

# MAPPING THE HUMAN BODY

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## The Body Region Connection Calculus *Analyzing anatomical ontologies with the RCC-8 model*



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# Outline

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- ◆ Objectives
- ◆ RCC8
- ◆ Anatomical relations in the FMA
- ◆ Mapping anatomical relations to FMA
- ◆ Results
- ◆ Discussion
- ◆ Conclusions



# Objectives

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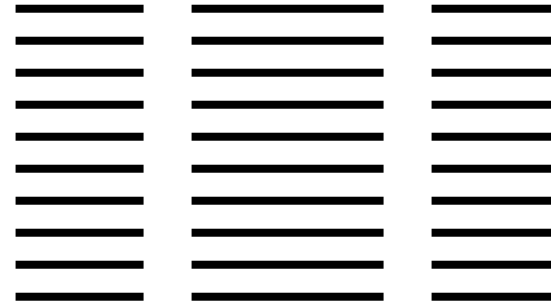
- ◆ To investigate consistency in the FMA
- ◆ Complementary to ontological analyses such as:
  - Zhang S, Bodenreider O.  
*Law and order: Assessing and enforcing compliance with ontological modeling principles.*  
Computers in Biology and Medicine 2005:(in press).
- ◆ Focus on anatomical relations
  - Assigned manually
  - Little enforcement possible in Protégé



# General idea Overview



Anatomical relations

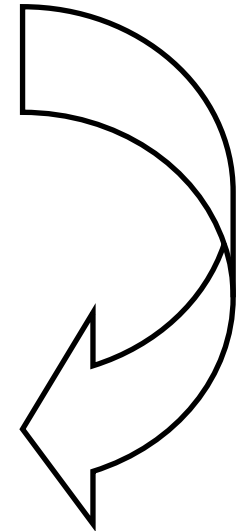


RCC-8 relations

RCC-8  
consistency?

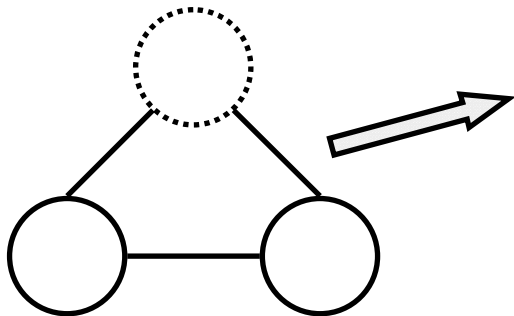
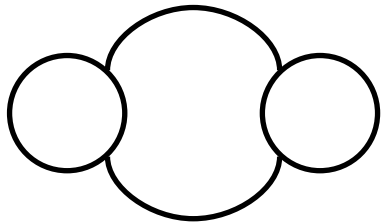
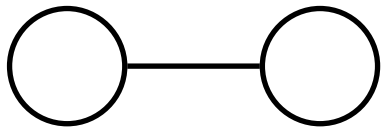


	DC	EC	PO	TPP	NT PP	TP Pi	NT TPi	EQ
DC	*	*	*	*	*	*	*	*
EC	*	*	*	*	*	*	*	*
PO	*	*	*	*	*	*	*	*
TPP	*	*	*	*	*	*	*	*
NTPP	*	*	*	*	*	*	*	*
TPPi	*	*	*	*	*	*	*	*
NTPPi	*	*	*	*	*	*	*	*
EQ	*	*	*	*	*	*	*	*

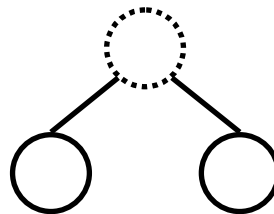


# General idea Details

FMA



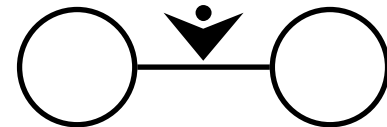
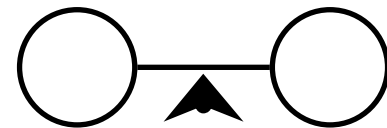
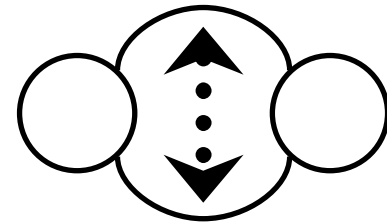
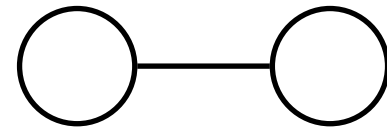
FMA-RCC  
conversion rules



Entity	EC	PC	TOP	RTOP	RTOP	RTOP	RTOP	RTOP
EC	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
PC	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
TOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000
RTOP	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000



RCC



# Foundational Model of Anatomy

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- ◆ Dec. 2, 2004
- ◆ 71,202 classes
- ◆ 220 slots
  - 7 *part\_of* slots
  - 81 slots for associative relations (*branch of, contains*)
- ◆ 101,200 partitive relations
- ◆ 33,685 associative relations



# Region Connection Calculus (RCC)

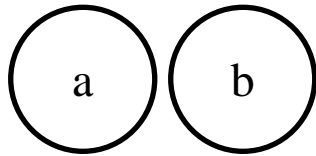
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- ◆ Axiomatic theory of spatial relations
- ◆ Spatial reasoning
- ◆ 8 topological relations (JEPD)
  - DC      Disconnection
  - EC      External Connection
  - PO      Partial Overlap
  - TPP     Tangential Proper Part (+ inverse)
  - NTPP   Non-Tangential Proper Part (+ inverse)
  - EQ      Equality

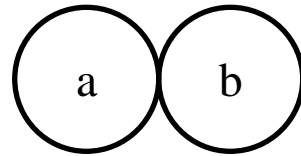


# RCC 8 topological relations

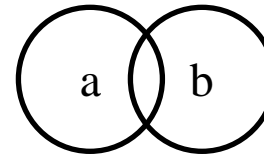
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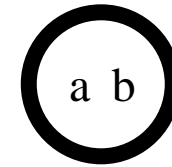
Disconnection



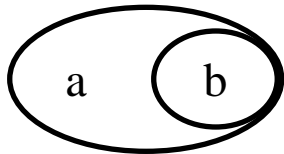
External  
Connection



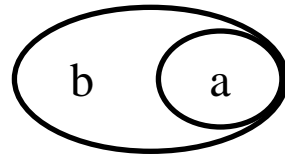
Partial  
Overlap



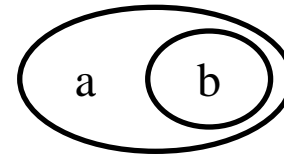
Equality



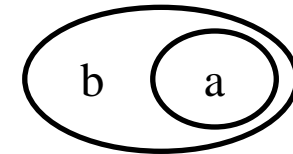
Tangential  
Proper Part



Tangential  
Proper Part (inv)



Non-Tangential  
Proper Part



Non-Tangential  
Proper Part (inv)



# Composition table for the 8 RCC relations

$R1(a,b) \backslash R2(b,c)$	DC	EC	PO	TPP	NTPP	TPPi	NTPPi	EQ
DC	$\top$	DR,PO,PP	DR,PO,PP	DR,PO,PP	DR,PO,PP	DC	DC	DC
EC	DR,PO,PPi	DR,PO TPP,TPi	DR,PO,PP	EC,PO,PP	PO,PP	DR	DC	EC
PO	DR,PO,PPi	DR,PO,PPi	$\top$	PO,PP	PO,PP	DR,PO,PPi	DR,PO PPi	PO
TPP	DC	DR	DR,PO,PP	PP	NTPP	DR,PO TPP,TPi	DR,PO PPi	TPP
NTPP	DC	DC	DR,PO,PP	NTPP	NTPP	DR,PO,PP	$\top$	NTPP
TPPi	DR,PO,PPi	EC,PO,PPi	PO,PPi	PO,TPP,TPi	PO,PP	PPi	NTPPi	TPPi
NTPPi	DR,PO,PPi	PO,PPi	PO,PPi	PO,PPi	O	NTPPi	NTPPi	NTPPi
EQ	DC	EC	PO	TPP	NTPP	TPPi	NTPPi	EQ

[Bennett, 1997]



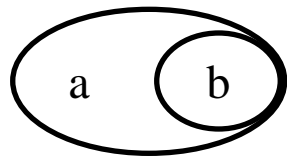
# Mapping FMA relations to RCC (1)

*part of*  
*general part of*  
*constitutional part of*  
*systemic part of*  
*clinical part of*  
*regional part of*  
*2D part of*  
*custom paratomy of*

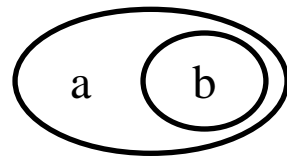
TPP ∨ NTPP

*part*  
*general part*  
*constitutional part*  
*systemic part*  
*clinical part*  
*regional part*  
*2D part*  
*custom paratomy*

TPPi ∨ NTPPi



Tangential  
Proper Part



Non-Tangential  
Proper Part

*attributed part*  
*attributed constitutional part*  
*attributed regional part*

TPPi ∨ NTPPi

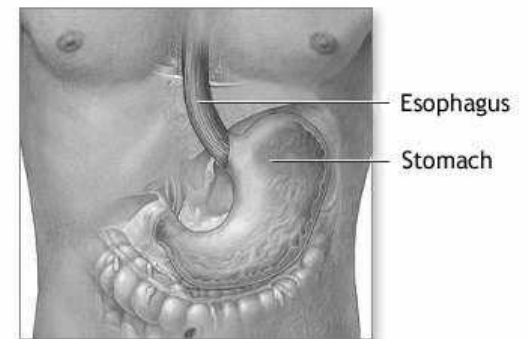
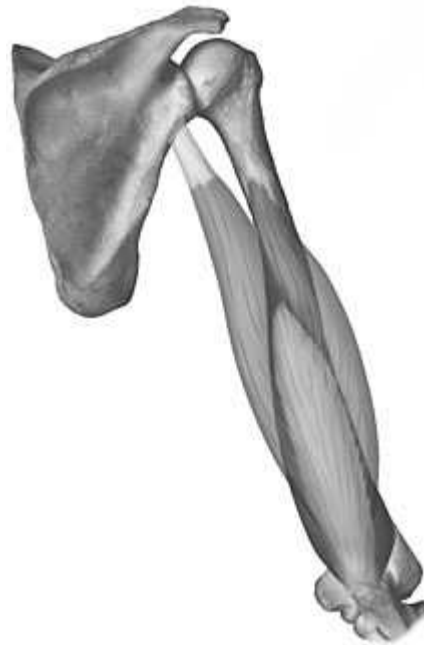
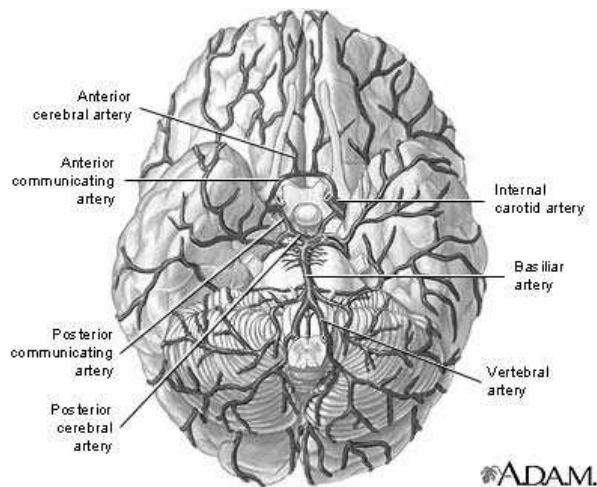


# Mapping FMA relations to RCC (2)

*adjacent to*  
*continuous with*  
*continuous with proximally*  
*continuous with distally*  
*branch of*  
*branch*  
*tributary of*  
*tributary*

*muscle origin*  
*muscle insertion*  
*muscle attachment*  
*location+adjacent(true)*  
*attributed continuous with+adjacent(true)*

EC



ADAM.

# Mapping FMA relations to RCC (3)

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*drains*  
*drains to*  
*venous drainage of*  
*venous drainage*  
*lymphatic drainage of*  
*lymphatic drainage*

DC  $\vee$  EC

EC Lung | venous drainage | Bronchial vein

DC Right paratracheal lymph node | drains to |  
Right bronchomediastinal lymphatic trunk

*bounded by*  
*bounds*

EQ

EQ Surface of thorax | bounds | Thorax

*surrounded by*  
*surrounds*

EC  $\vee$  EQ

EQ Pleural sac | surrounds | Lung

EC Wall of right side of heart | surrounds |  
Cavity of right atrium



# Mapping FMA relations to RCC (4)

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*arterial supply of*  
*venous supply of*  
*nerve supply of* } DC ∨ PO ∨  
TPP ∨ NTPP

*arterial supply*  
*venous supply*  
*nerve supply* } DC ∨ PO ∨  
TPPi ∨ NTPPi

TPP Right coronary artery | arterial supply of | Heart

DC Gastric branch of right vagus nerve | nerve supply of | Stomach

DC Spinal cord | arterial supply | Vertebral artery

DC / PO vs. EC ??
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*contains* PO ∨ TPPi ∨ NTPPi ∨ EQ

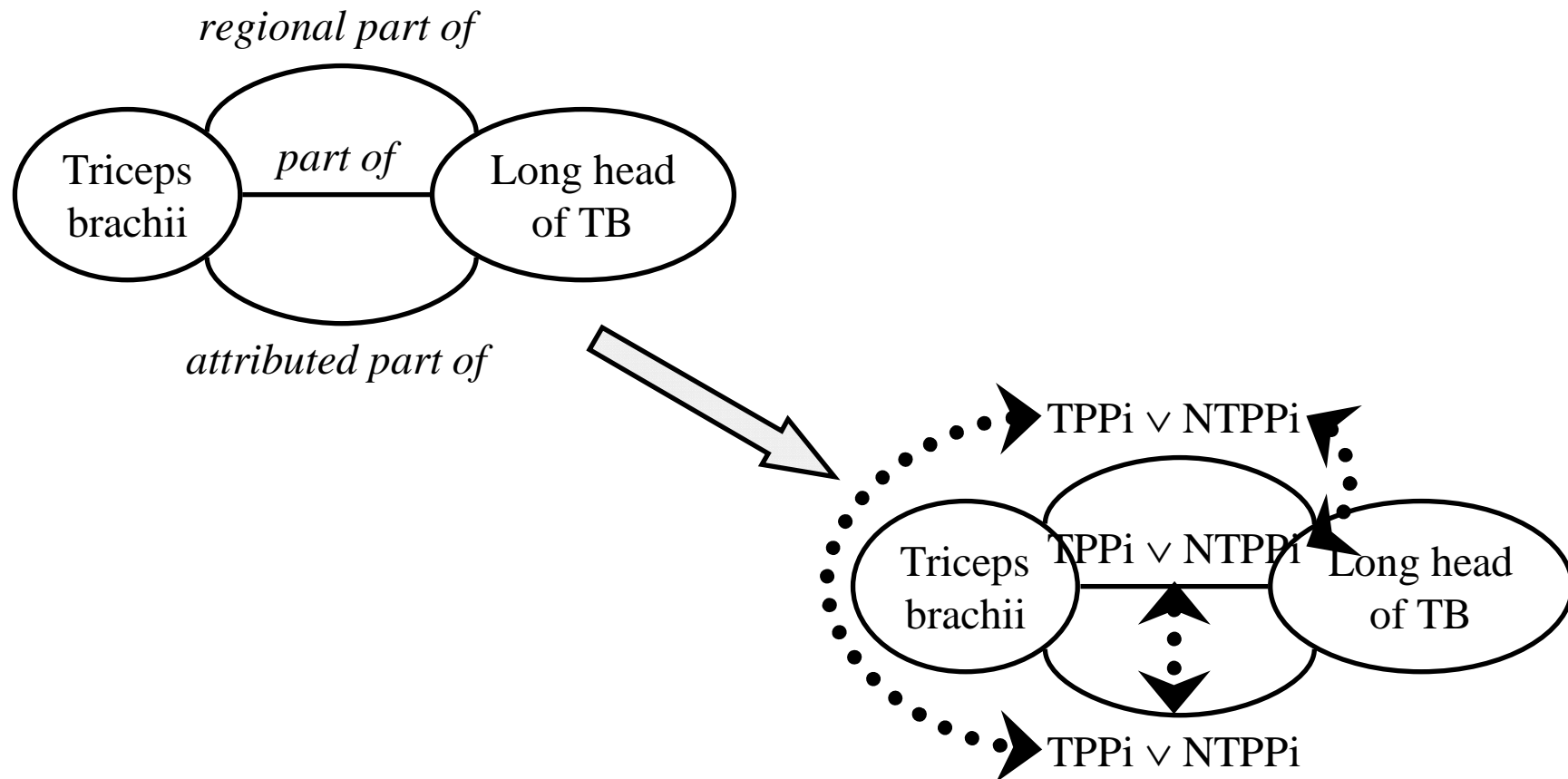
*contained in* PO ∨ TPP ∨ NTPP ∨ EQ

TPP Posterior compartment of arm|contains|Triceps brachii

*location+adjacent(false)*  
*attributed continuous with+adjacent(false)* } DC

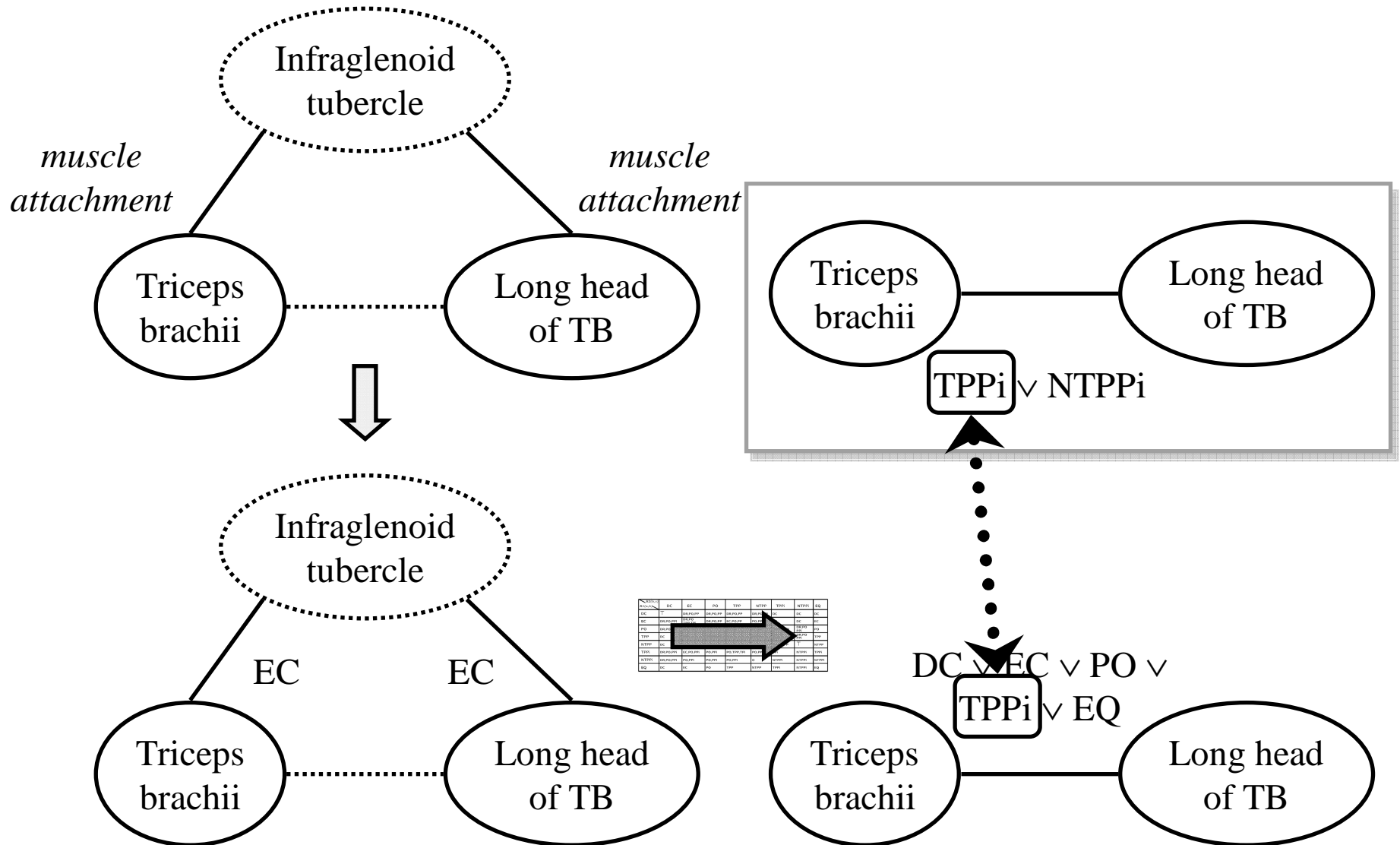


# Example (direct)



# Example (indirect)

$R2(b,c)$		
$R1(a,b)$	DC	EC
DC	$\top$	DR,PO,PP
EC	DR,PO,PPi	DR,PO TPP,TPI



# Quantitative results

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## ◆ Conversion

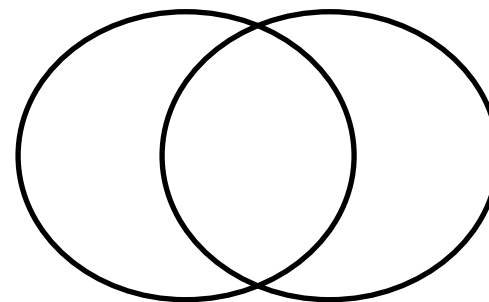
- 84,284 pairs with RCC relations
  - 18,112 with only one relation
  - 66,172 with multiple relations
    - 64,354 consistent
    - 1,818 inconsistent

## ◆ Composition

- 707,284 pairs

composition

698,588



conversion

75,588

8,696





# Quantitative results

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## ◆ Composition

- 698,588 pairs specific to composition
  - 28,042 with only one relation
  - 670,546 with multiple relations
    - 669,026 consistent
    - 1,520 inconsistent

## ◆ Inconsistent

- Conflicting relations
- Inaccurate conversion rules



# Example of inconsistency

Surface of brain   bounds   Brain
Surface of brain   bounds   Forebrain
Forebrain   regional part of   Brain

EQ  
EQ  
TPP  $\vee$  NTPP

EQ  
TPP  $\vee$  NTPP

EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ
EQ	EC	ED	EE	EF	EG	EH	EQ

TPP  $\vee$  NTPP

$$(TPP \vee NTPP) \wedge EQ = \perp$$

*bounded by  
bounds*

} EQ ?



# Advantages

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- ◆ Supports consistency analysis of spatial relations
- ◆ Almost fully automatic
  - Except for establishing the mapping between FMA and RCC relations
  - Analysis requires domain knowledge



# Limitations

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- ◆ Loss in expressiveness
  - Different FMA relations are converted into the same RCC relation  
(e.g., *continuous with* and *adjacent to* into EC)
- ◆ Interpretation
  - Inconsistent is not necessarily wrong
  - Consistent is not necessarily valid
- ◆ Granularity issues
- ◆ Issue with shared parts





# Conclusions

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- ◆ RCC relations
  - Less expressive than FMA relations
  - Enable reasoning
  - Useful for detecting inconsistency
- ◆ Disjunctions can be reduced by comparing direct relations to composed relations
- ◆ Usage in FMA
  - Detect potentially inconsistent representation
  - Focus the effort of experts
- ◆ Refine conversion rules



# References

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- ◆ D A Randell, Z Cui, and A G Cohn. *A spatial logic based on regions and connection*. In Proc. 3rd Int. Conf. on Knowledge Representation and Reasoning, pages 165--176, San Mateo, 1992. Morgan Kaufmann
- ◆ B. Bennett. *Spatial reasoning with propositional logics*. In J Doyle, E Sandewall, and P Torasso, editors, *Principles of Knowledge Representation and Reasoning: Proceedings of the 4th International Conference (KR94)*, San Francisco, CA., 1994. Morgan Kaufmann



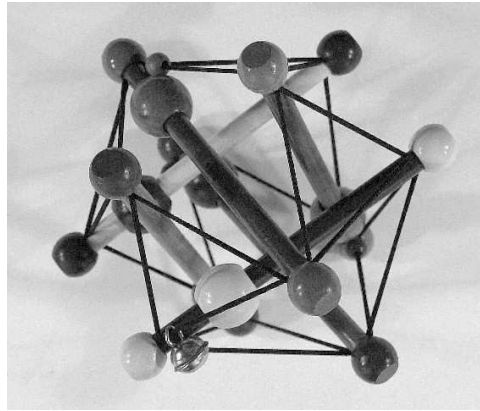
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- ◆ Bennett, B. (1998). *Determining consistency of topological relations*. *Constraints*, 3, 213--225.
- ◆ Schulz S, Hahn U, Romacker M. *Modeling anatomical spatial relations with description logics*. *Proc AMIA Symp.* 2000;:779-83.







# Medical Ontology Research

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