killing(_,X,_,_).
```

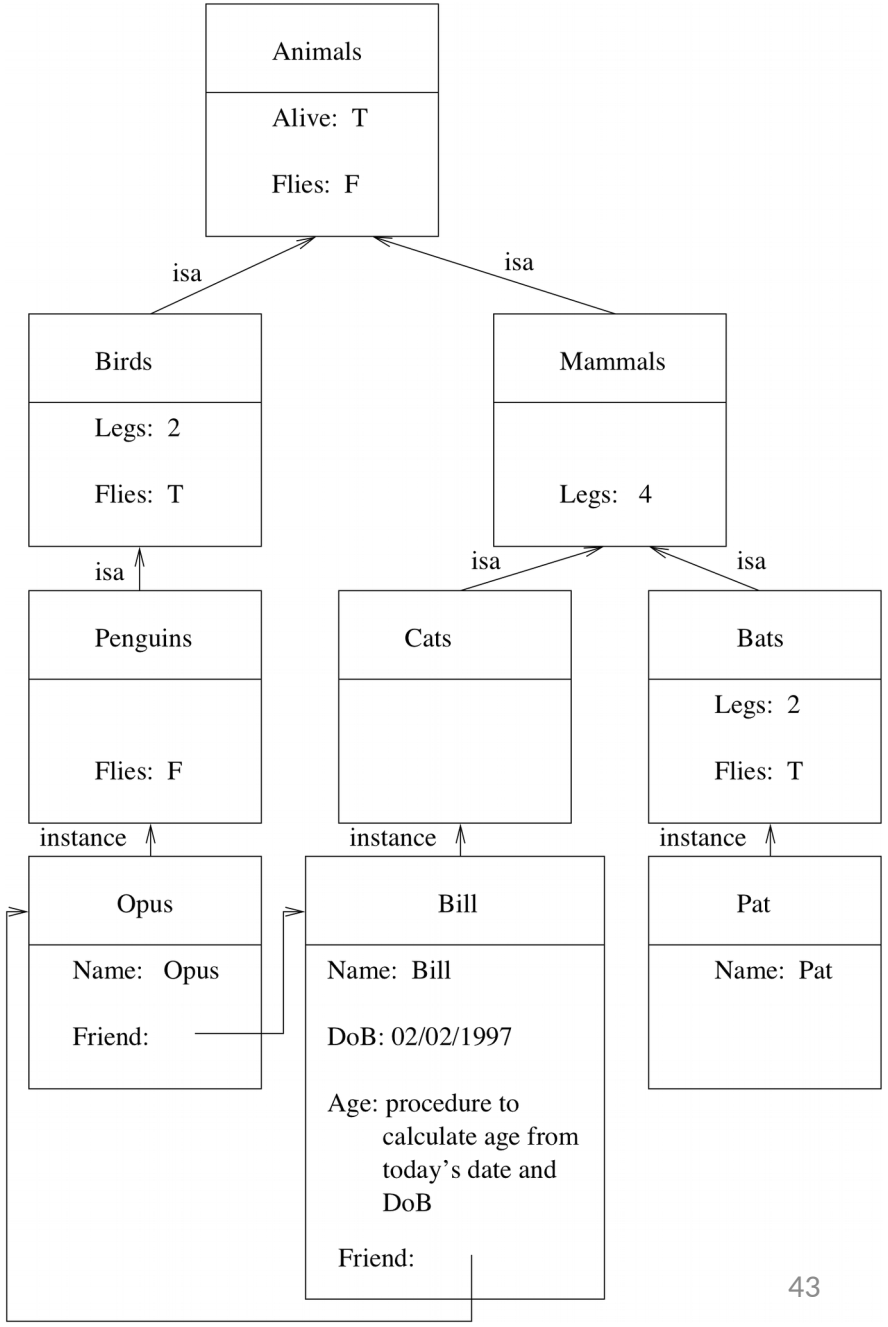
Frames

- Development of semantic nets
- Desire to exploit the powerful mechanism of inheritance
- Observation: things of a given type participate in the same set of relationships
- A lot of information is available by default – it is the exceptions that are interesting

Frames

- Frames - semantic net with *properties and methods*
  - Devised by Marvin Minsky, 1974.
- Incorporates certain valuable human thinking characteristics:
  - Expectations, assumptions, stereotypes, exceptions.

- The essence of this form of knowledge is that we represent the typical case *and exceptions*, *rather* than give *definitions*.
- Hierarchical structure, similar to class hierarchies.



Problems with Frames & Semantic Nets

- Both frames and semantic nets are essentially *arbitrary.*
- Both are useful for representing certain sorts of knowledge.
- But both are essentially *ad hoc - they lack precise* meaning, or *semantics*.
- Inference procedures poorly defined and justified, and often special purpose.
- The *syntax of KR scheme is irrelevant*.
- *Logic generalises these schemes*.

Developments

- Many of the ideas of frames are now expressed in ontologies (see next lecture)
- Frame system + procedures for retrieving and manipulating knowledge = Object System
- AI research influenced the development of Object Oriented Programming, which has become a standard paradigm
- In Object Oriented Programming we use the procedural reading: in AI objects are intended to model or simulate the domain.
- OO Programming is a good example of how AI contributes to mainstream computing

Agents

- Agents can be seen as a development from OO programming:
  - Agents don't wait for messages: they proactively poll the environment to find new information.
  - Agents decide whether to respond to messages.
  - The elements of proactivity and autonomy make them part of AI.

Summary

- Semantic networks were a popular method of structuring information
- In recent years people have attempted to be more principled and formal
  - Simply working on special cases and limited domains is no longer enough
  - Next we will consider these developments in the context of ontologies and logic-based approaches
- Structured objects developed into OO programming, now a conventional technique

- Next time
  - Expert systems and ontologies