

# An Intuitive Graphical Query Interface for Protégé Knowledge Bases

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# Emily

- Query interface for Protégé KBs
  - Graphical, point-and-click
  - Stand-alone Java application
  - Built on the Protégé API library
  - Class-to-class relationships
- Foundational Model of Anatomy (FMA)
- Goal: Usable by novice users with little instruction

# FMA

- Foundational Model of Anatomy
- Symbolic model of the physical organization of the human body
- Goals
  - Foundation for interoperability between biological domains
  - Basis for the construction of intelligent biomedical applications

# FMA Complications

## ● Space complexity

- > 70,000 classes
- > 185,000 frames
- > 170 slots in use
- > 1.5 million slot values

## ● Classes without the instances (individuals)

## ● Existing tools and the FMA

# Example Questions

- What is the heart?
- What are the parts of the heart?
- Is the epicardium a part of the heart?
- Which part of the heart is continuous with the superior pulmonary vein?
- What is the relationship between the right atrium and blood?

# Example Questions

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**EMILY - Foundational Model query interface**

Select tree to search: ☒ Subject ☐ Object Heart Search

**Subject**

- Please choose an item
- Unknown
- Physical anatomical entity
  - Material physical anatomical entity
    - Anatomical structure
      - Body
        - Organ
          - Solid organ
          - Cavitated organ
            - Organ with organ cavity
              - Organ with cavitated organ parts
                - Heart
                - Bone (organ)
                - Cavernous organ
    - Organ part
    - Tissue
    - Tissue subdivision
    - Cell
    - Cell part
    - Body part
    - Body part subdivision
    - Organ system
    - Organ system subdivision
    - Acellular anatomical structure
    - Biological macromolecule
    - Gestational structure
    - Vestigial embryonic structure

**Relation**

- Please choose a relation
- Unknown
  - has superclass
    - has superclass(directly)
    - has superclass
  - has subclass
  - is part of
  - has part
  - is boundary of
  - has boundary
  - is contained in
  - contains
  - is branch of
  - has branch
  - is tributary of
  - has tributary
  - is segmental contribution to
  - has segmental contribution from
  - is continuous with
  - is nerve supply of
  - has nerve supply
  - is adjacent to

**Object**

- Please choose an item
- Unknown
  - Physical anatomical entity
    - Material physical anatomical entity
    - Non-material physical anatomical entity
  - U1

Make relation
query

V	D	C	I	E	
Number	Not	Logic			Query
1	<input type="checkbox"/>	AND			Heart has superclass(directly) Unknown (U1)
2	<input type="checkbox"/>	AND			
3	<input type="checkbox"/>	AND			
4	<input type="checkbox"/>	AND			
5	<input type="checkbox"/>	AND			
6	<input type="checkbox"/>	AND			
7	<input type="checkbox"/>	AND			
8	<input type="checkbox"/>	AND			
9	<input type="checkbox"/>	AND			
10	<input type="checkbox"/>	AND			
11	<input type="checkbox"/>	AND			
12	<input type="checkbox"/>	AND			
13	<input type="checkbox"/>	AND			
14	<input type="checkbox"/>	AND			
15	<input type="checkbox"/>	AND			
16	<input type="checkbox"/>	AND			
17	<input type="checkbox"/>	AND			
18	<input type="checkbox"/>	AND			

Perform logic

Result

V	D	C	I	E	Perform logic	
Number	Not	Logic	Query		Result	
1	<input type="checkbox"/>	AND	Heart has superclass(directly) Unknown (U1)		Organ with cavitated organ parts	
2	<input type="checkbox"/>	AND				
3	<input type="checkbox"/>	AND				
4	<input type="checkbox"/>	AND				
5	<input type="checkbox"/>	AND				
6	<input type="checkbox"/>	AND				
7	<input type="checkbox"/>	AND				
8	<input type="checkbox"/>	AND				
9	<input type="checkbox"/>	AND				
10	<input type="checkbox"/>	AND				
11	<input type="checkbox"/>	AND				
12	<input type="checkbox"/>	AND				
13	<input type="checkbox"/>	AND				
14	<input type="checkbox"/>	AND				
15	<input type="checkbox"/>	AND				
16	<input type="checkbox"/>	AND				
17	<input type="checkbox"/>	AND				
18	<input type="checkbox"/>	AND				

# Composing a Simple Query

Subject	Relation	Object
<p>Please choose an item</p> <ul style="list-style-type: none"><li>Unknown</li><li>Physical anatomical entity<ul style="list-style-type: none"><li>Material physical anatomical entity<ul style="list-style-type: none"><li>Anatomical structure<ul style="list-style-type: none"><li>Body<ul style="list-style-type: none"><li>Organ<ul style="list-style-type: none"><li>Solid organ</li><li>Cavitated organ<ul style="list-style-type: none"><li>Organ with organ cavity</li><li>Organ with cavitated organ parts<ul style="list-style-type: none"><li>Heart</li><li>Bone (organ)</li><li>Cavernous organ</li></ul></li></ul></li></ul></li><li>Organ part</li></ul></li><li>Tissue</li><li>Tissue subdivision</li><li>Cell</li><li>Cell part</li><li>Body part</li></ul></li><li>Biological macromolecule</li><li>Gestational structure</li><li>Vestigial embryonic structure</li></ul></li></ul></li></ul>	<p>Please choose a relation</p> <ul style="list-style-type: none"><li>Unknown<ul style="list-style-type: none"><li>has superclass<ul style="list-style-type: none"><li>has superclass(directly)</li><li>has superclass</li></ul></li><li>has subclass</li><li>is part of</li><li>has part</li><li>is boundary of</li><li>has boundary</li><li>is contained in</li><li>contains</li><li>is branch of</li><li>has branch</li><li>is tributary of</li><li>has tributary</li><li>is segmental contribution to</li><li>has segmental contribution from</li><li>is continuous with</li><li>is nerve supply of</li></ul></li></ul>	<p>Please choose an item</p> <ul style="list-style-type: none"><li>Unknown</li><li>Physical anatomical entity<ul style="list-style-type: none"><li>Material physical anatomical entity</li><li>Non-material physical anatomical entity</li></ul></li><li>U1</li></ul>
Subject	Relationship	Object



# What is the heart?

Subject	Relationship	Object
Heart	has superclass (directly)	Unknown

# Subject Tree

## Subject

Please choose an item

Unknown

Physical anatomical entity

Material physical anatomical entity

Anatomical structure

Body

Organ

Solid organ

Cavitated organ

Organ with organ cavity

Organ with cavitated organ parts

Heart

Bone (organ)

Cavernous organ

Organ part

Tissue

# Relationship Tree

## Relation

 Please choose a relation

└ Unknown

  has superclass

└ has superclass(directly)

└ has superclass

  has subclass

  is part of

  has part

  is boundary of

  has boundary

  is contained in

  contains

# Object Tree

## Object

 Please choose an item

 Unknown

  Physical anatomical entity

  Material physical anatomical entity

  Non-material physical anatomical entity

 U1

# What is the heart?

Subject	Relationship	Object
Heart	has superclass (directly)	Unknown

## Results

Organ with cavitated organ parts

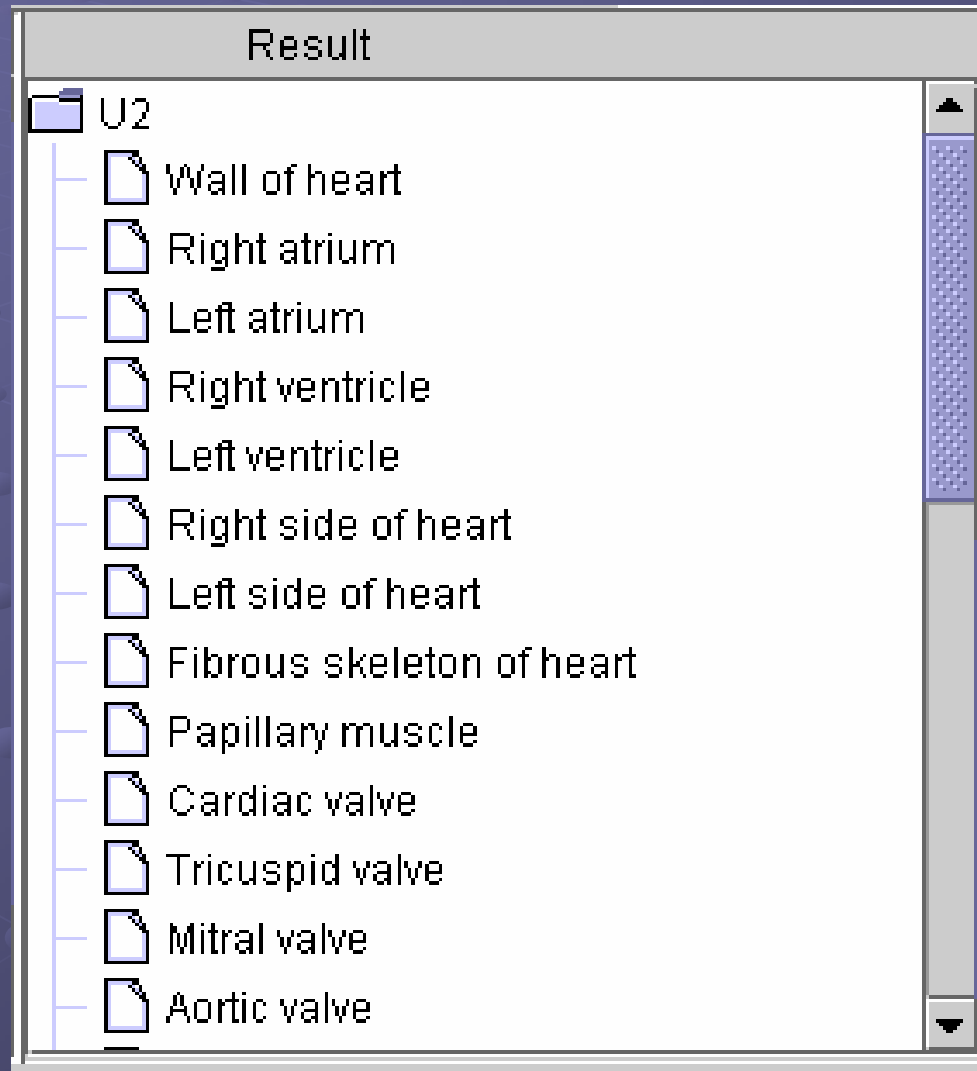
# Example Questions

- What is the heart?
- What are the parts of the heart?
- Is the epicardium a part of the heart?
- Which part of the heart is continuous with the superior pulmonary vein?
- What is the relationship between the right atrium and blood?

# What are the parts of the heart?

Subject	Relationship	Object
Heart	has part (directly)	Unknown

# What are the parts of the heart?





# Example Questions

- What is the heart?
- What are the parts of the heart?
- Is the epicardium a part of the heart?
- Which part of the heart is continuous with the superior pulmonary vein?
- What is the relationship between the right atrium and blood?

# Is the epicardium a part of the heart?

- Why was Epicardium not in the previous result set?
  - Epicardium not a direct part of heart
  - Heart has part Wall of heart which has part Epicardium
- But aren't the parts of any direct part of the Heart still a part of the Heart?
  - Yes, because part is transitive

# Relationship Tree

## Relation

Please choose a relation

Unknown

has superclass

has subclass

is part of

has part

has part(directly)

has part

is boundary of

has boundary

Directly  
related

Transitively  
related

# Is the epicardium a part of the heart?

Subject	Relationship	Object
Heart	has part	Epicardium

Results
Yes

# Example Questions

- What is the heart?
- What are the parts of the heart?
- Is the epicardium a part of the heart?
- Which part of the heart is continuous with the superior pulmonary vein?
- What is the relationship between the right atrium and blood?

# Which part of the heart is continuous with the superior pulmonary vein?

- What is the Subject?
- What is the Relationship?
- What is the Object?

# Compound queries

- Two methods for creating compound queries
  - Query chaining
  - Set operations

# Which part of the heart is continuous with the superior pulmonary vein?

- Subject: part of the heart
- Relationship: is continuous with
- Object: Superior pulmonary vein



# Which part of the heart is continuous with the superior pulmonary vein?

● Subject: part of the heart

- Subject: Heart
- Relationship: has part
- Object: Unknown

} U1

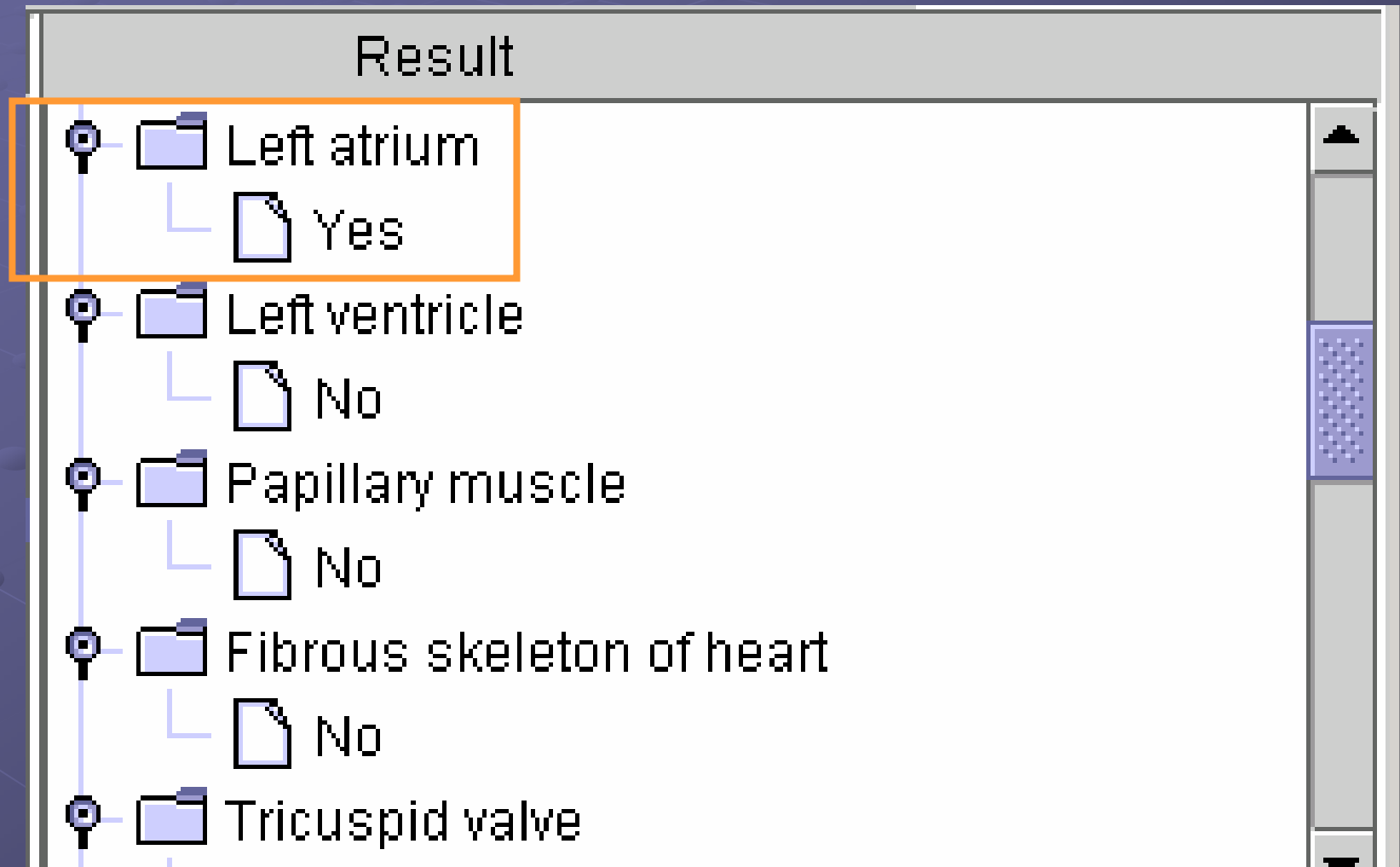
● Relationship: is continuous with

● Object: Superior pulmonary vein

# Which part of the heart is continuous with the superior pulmonary vein?

- Subject: U1
- Relationship: is continuous with
- Object: Superior pulmonary vein

Which part of the heart is continuous with the superior pulmonary vein?



Which part of the heart is continuous with the superior pulmonary vein?

Subject	Relationship	Object
Heart	has part	Unknown (U1)
U1	is continuous with	Unknown (U2)

# Result Sets

## Subject

 Please choose an item

— Unknown

  Physical anatomical entity

—   Material physical anatomical entity

—   Non-material physical anatomical entity

—  U1

— U2

# Query History Panel

Query	Result
Heart has part Unknown (U1)	U2
U1 is continuous with Unknown (U2)	Right atrium
	Coronary sinus
	Small cardiac vein
	Anterior cardiac vein
	Superior vena cava
	Inferior vena cava
	Right ventricle
	Pulmonary trunk
	Left atrium
	Superior pulmonary vein
	Right superior pulmonary vein
	Left superior pulmonary vein
	Inferior pulmonary vein

What part of the heart is continuous with the superior pulmonary vein?

U1 U2

# Compound queries

- Two methods for creating compound queries
  - Query chaining
  - Set operations

# Set Operations

- Results of some queries are sets
- Available operations
  - AND
  - OR
  - NOT



Which part of the heart is continuous with the superior pulmonary vein?

Subject	Relationship	Object
Heart	has part	Unknown (U1)
Unknown (U2)	is continuous with	Superior pulmonary vein
U1	AND	U2

# Set Operations

Not	Logic	Query
<input type="checkbox"/>	AND	Heart has part Unknown (U1)
<input type="checkbox"/>	AND	Unknown (U2) is continuous with(directly) Superior pulmon...
<input type="checkbox"/>	AND	U3 = [(U1)] AND [(U2)]
<input type="checkbox"/>	AND	

U3

Left atrium

What part of the heart is continuous with the superior pulmonary vein?

# Example Questions

- What is the heart?
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# Unknown Relationship

- What if the user chooses the 'Unknown' node for the query relationship?
  - FMA is highly connected
    - Many paths between classes
    - Not practical (nor useful) to find all paths
  - First path
    - Assumption: The simplest path is likely to be the most desirable

# Unknown Relationship

## ● Algorithm

- Direct connections
- Transitive closure connections
- Predetermined connection types
- Depth-limited breadth-first search

# What is the relationship between the right atrium and blood

Subject	Relationship	Object
Right atrium	Unknown	Blood

## Results

Right atrium **part** Cavity of right atrium **contains**  
Blood in right atrium :**DIRECT-SUPERCLASSES**  
Blood

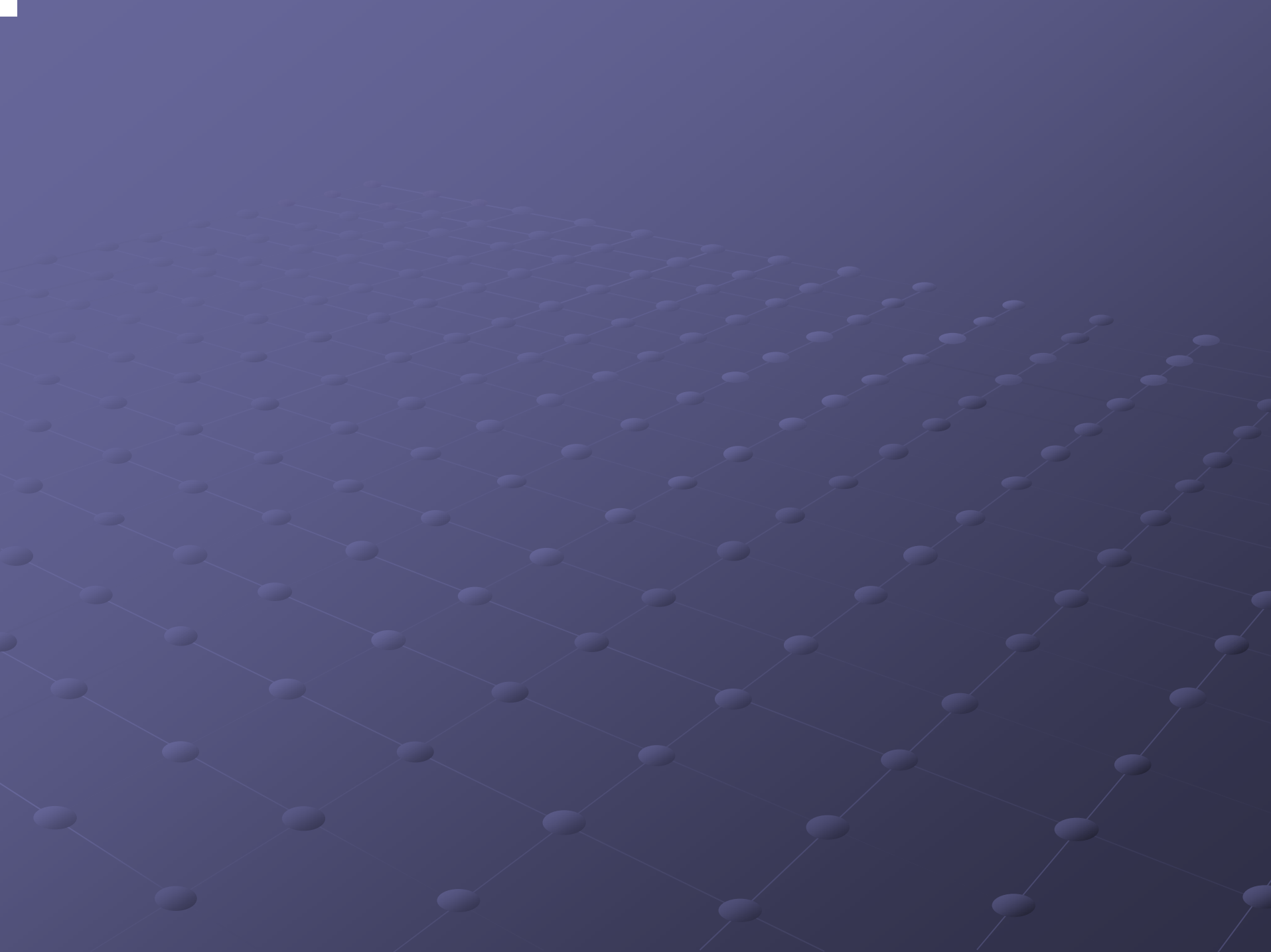
# Issues

- Translating into S-R-O triple
- Translating into FMA terms
- Attributed relationships (e.g. right lateral adjacency)

# Conclusion

- Simple, point-and-click query construction
- Query types
  - Simple
  - Compound
- “Real world” limits
  - Triple formulation
  - Knowledge base content





# Future Work












- Web accessibility
- Improved transitive closure performance
- Attributed relationship handling
- Hierarchical transitive closures
- Relationship synonyms

# Simple Queries

- Subject – Relationship – Object triplets
  - Basic English sentence structure
  - Choose an icon from each field
  - At most 1 may be “Unknown”

# Query chaining

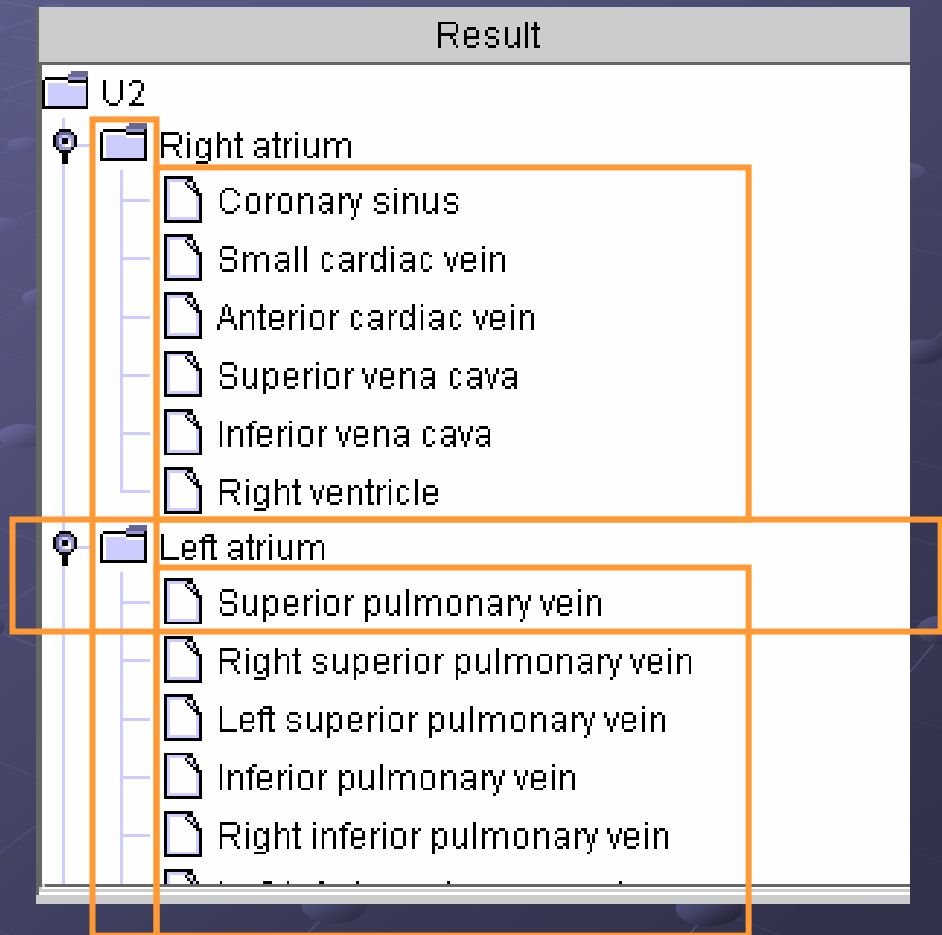
Heart has part Unknown  
(U1)

Result	
	U1
	Wall of heart
	Right atrium
	Left atrium
	Right ventricle
	Left ventricle
	Right side of heart
	Left side of heart
	Fibrous skeleton of heart
	Papillary muscle
	Cardiac valve
	Tricuspid valve
	Mitral valve
	Aortic valve

# Query chaining

U1 is continuous with  
Unknown (U2)

What part of the heart is  
continuous with the superior  
pulmonary vein?



U1

U2

# Which part of the heart is continuous with the superior pulmonary vein?

- Subject: U1
- Relationship: is continuous with
- Object: Unknown