CC7220-1
La Web de Datos
Primavera 2021

Lecture 4: Web Ontology Language (OWL) [I]

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Last time …

* More or less

Semantic Web: Logic

Data:

Logic: "(b,capital,a) $\rightarrow$ (a,partOf,b)"
"(a,partOf,b), (b,partOf,c) $\rightarrow$ (a,partOf,c)"

Query: "(x,partOf,y)?"

Output: {($x \mapsto$ Ireland, $y \mapsto$ Europe),
($x \mapsto$ Dublin, $y \mapsto$ Ireland),
($x \mapsto$ Dublin, $y \mapsto$ Europe)}

RDF Schema: RDFS

Class c is a **sub-class** of Class d

If `(x,rdf:type,c)` then `(x,rdf:type,d)`

Property p is a **sub-property** of q

If `(x,p,y)` then `(x,q,y)`

Property p has **domain** class c

If `(x,p,y)` then `(x,rdf:type,c)`

Property p has **range** class c

If `(x,p,y)` then `(y,rdf:type,c)`

TODAY'S TOPIC ...

* More or less

Semantic Web: Logic

Data:

Ireland

(Ireland,partOf,Europe)
(Ireland,isA,Country)
(Ireland,capital,Dublin)

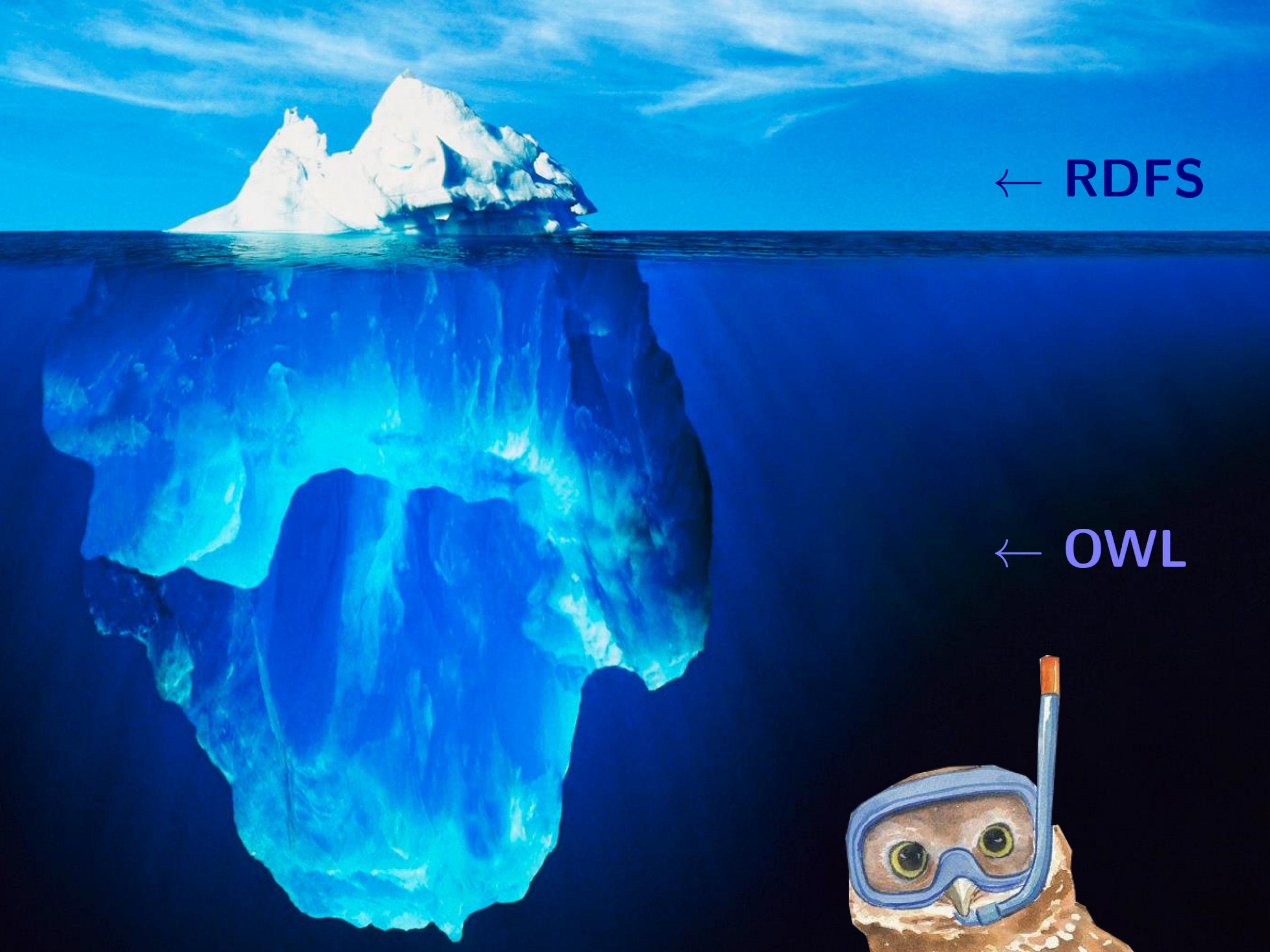
Dublin

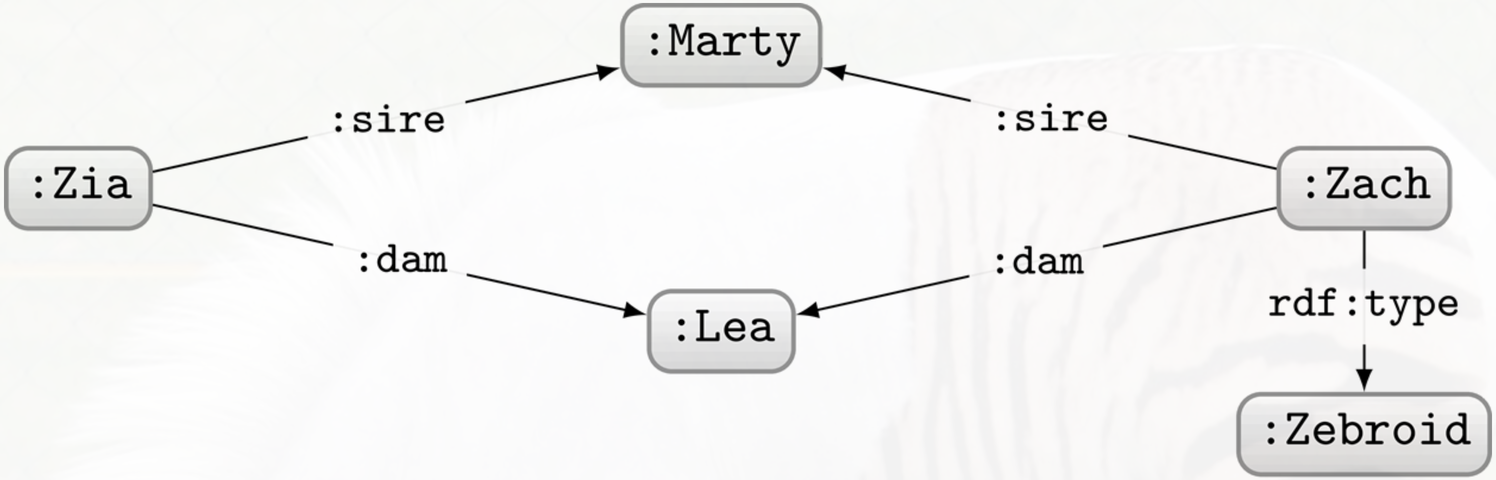
(Ireland,capital,Dublin)
(Dublin,population,1000000)

Logic: "(b,capital,a) $\rightarrow$ (a,partOf,b)"
"(a,partOf,b), (b,partOf,c) $\rightarrow$ (a,partOf,c)"

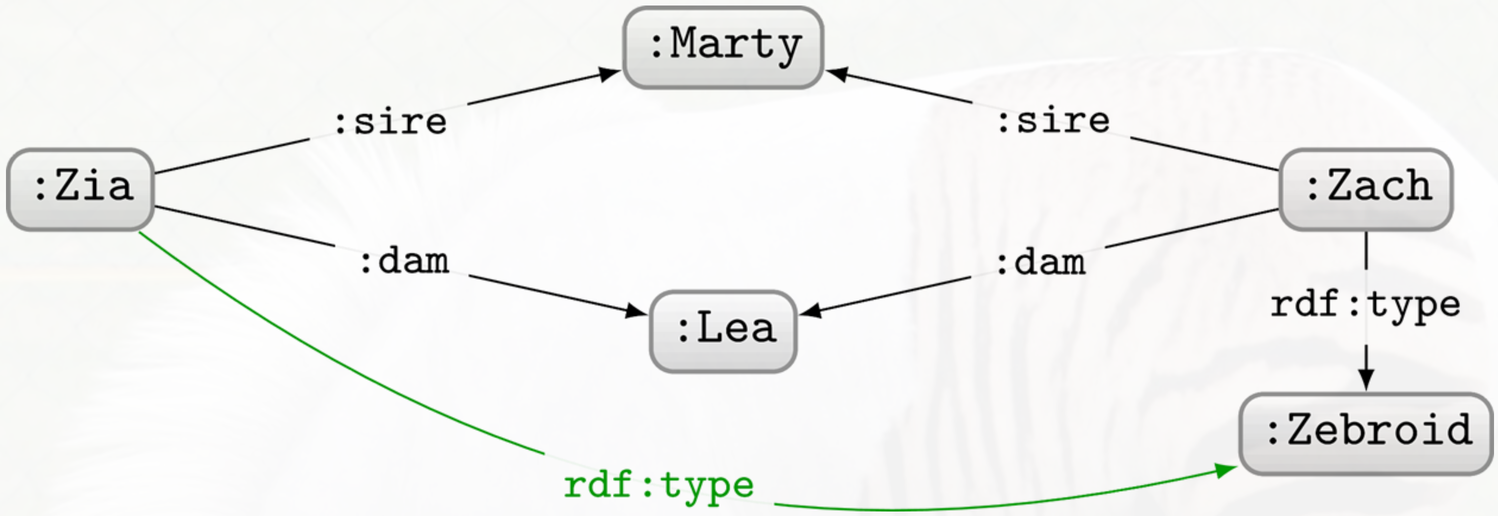
Query: "(x,partOf,y)?"

Output: $\{(x \mapsto$ Ireland, $y \mapsto$ Europe$)$,
$(x \mapsto$ Dublin, $y \mapsto$ Ireland$)$,
$(x \mapsto$ Dublin, $y \mapsto$ Europe$)\}$


← RDFS
← OWL



What can we intuitively conclude about Zia?

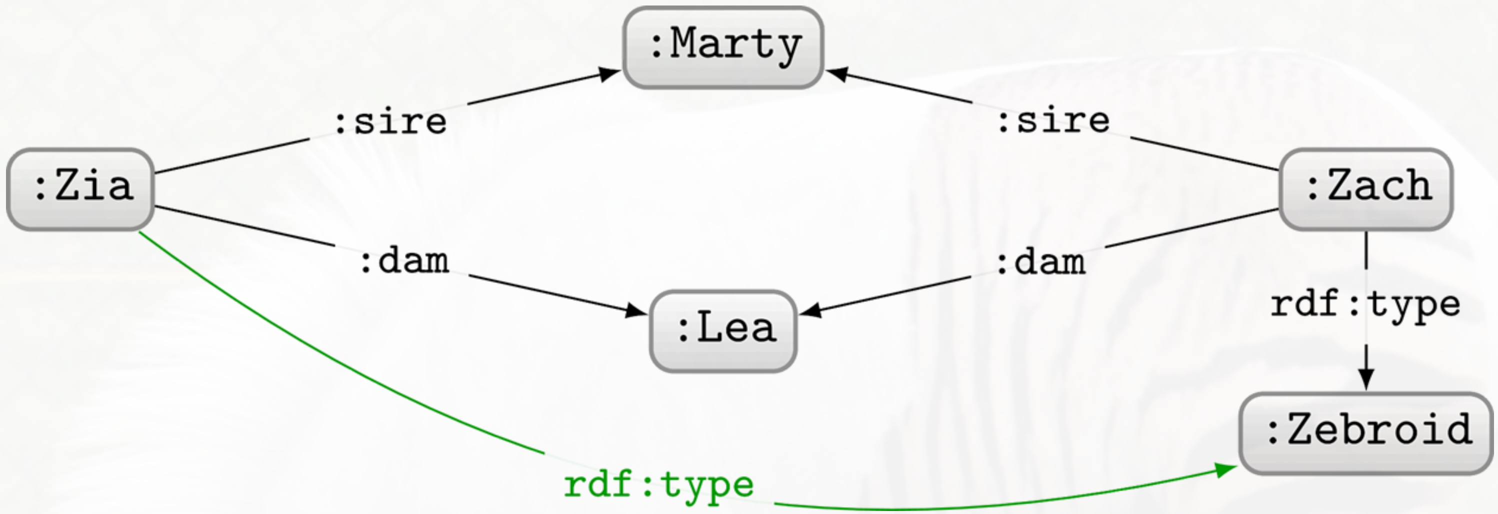


What can we intuitively conclude about `Zia`?

`Zia` is also a `Zebroid`!

What kind of reasoning are we using here?

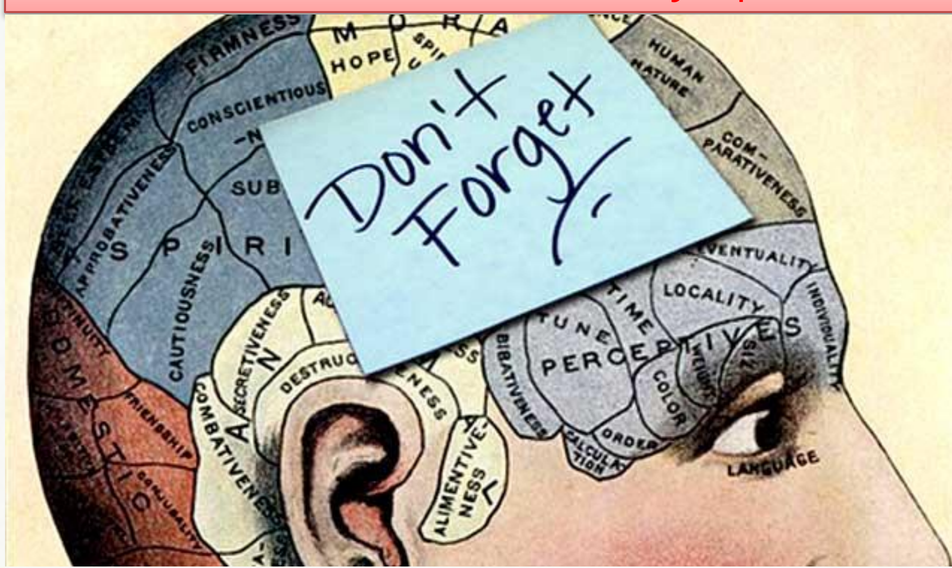
Deductive (mostly)



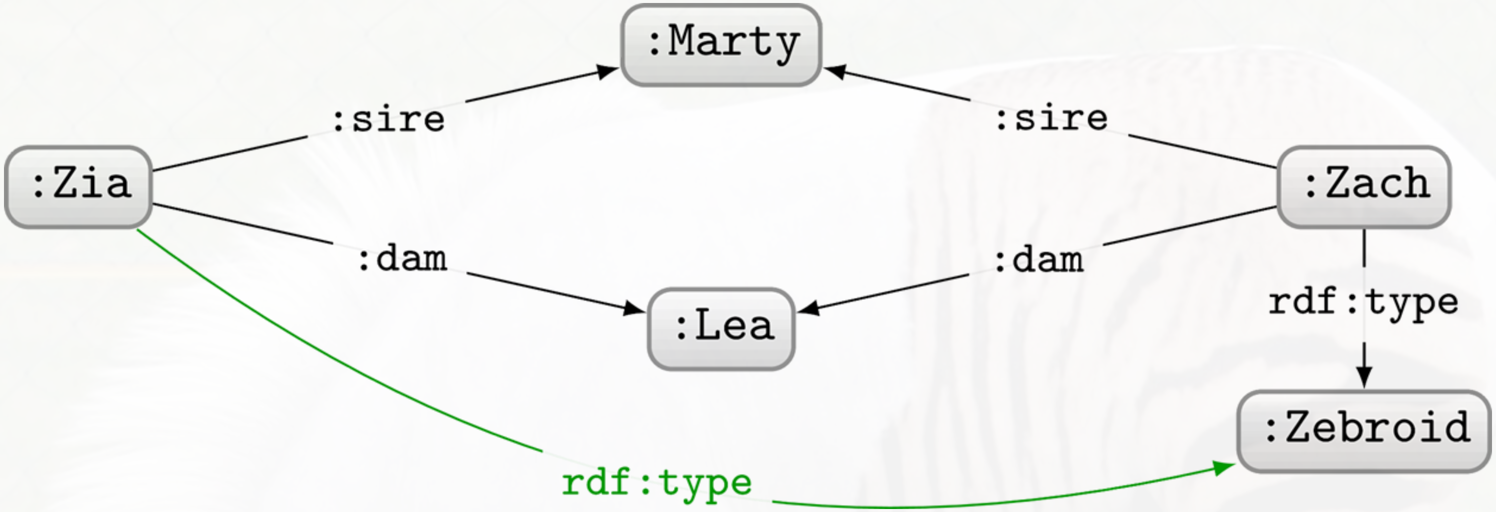
What assumptions do we make to conclude that `Zia` is a `Zebroid`?

If x has same `sire` and `dam` as y and y is a `Zebroid` then x is a `Zebroid`!

Very specific to this example

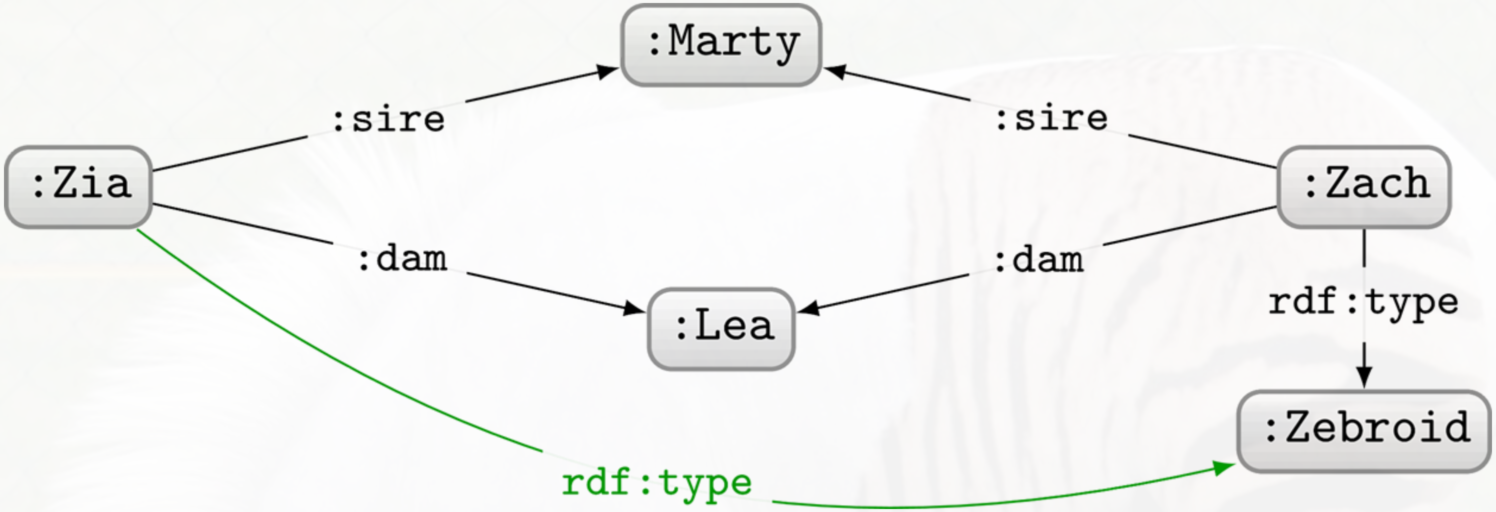


$$(x,\texttt{:dam},z_1),\ (x,\texttt{:sire},z_2),$$
$$(y,\texttt{:dam},z_1),\ (y,\texttt{:sire},z_2),$$
$$(y,\texttt{rdf:type},\texttt{:Zebroid})$$
$$\rightarrow\ (x,\texttt{rdf:type},\texttt{:Zebroid})$$



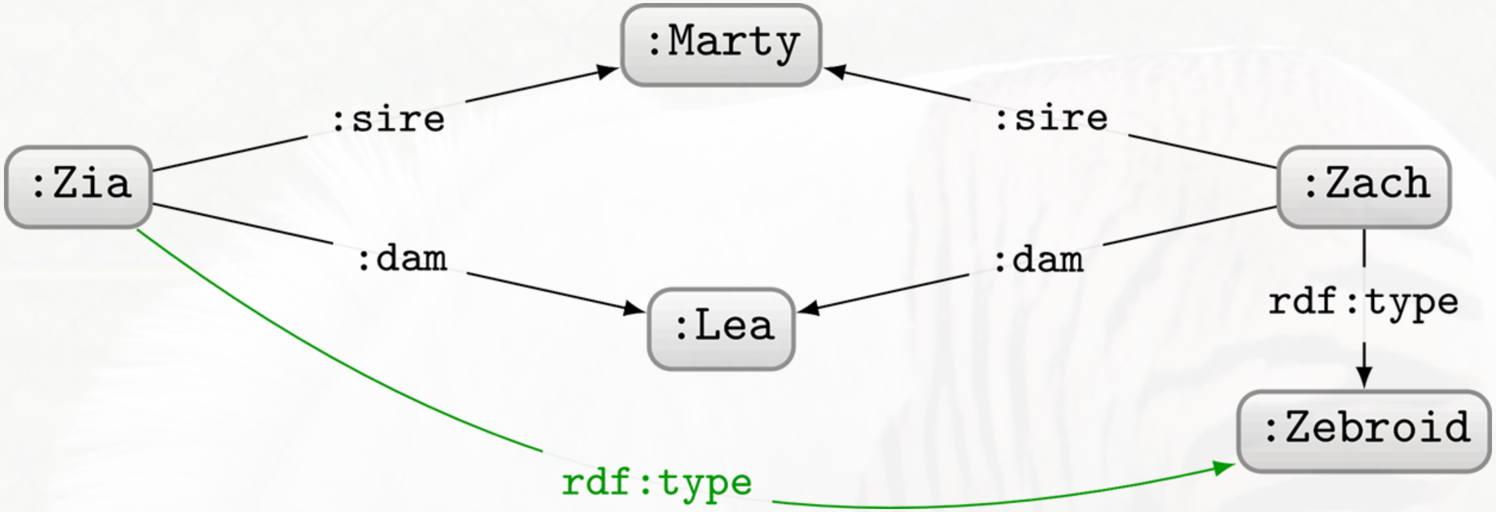
What assumptions do we make to conclude that `Zia` is a `Zebroid`?

- `sire` is a sub-property of `parent`
- `dam` is a sub-property of `parent`



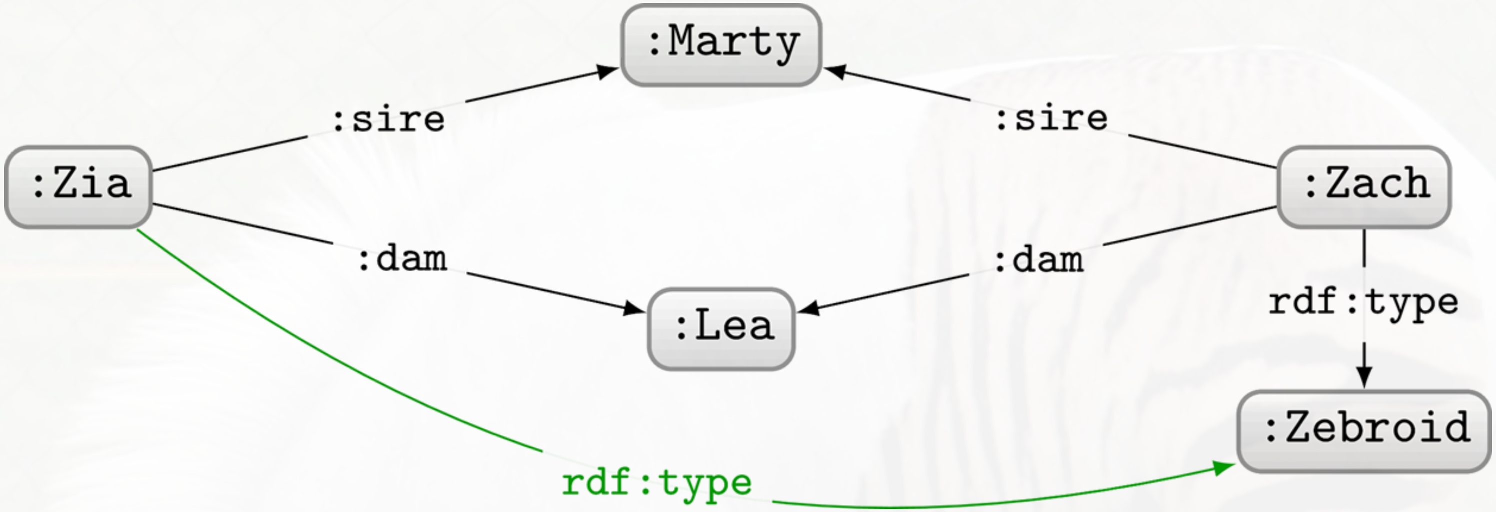
What assumptions do we make to conclude that `Zia` is a `Zebroid`?

- `sire` is a sub-property of `parent`
- `dam` is a sub-property of `parent`
- A `Zebroid` has exactly one `parent` a `Zebra`
- A `Zebroid` has exactly one `parent` a (¬`Zebra` and a `Equine`)



What assumptions do we make to conclude that Zia is a Zebroid?

- sire is a sub-property of parent
- dam is a sub-property of parent
- A Zebroid has exactly one parent a Zebra
- A Zebroid has exactly one parent a (¬Zebra and a Equine)
- A Zebroid is a sub-class of Equine
- An Equine has exactly two parents



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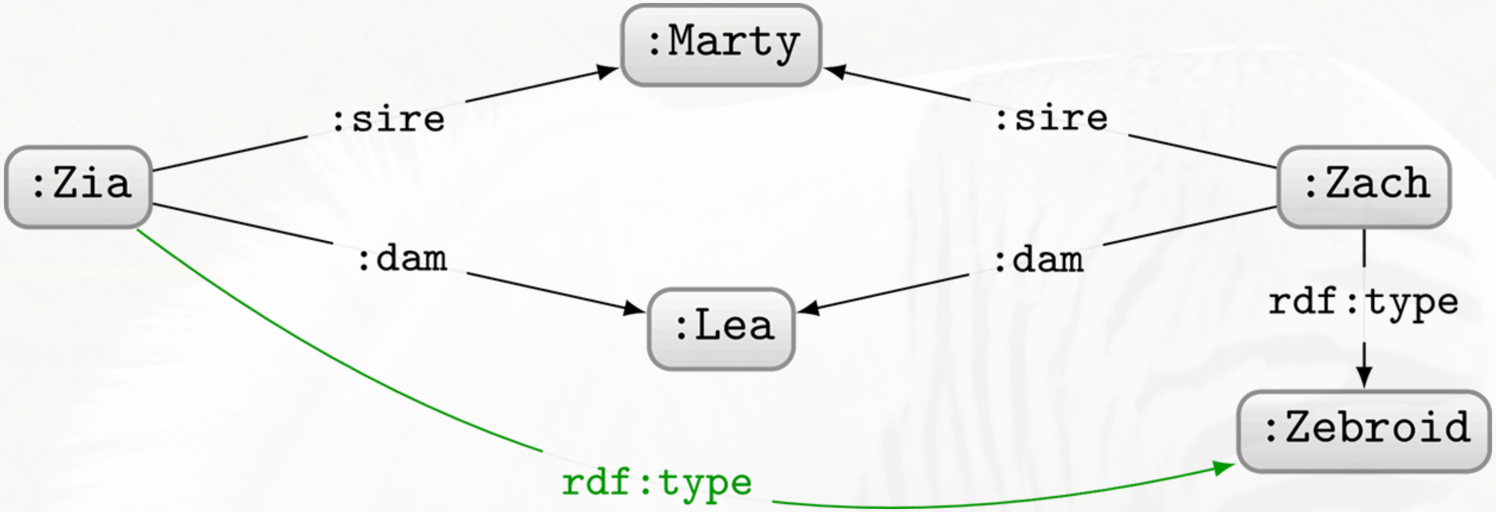
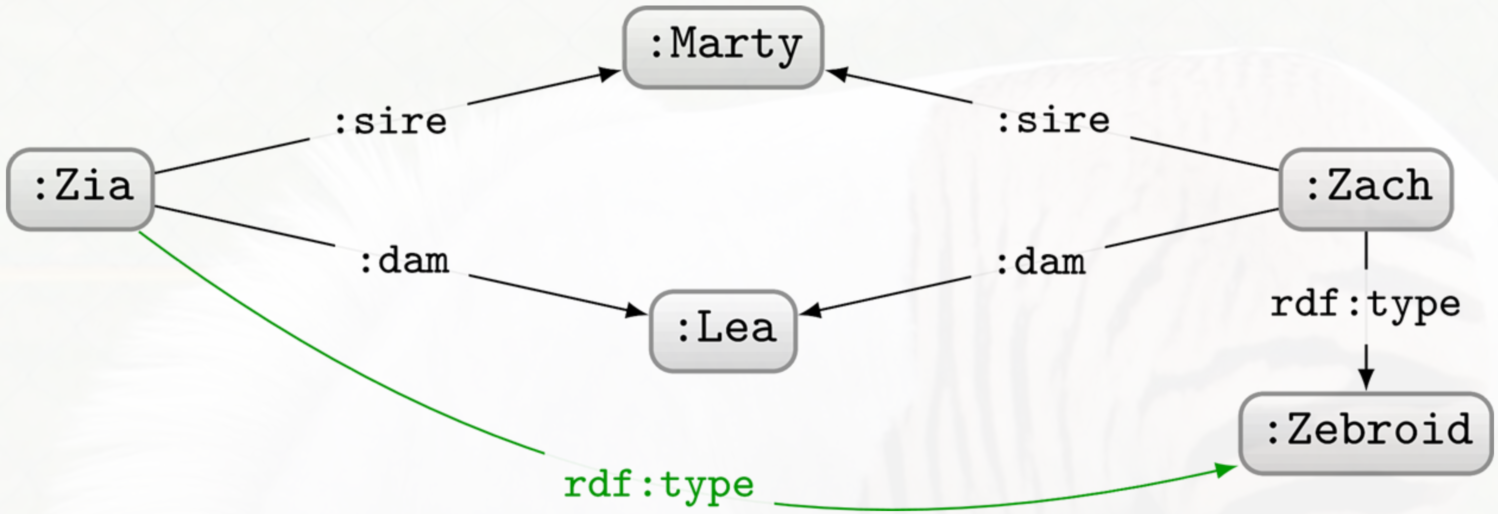
- A `Zebroid` has exactly one `parent` a (¬`Zebra` and a `Equine`)
- A `Zebroid` is a sub-class of `Equine`
- An `Equine` has exactly two `parents`
- Two things cannot be related by `sire` and `dam` at the same time



What assumptions do we make to conclude that Zia is a Zebroid?

Which are expressible in RDFS?

- sire is a sub-property of parent
- dam is a sub-property of parent
- A Zebroid has exactly one parent a Zebra
- A Zebroid has exactly one parent a (¬Zebra and a Equine)
- A Zebroid is a sub-class of Equine
- An Equine has exactly two parents
- Two things cannot be related by sire and dam at the same time



What assumptions do we make to conclude that `Zia` is a `Zebroid`?

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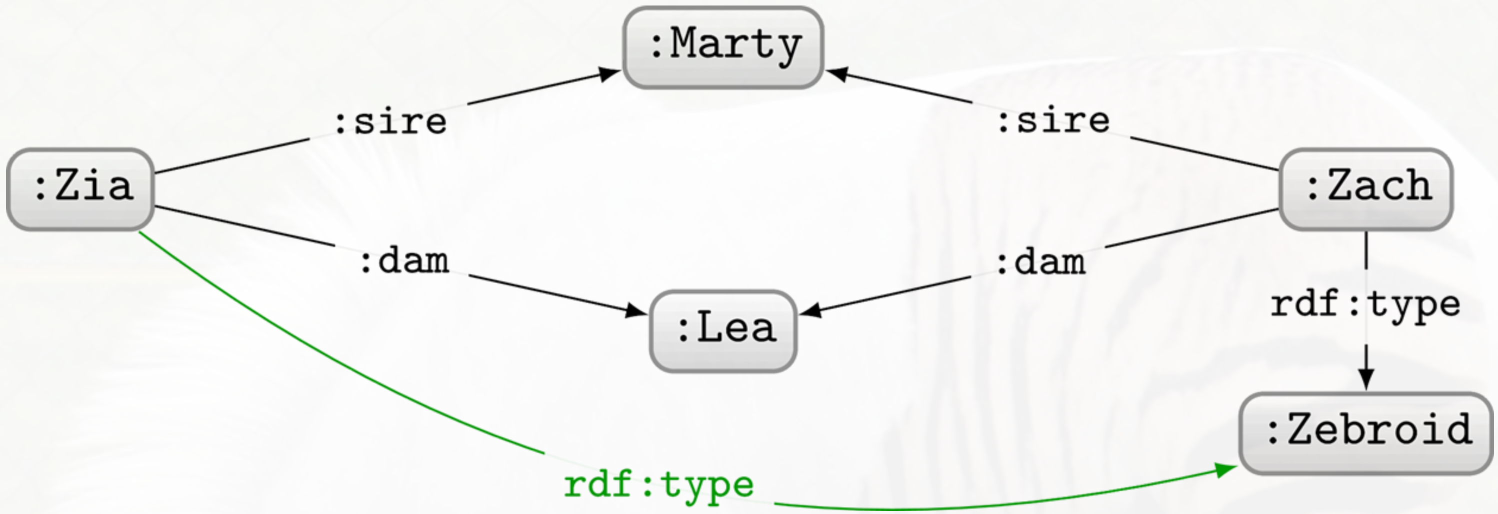


What assumptions do we make to conclude that `Zia` is a `Zebroid`?

Which are expressible in RDFS?

The rest we can express in OWL

- `sire` is a sub-property of `parent`
- `dam` is a sub-property of `parent`
- A `Zebroid` has exactly one `parent` a `Zebra`
- A `Zebroid` has exactly one `parent` a (¬`Zebra` and a `Equine`)
- A `Zebroid` is a sub-class of `Equine`
- An `Equine` has exactly two `parents`
- Two things cannot be related by `sire` and `dam` at the same time

Web Ontology Language: OWL

OWL (2): A Web Standard

https://www.w3.org/TR/owl2-overview/

W3C Recommendation

W3C®

OWL 2 Web Ontology Language Document Overview (Second Edition)

W3C Recommendation 11 December 2012

This version:
  http://www.w3.org/TR/2012/REC-owl2-overview-20121211/
Latest version (series 2):
  http://www.w3.org/TR/owl2-overview/
Latest Recommendation:
  http://www.w3.org/TR/owl-overview
Previous version:
  http://www.w3.org/TR/2012/PER-owl2-overview-20121018/
Editors:
  W3C OWL Working Group (see Acknowledgements)

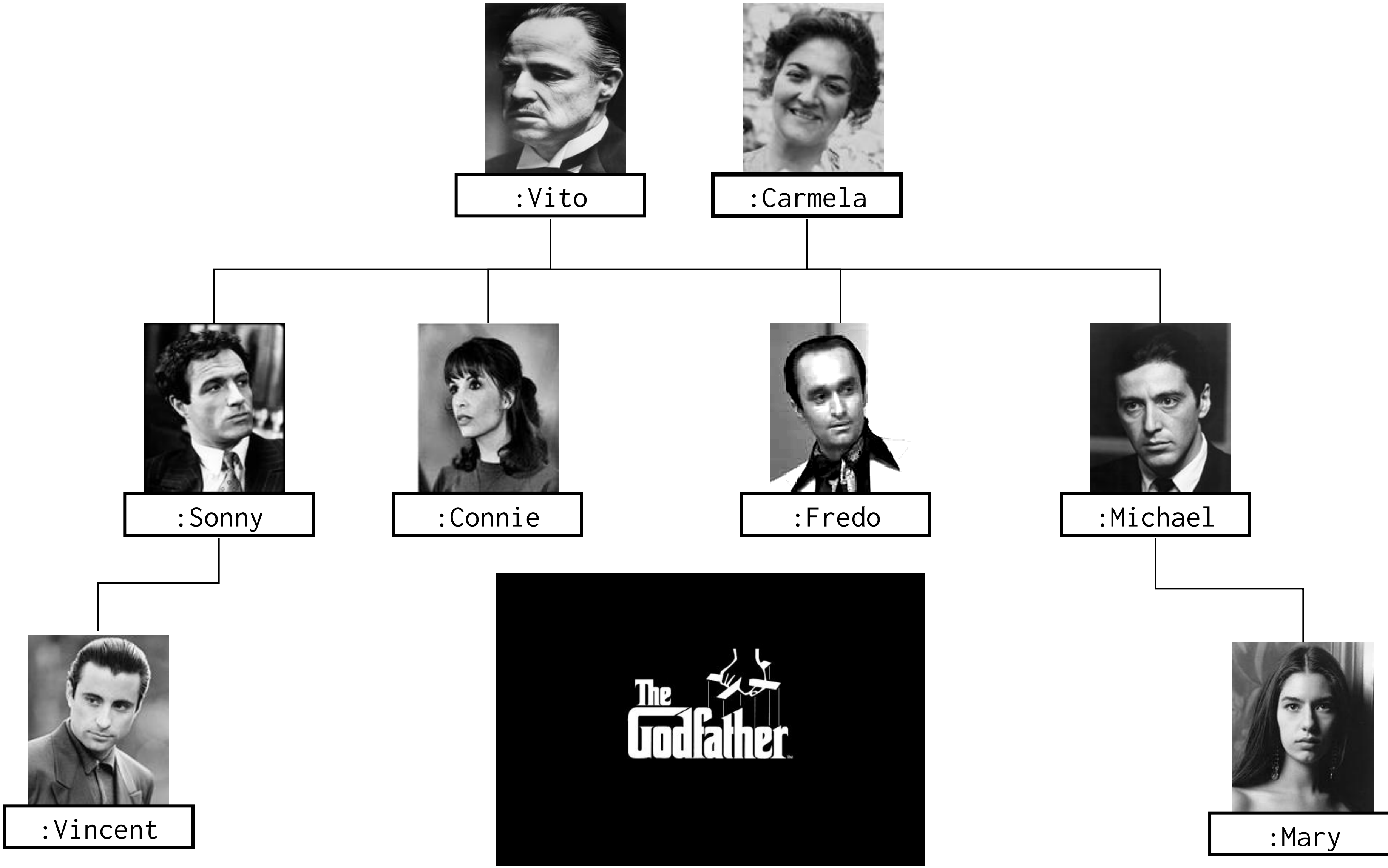
Please refer to the **errata** for this document, which may include some normative corrections.

A color-coded version of this document showing changes made since the previous version is also available.

Formal Underpinnings: Description Logics

Name	Syntax	OWL key-term	DL
		CONCEPT DEFINITIONS	
Atomic Concept	A	owl:Class	$\mathcal{ALC}$
Top Concept	$\top$	owl:Thing	$\mathcal{ALC}$
Bottom Concept	$\bot$	owl:Nothing	$\mathcal{ALC}$
Concept Negation	$\neg C$	owl:complementOf	$\mathcal{ALC}$
Concept Intersection	$C \sqcap D$	owl:intersectionOf	$\mathcal{ALC}$
Concept Union	$C \sqcup D$	owl:unionOf	$\mathcal{ALC}$
Nominal	$\{a_1, ..., a_n\}$	owl:oneOf	$\mathcal{O}$
Existential Restriction	$\exists R.C$	owl:someValuesFrom	$\mathcal{ALC}$
Universal Restriction	$\forall R.C$	owl:allValuesFrom	$\mathcal{ALC}$
Self Restriction	$\exists R.\mathsf{Self}$	owl:hasSelf	$\mathcal{R}$
Number Restriction	$\leq n\, R, \geq n\, R, = n\, R$	owl:*cardinality	$\mathcal{N}$
Qualified Number Restriction	$\leq n\, R.C, \geq n\, R.C, = n\, R.C$	owl:*qualifiedCardinality	$\mathcal{Q}$
		CONCEPT AXIOMS (T-BOX)	
Concept Inclusion	$C \sqsubseteq D$	rdfs:subClassOf	$\mathcal{ALC}$
		ROLE DEFINITIONS	
Role	R	owl:*Property	$\mathcal{ALC}$
Inverse Role	R^-	owl:inverseOf	$\mathcal{I}$
Universal Role	U	owl:top*Property	$\mathcal{R}$
		ROLE AXIOMS (R-BOX)	
Role Inclusion	$R \sqsubseteq S$	rdfs:subPropertyOf	$\mathcal{H}$
Complex Role Inclusion	$R_1 \circ ... \circ R_n \sqsubseteq S$	owl:propertyChainAxiom	$\mathcal{R}$
Transitive Roles	$\mathsf{Trans}(R)$	owl:TransitiveProperty	$\mathcal{S}$
Functional Roles	$\mathsf{Func}(R)$	owl:FunctionalProperty	$\mathcal{F}$
Reflexive Roles	$\mathsf{Ref}(R)$	owl:ReflexiveProperty	$\mathcal{R}$
Irreflexive Roles	$\mathsf{Irref}(R)$	owl:IrreflexiveProperty	$\mathcal{R}$
Symmetric Roles	$\mathsf{Sym}(R)$	owl:SymmetricProperty	$\mathcal{I}$
Asymmetric Roles	$\mathsf{Asym}(R)$	owl:AsymmetricProperty	$\mathcal{R}$
Disjoint Roles	$\mathsf{Disj}(R, S)$	owl:disjointPropertyWith	$\mathcal{R}$
		ASSERTIONAL DEFINITIONS	
(Named) Individual	a	*(RDF IRI or Literal)*	$\mathcal{ALC}$
		ASSERTIONAL AXIOMS (A-BOX)	
Role Assertion	$R(a, b)$	*(RDF triple)*	$\mathcal{ALC}$
Negative Role Assertion	$\neg R(a, b)$	owl:NegativePropertyAssertion	$\mathcal{ALC}$
Concept Assertion	$C(a)$	rdf:type	$\mathcal{ALC}$
Equality	$a = b$	owl:sameAs	$\mathcal{ALC}$
Inequality	$a \neq b$	owl:differentFrom	$\mathcal{ALC}$

For today: A running example

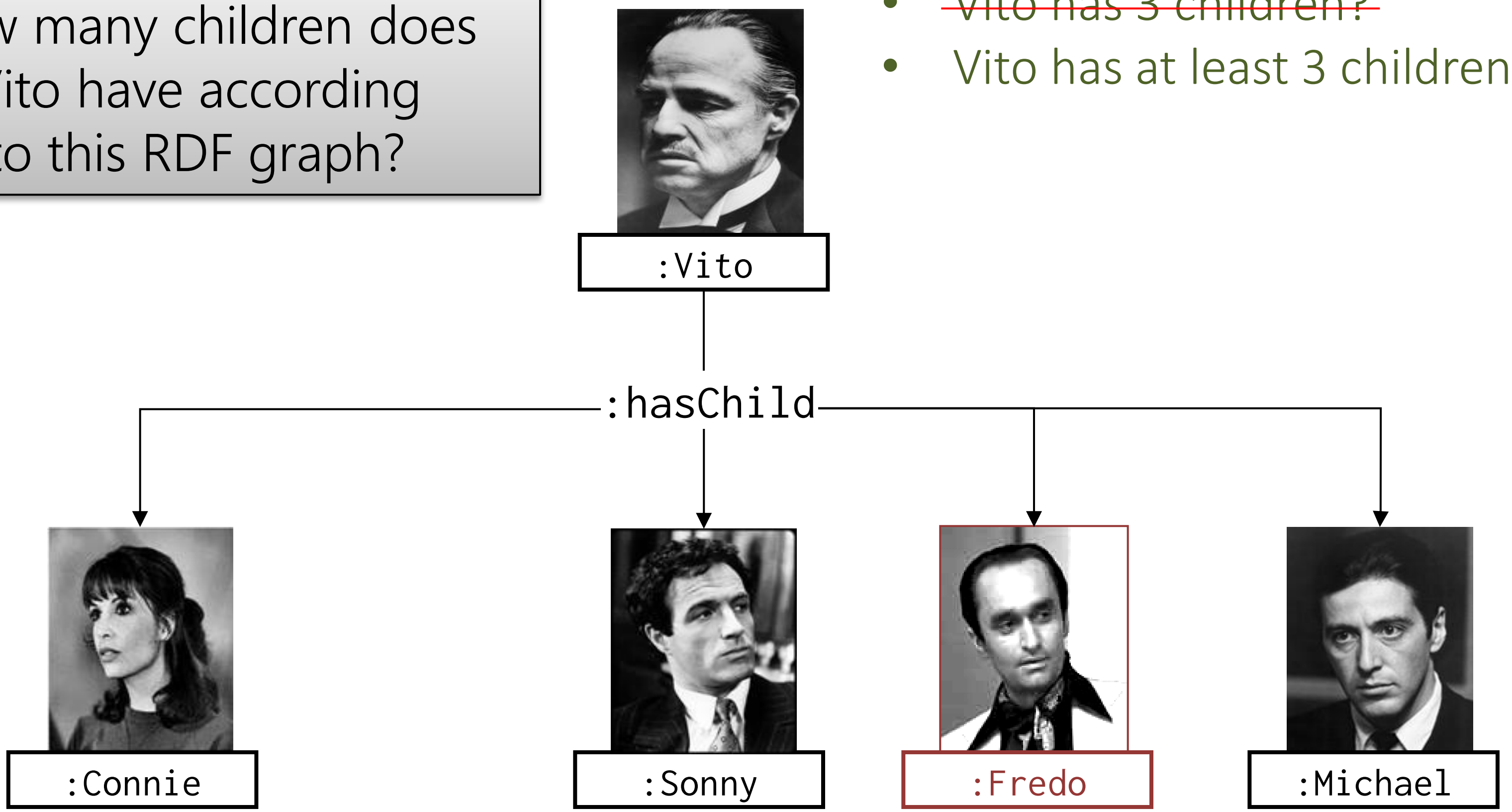


Logical Assumptions

Open World Assumption (OWA)

How many children does Vito have according to this RDF graph?

- ~~Vito has 3 children?~~
- Vito has at least 3 children?




```
:Vito :hasChild :Connie , :Sonny , :Michael .
:Vito :hasChild :Fredo .
... ?
```

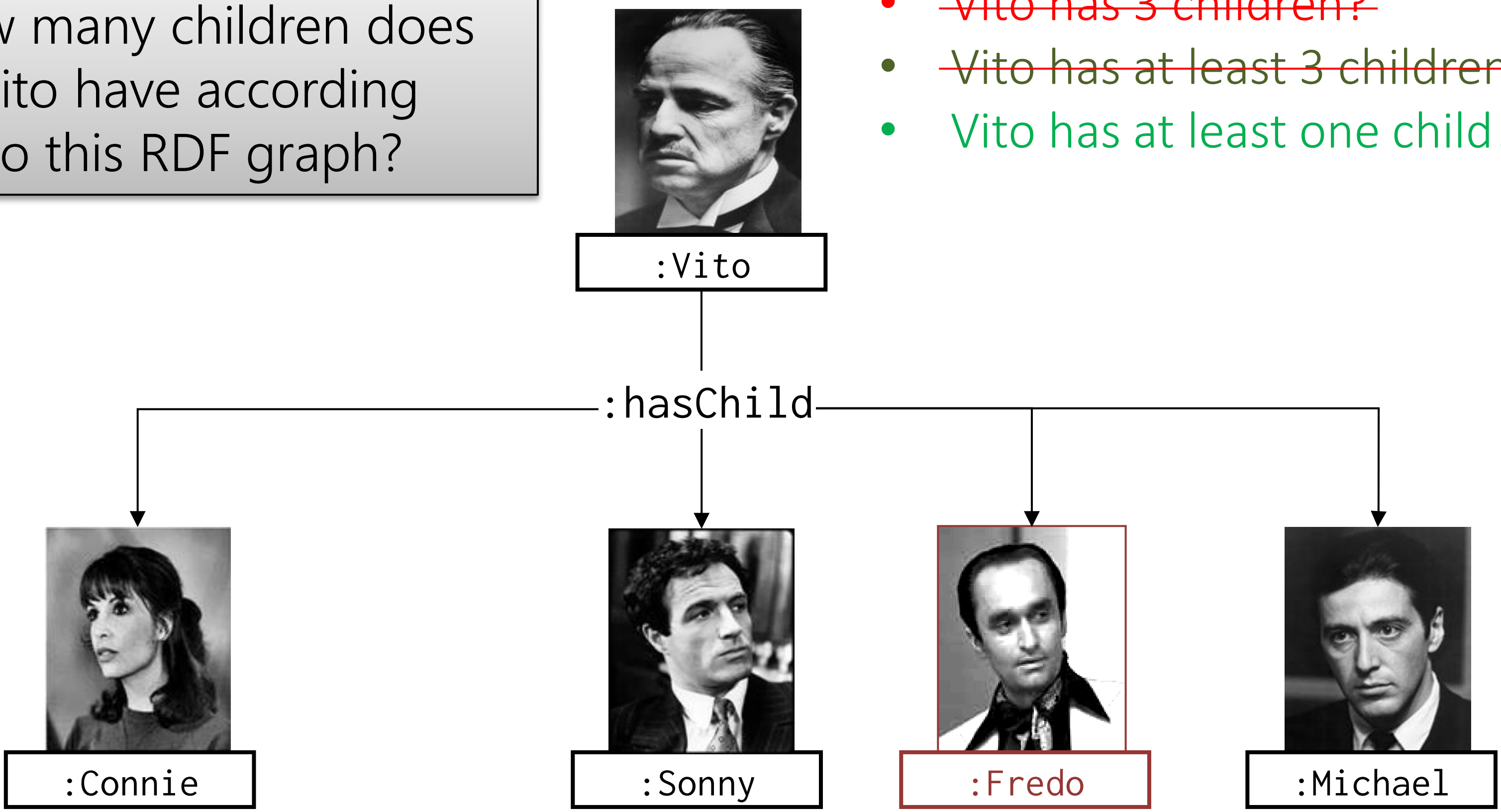
Open World Assumption

- RDF(S) and OWL:
  - Take an Open World Assumption (OWA):
    - Anything not known is <u>not</u> assumed to be false, simply unknown
    - Without further information, Vito may have children that we don't know about!

Why might this assumption be important for the Web?
OWA: Assuming Web data to be complete a Bad Idea®.

No Unique Name Assumption (No UNA)

How many children does Vito have according to this RDF graph?



- ~~Vito has 3 children?~~
- ~~Vito has at least 3 children?~~
- Vito has at least one child!

```
:Vito :hasChild :Connie , :Sonny , :Michael .
:Vito :hasChild :Fredo .
... ?
```

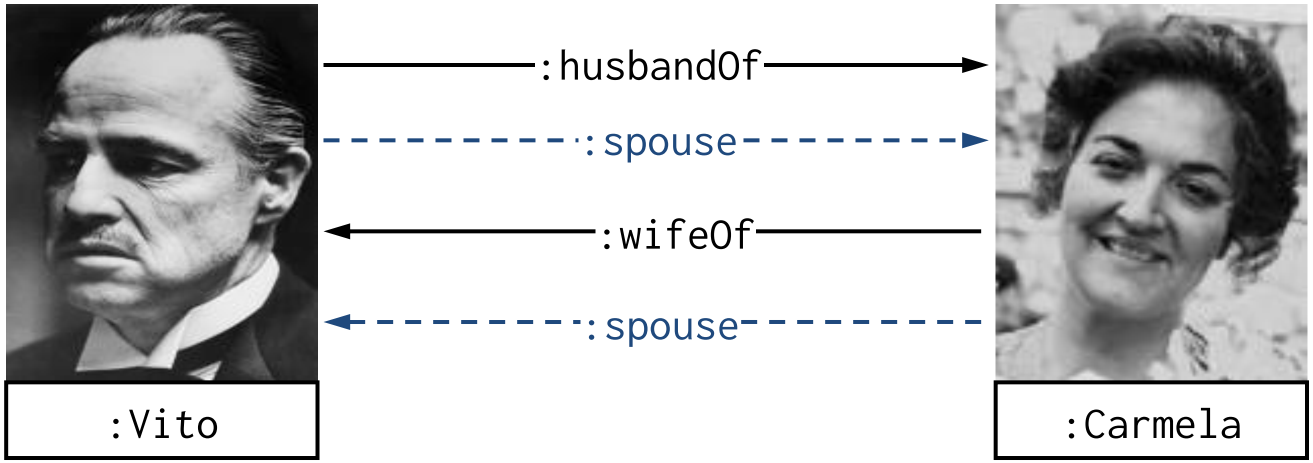
No Unique Name Assumption (No UNA)

- RDF(S) and OWL:
  - Do not take a Unique Name Assumption:
    - Two or more IRIs may refer to the same thing!
    - Without further information, the IRIs we know to be Vito's children may refer to one real-world thing!

Why might this assumption be important for the Web?
No UNA: Assuming strict naming agreement on the Web a Bad Idea®.

Let's start with some RDFS …

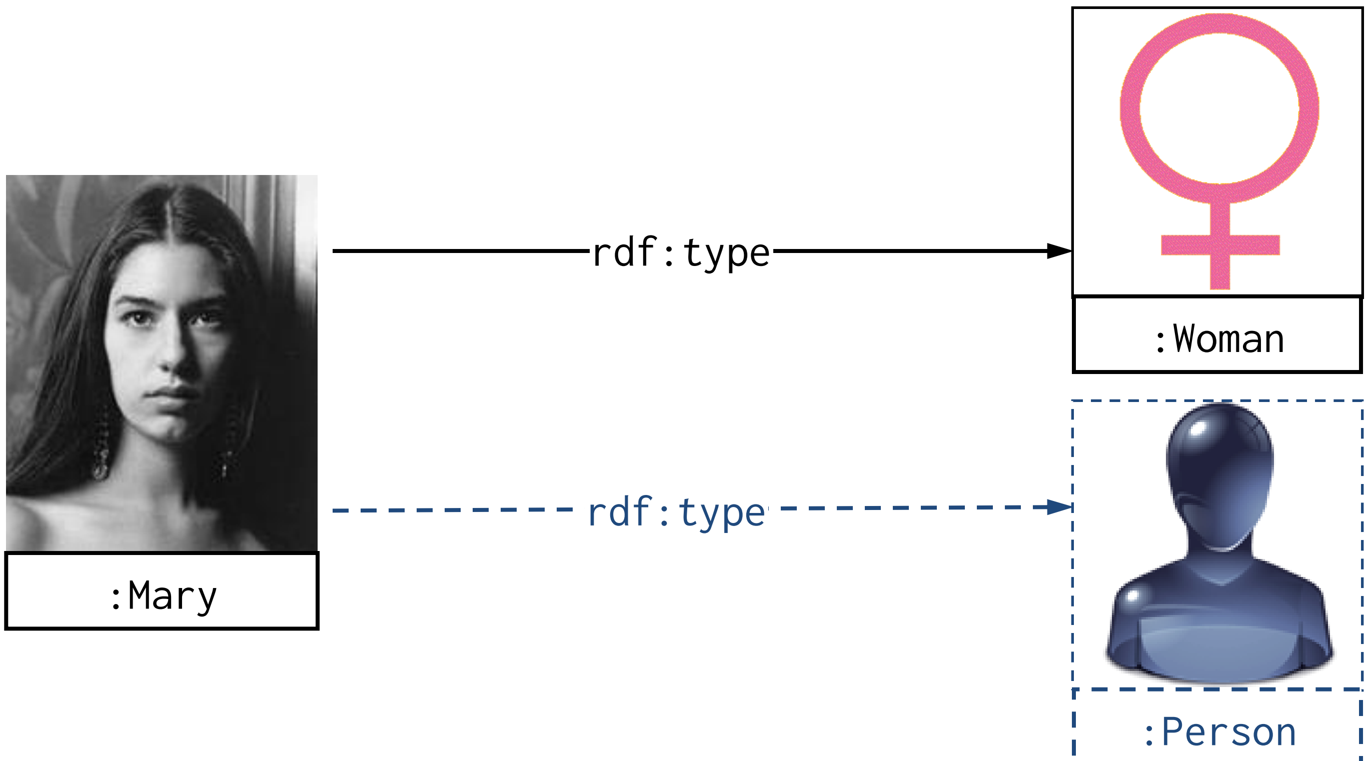
rdfs:subPropertyOf




```
:Vito :husbandOf :Carmela .
:husbandOf rdfs:subPropertyOf :spouse .
⇒  :Vito :spouse :Carmela .
```

```
:Carmela :wifeOf :Vito .
:wifeOf rdfs:subPropertyOf :spouse .
⇒  :Carmela :spouse :Vito .
```

rdfs:subClassOf




```
:Mary rdf:type :Woman .
:Woman rdfs:subClassOf :Person .
⇒  :Mary rdf:type :Person .
```

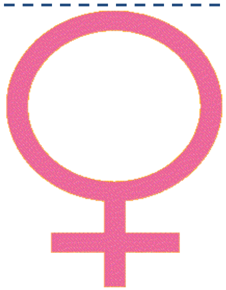
rdfs:domain

:motherOf

:Carmela

:Fredo

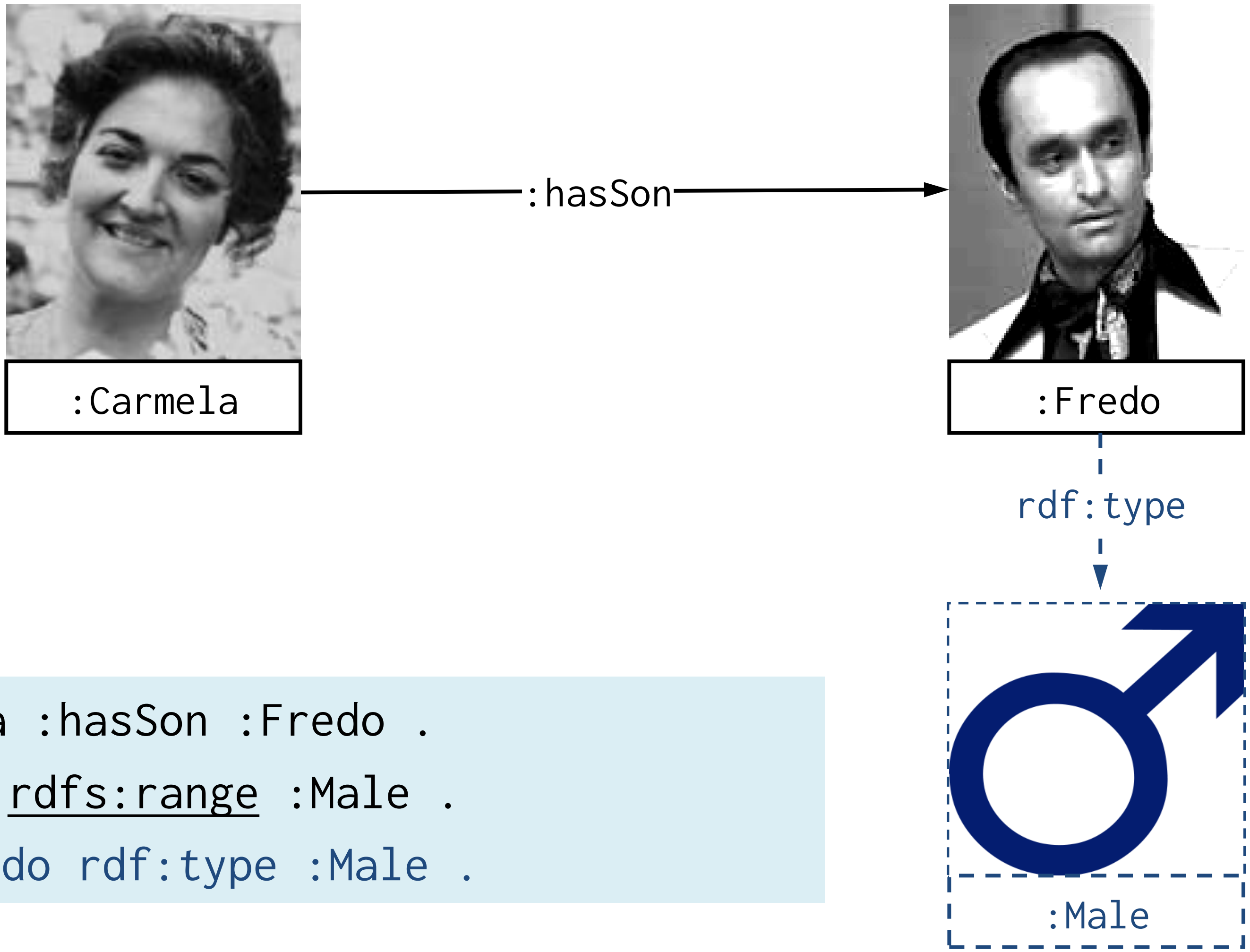
rdf:type



:Female

```
:Carmela :motherOf :Fredo .
:motherOf rdfs:domain :Female.
⇒  :Carmela rdf:type :Female .
```

rdfs:range



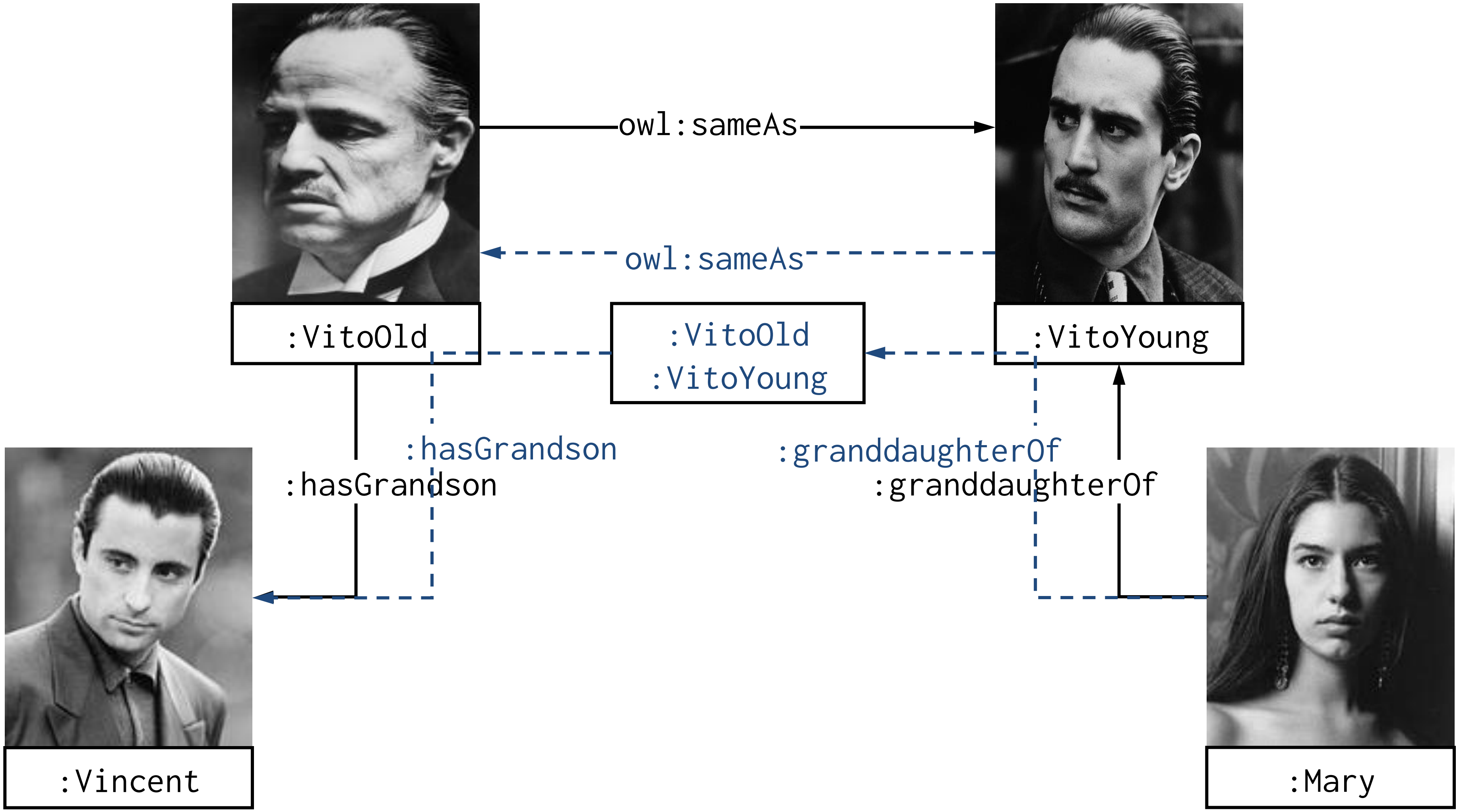
:Carmela :hasSon :Fredo .

:hasSon rdfs:range :Male .

⇒ :Fredo rdf:type :Male .

(In)Equality in OWL …

owl:sameAs

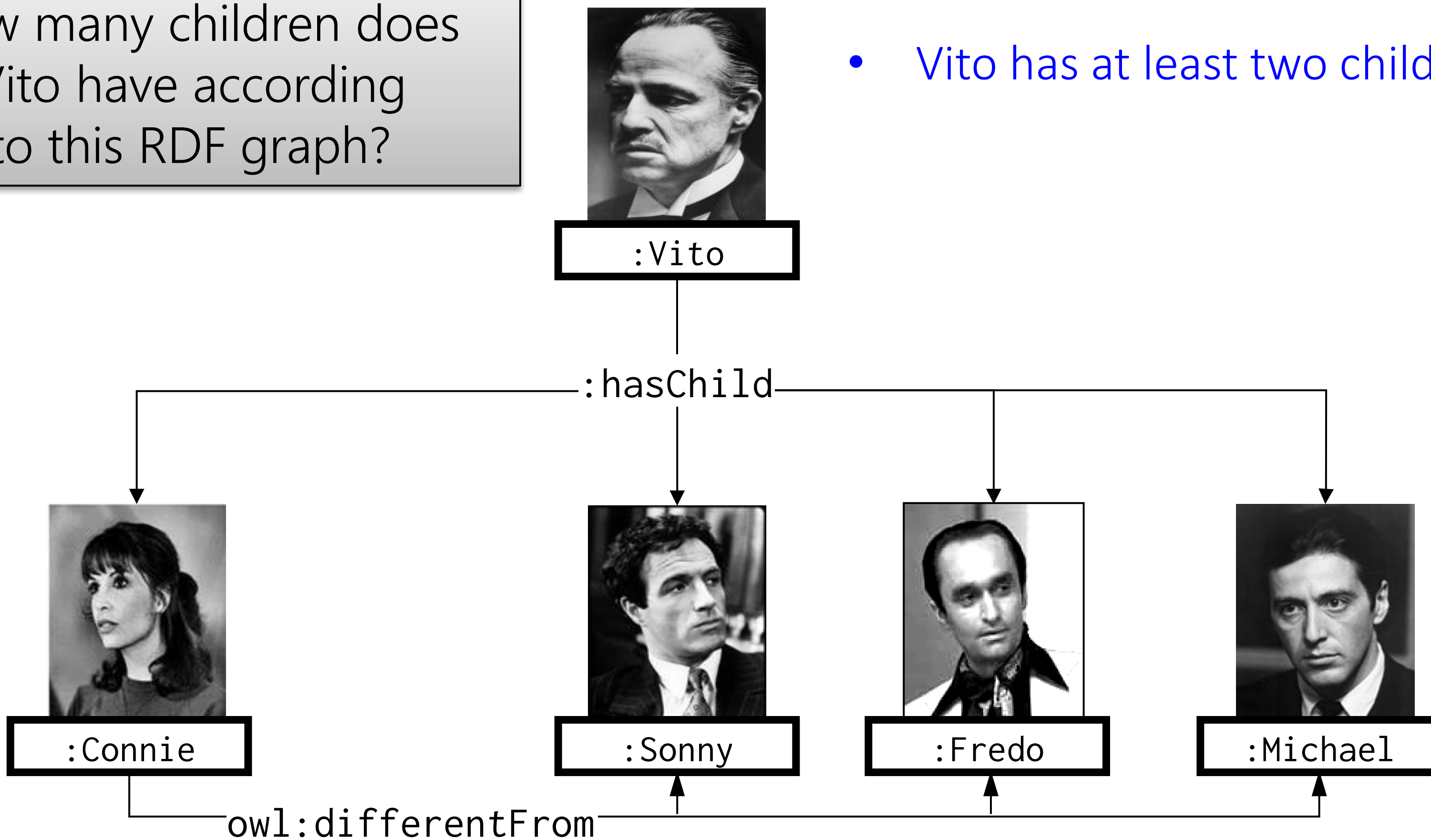



```
:VitoOld owl:sameAs :VitoYoung .
```

owl:differentFrom

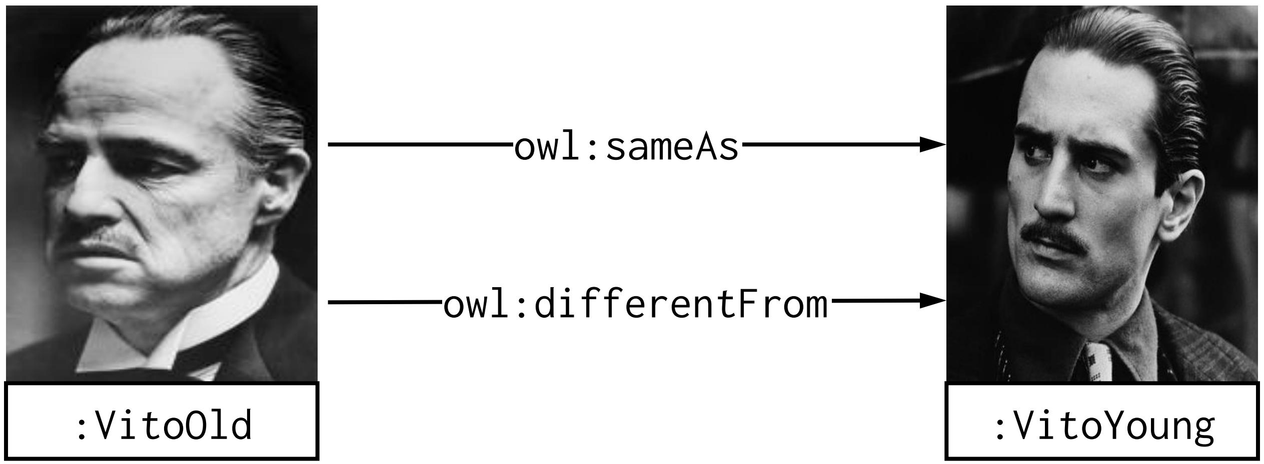
How many children does Vito have according to this RDF graph?

- Vito has at least two children!




```
:Vito :hasChild :Connie, :Sonny, :Michael, :Fredo .
:Connie owl:differentFrom :Sonny, :Michael, :Fredo .
```

Inconsistency in OWL ...

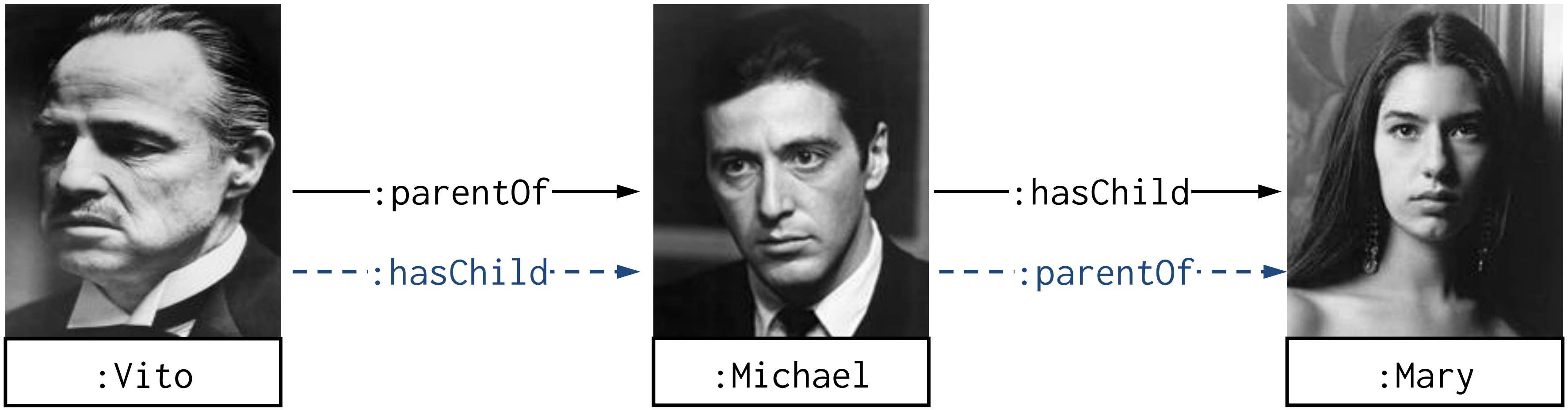



```
:VitoOld owl:sameAs :VitoYoung .
:VitoOld owl:differentFrom :VitoYoung .
```

⇒ FALSE

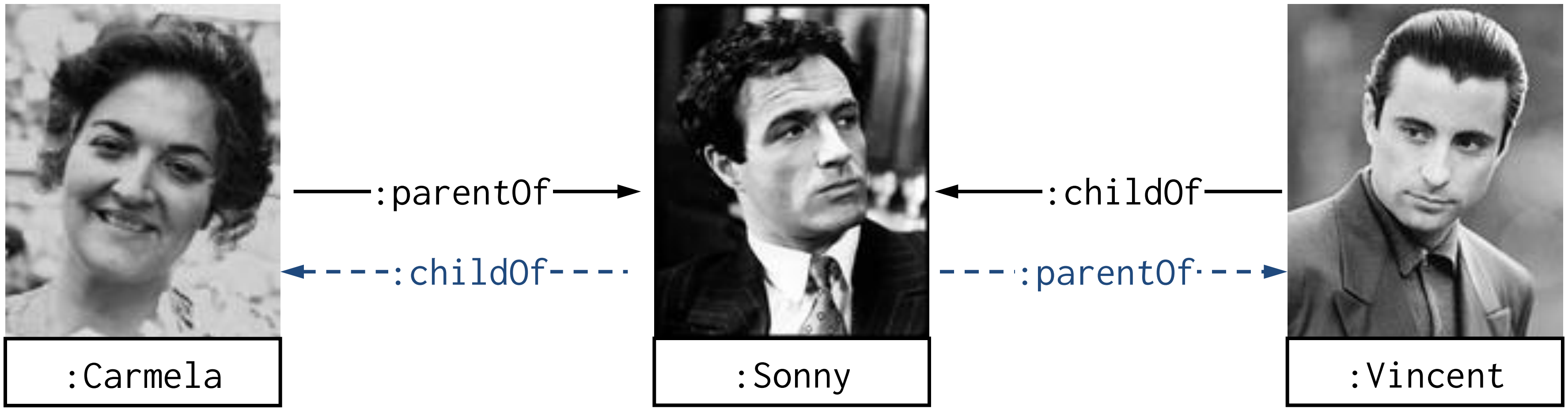
Property Axioms in OWL …

owl:equivalentProperty



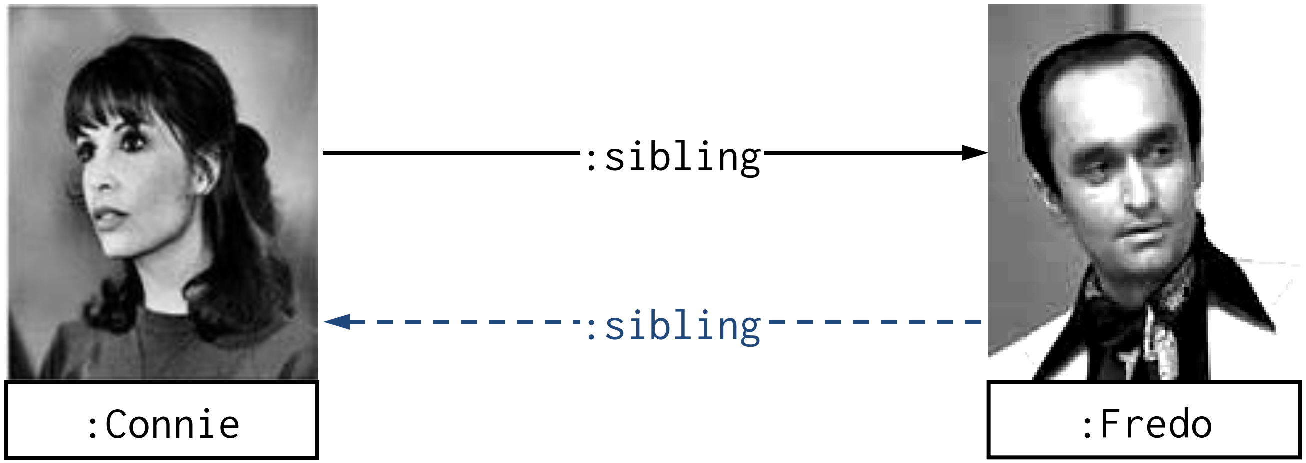

```
:Vito :parentOf :Michael .
:Michael :hasChild :Mary .
:parentOf owl:equivalentProperty :hasChild .
⇒  :Vito :hasChild :Michael .
⇒  :Michael :parentOf :Mary .
```

owl:inverseOf




```
:Carmela :parentOf :Sonny .
:Vincent :childOf :Sonny .
:parentOf owl:inverseOf :childOf .
⇒  :Sonny :parentOf :Vincent .
⇒  :Sonny :childOf :Carmela .
```

owl:SymmetricProperty

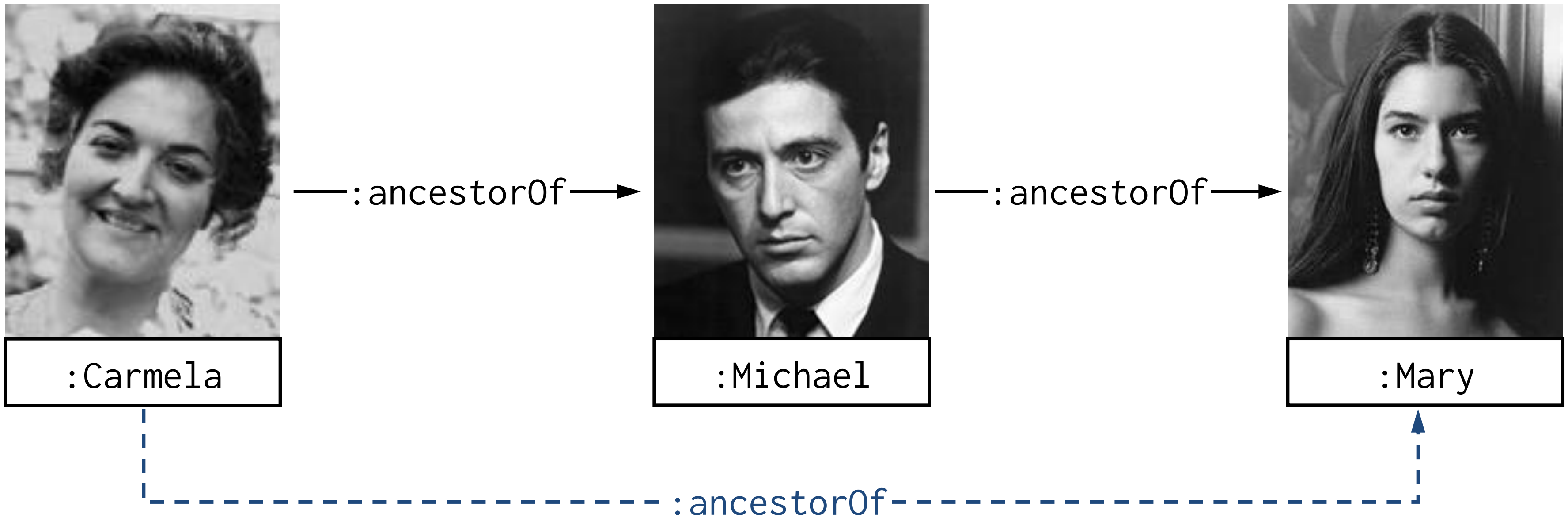


:Connie :sibling :Fredo .

:sibling rdf:type owl:SymmetricProperty .

⇒ :Fredo :sibling :Connie .

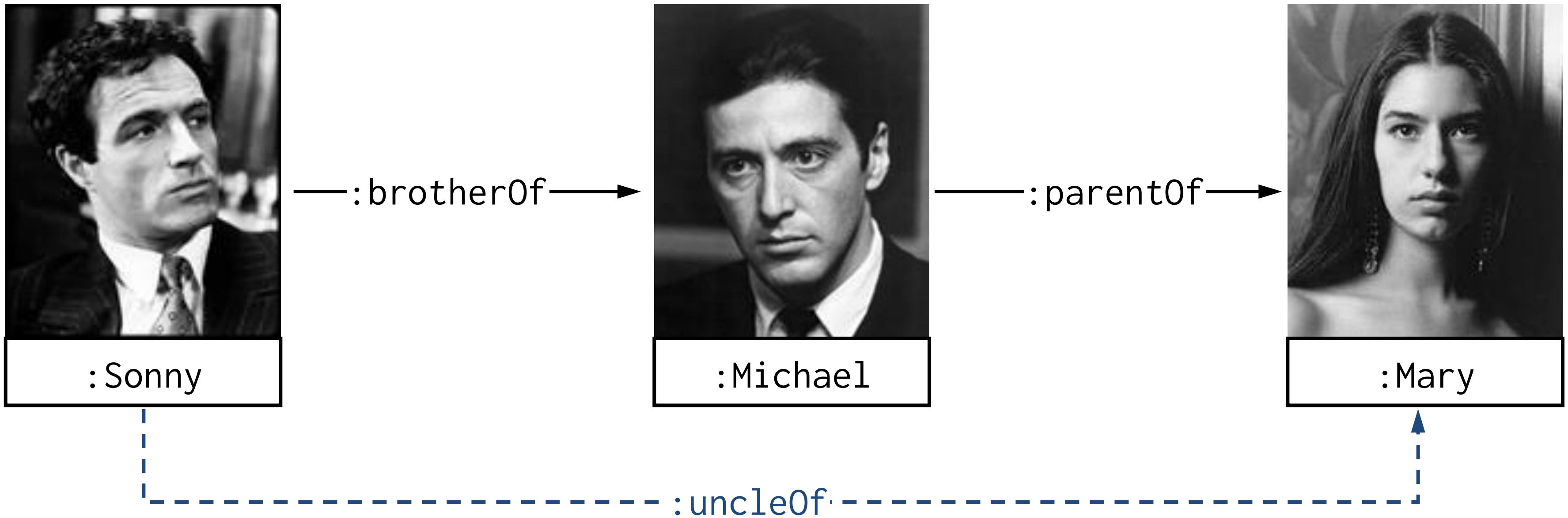
owl:TransitiveProperty




```
:Carmela :ancestorOf :Michael .
:Michael :ancestorOf :Mary .
:ancestorOf rdf:type owl:TransitiveProperty .
⇒  :Carmela :ancestorOf :Mary .
```

owl:propertyChainAxiom

Means new to OWL version 2.0!




```
:Sonny :brotherOf :Michael .
:Michael :parentOf :Mary .
:uncleOf owl:propertyChainAxiom (:brotherOf :parentOf) .
⇒  :Sonny :uncleOf :Mary .
```

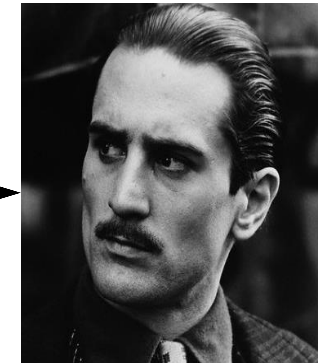
owl:ReflexiveProperty


```
:similarTo rdf:type owl:ReflexiveProperty .
⇒ :Connie :similarTo :Connie .
  :Freddie :similarTo :Freddie .
  # everything :similarTo itself
```

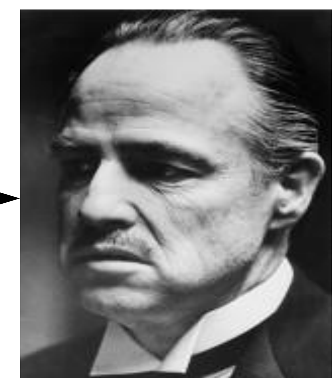
owl:FunctionalProperty

:Fredo

:hasBioFather



:VitoOld
:VitoYoung



:VitoOld

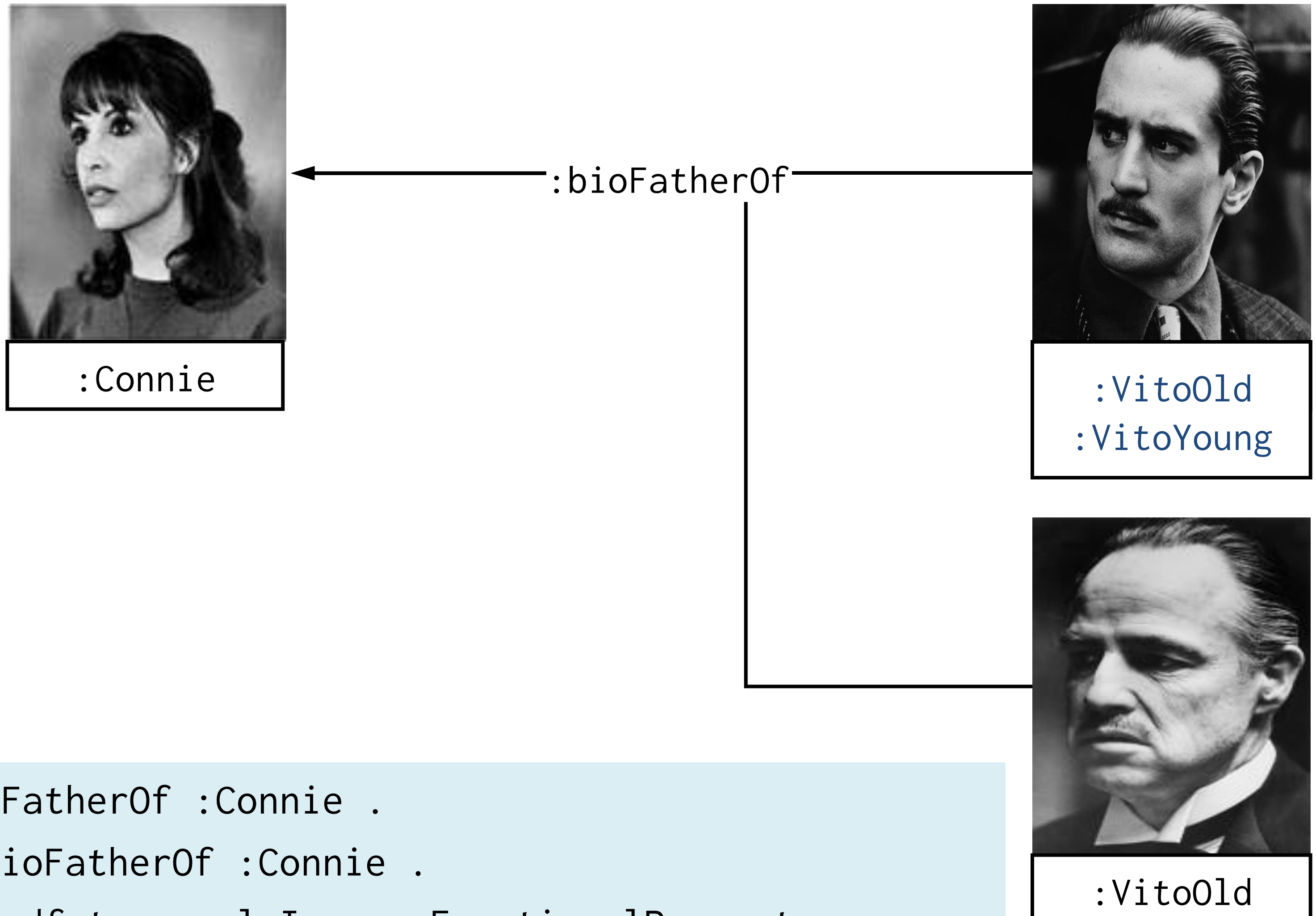
```
:Fredo :hasBioFather :VitoOld .
:Fredo :hasBioFather :VitoYoung .
:hasBioFather rdf:type owl:FunctionalProperty .
⇒ :VitoOld owl:sameAs :VitoYoung .
```

Aside …

What if we said `:hasFather` was functional?

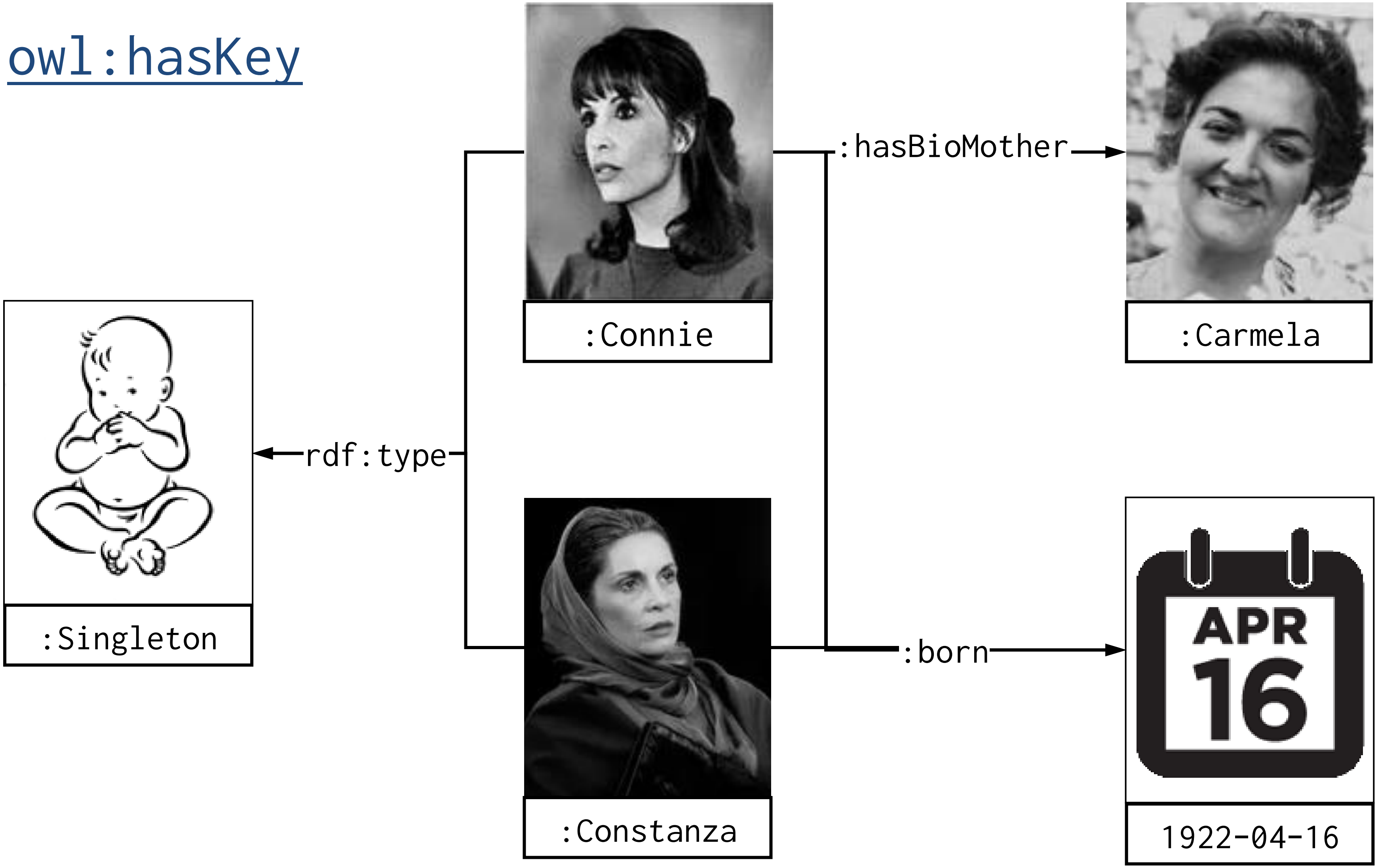
- Tom Hagen, the adopted son of Vito
  - Maybe he has two fathers?

owl:InverseFunctionalProperty



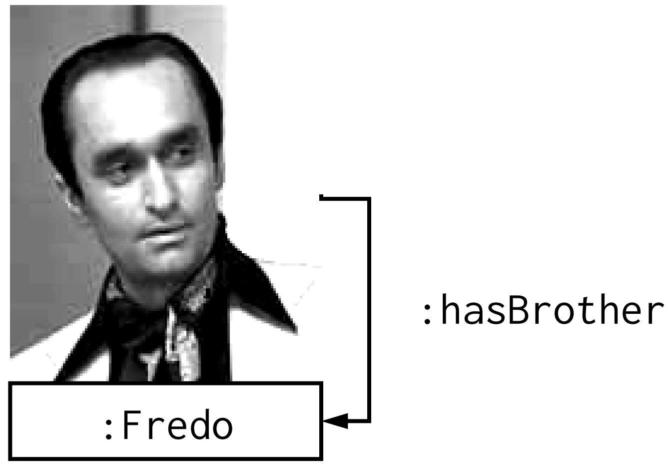

```
:VitoOld :bioFatherOf :Connie .
:VitoYoung :bioFatherOf :Connie .
:bioFatherOf rdf:type owl:InverseFunctionalProperty .
⇒ :VitoOld owl:sameAs :VitoYoung .
```

owl:hasKey



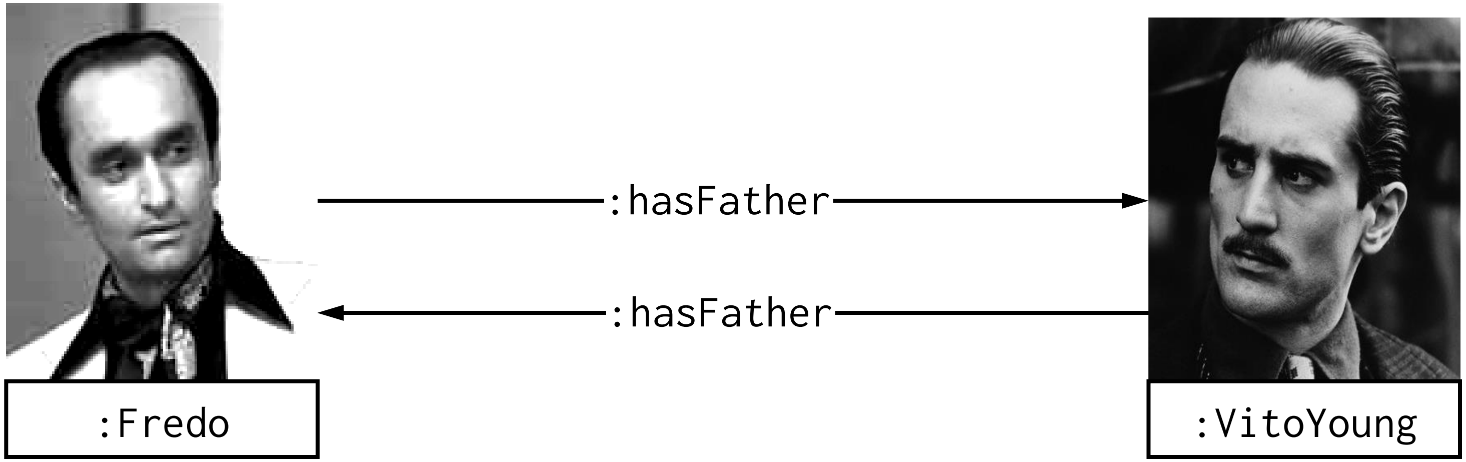

```
:Connie a :Singleton ; :hasBioMother :Carmela ; :born “1922-04-16”^^xsd:date .
:Constanza a :Singleton ; :hasBioMother :Carmela ; :born “1922-04-16”^^xsd:date .
:Singleton owl:hasKey ( :hasBioMother :born ) .
⇒ :Connie owl:sameAs :Constanza .
```

owl:IrreflexiveProperty



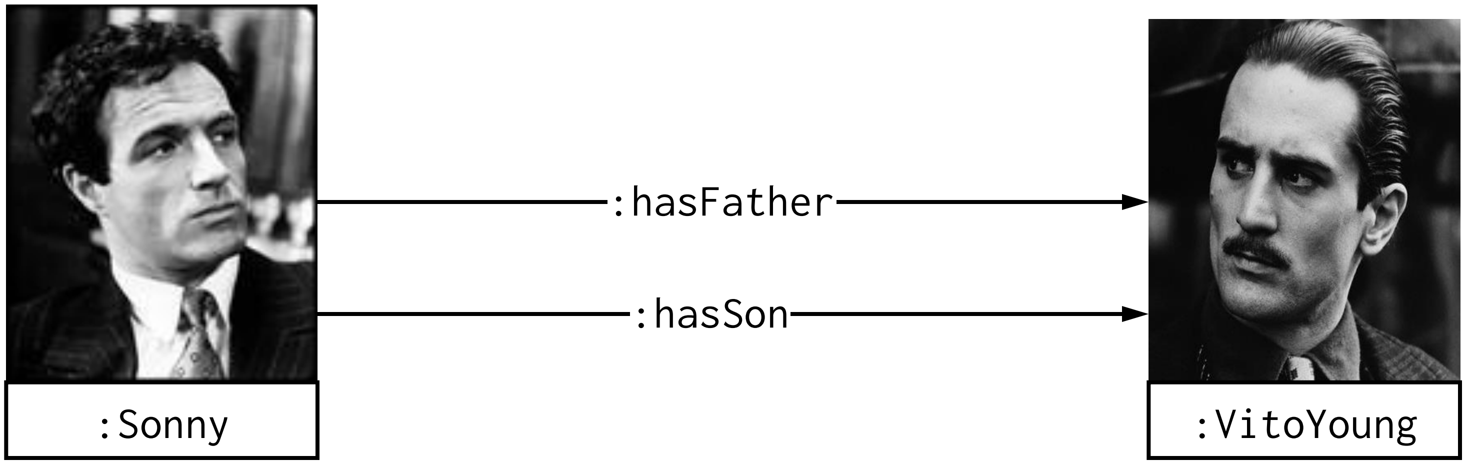

```
:Fredo :hasBrother :Fredo .
:hasBrother rdf:type owl:IrreflexiveProperty .
⇒ FALSE
```

owl:AsymmetricProperty



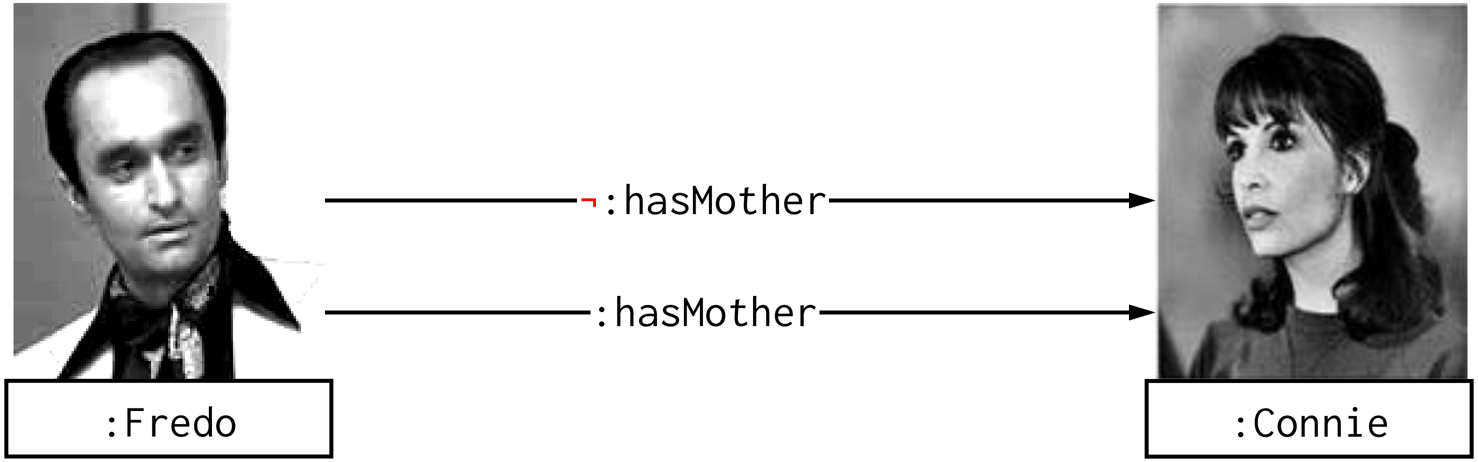

```
:Fredo :hasFather :VitoYoung .
:VitoYoung :hasFather :Fredo .
:hasFather rdf:type owl:AsymmetricProperty .
⇒ FALSE
```

owl:propertyDisjointWith




```
:Sonny :hasFather :VitoYoung .
:Sonny :hasSon :VitoYoung .
:hasSon owl:propertyDisjointWith :hasFather .
⇒ FALSE
```

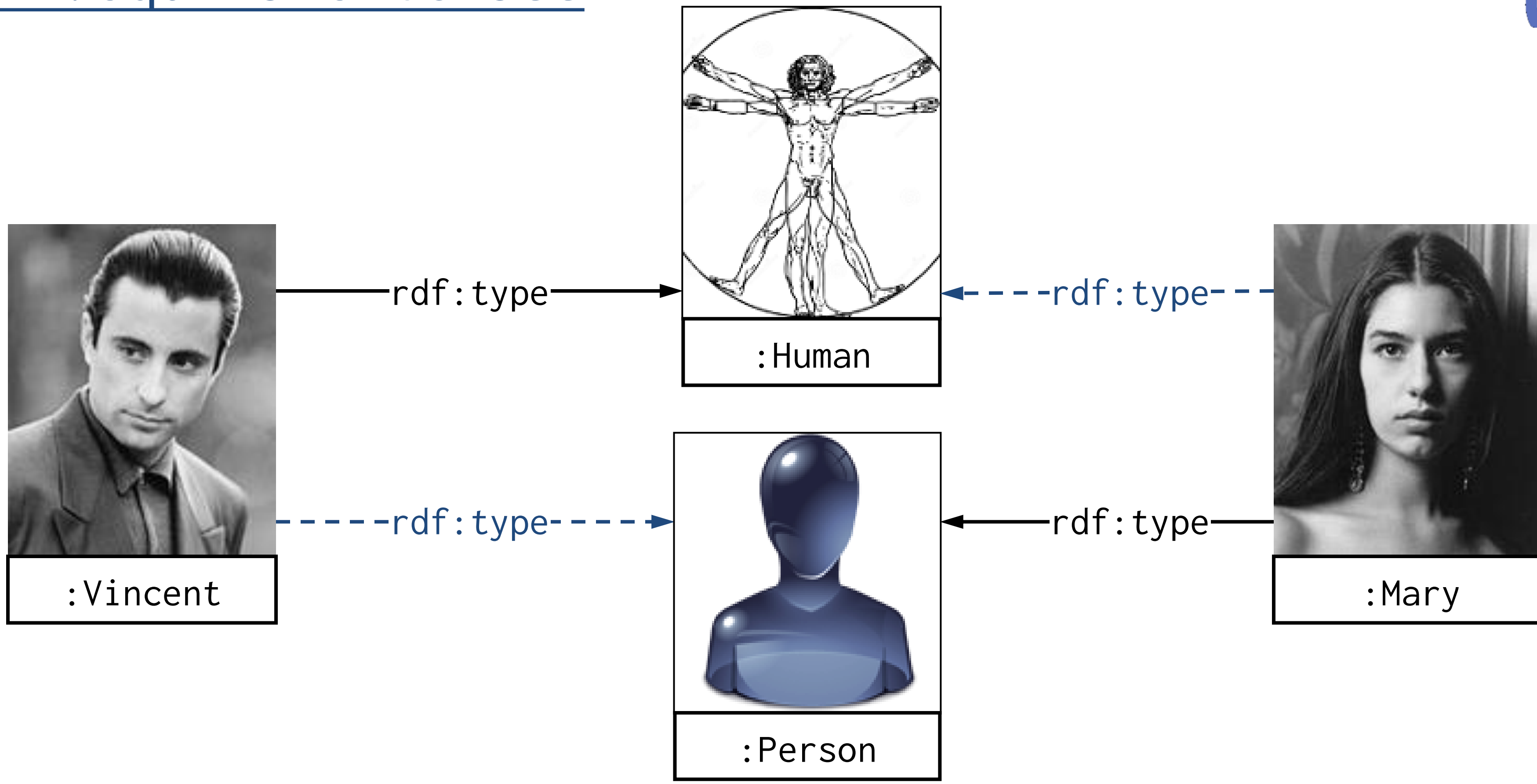
Negative property assertions




```
[] owl:sourceIndividual :Fredo ;
   owl:assertionProperty :hasMother ;
   owl:targetIndividual :Connie .
:Fredo :hasMother :Connie .
⇒ FALSE
```

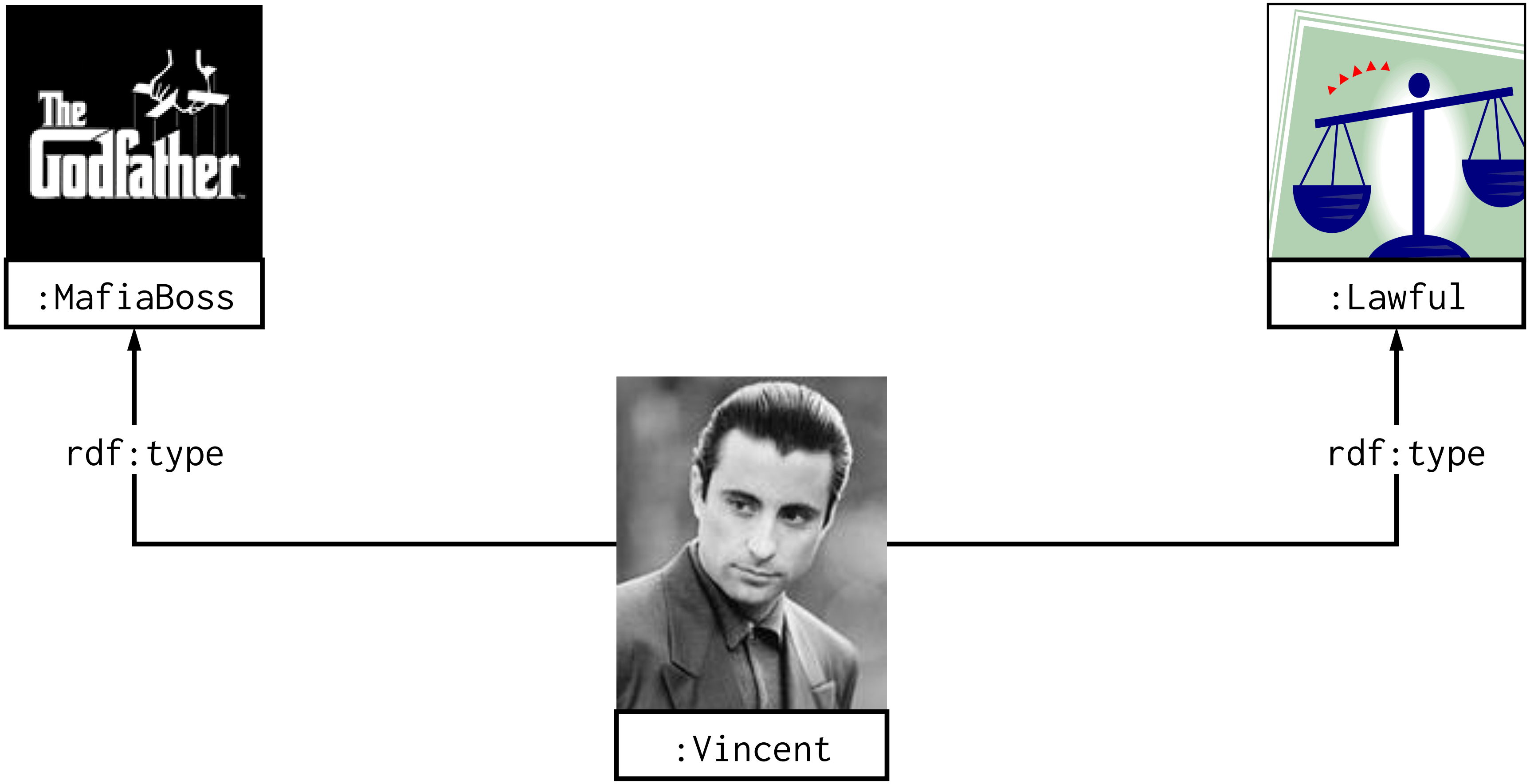
Class Axioms in OWL

owl:equivalentClass




```
:Vincent rdf:type :Human .
:Mary rdf:type :Person .
:Human owl:equivalentClass :Person .
⇒ :Vincent rdf:type :Person .
  :Mary rdf:type :Human .
```

owl:disjointWith

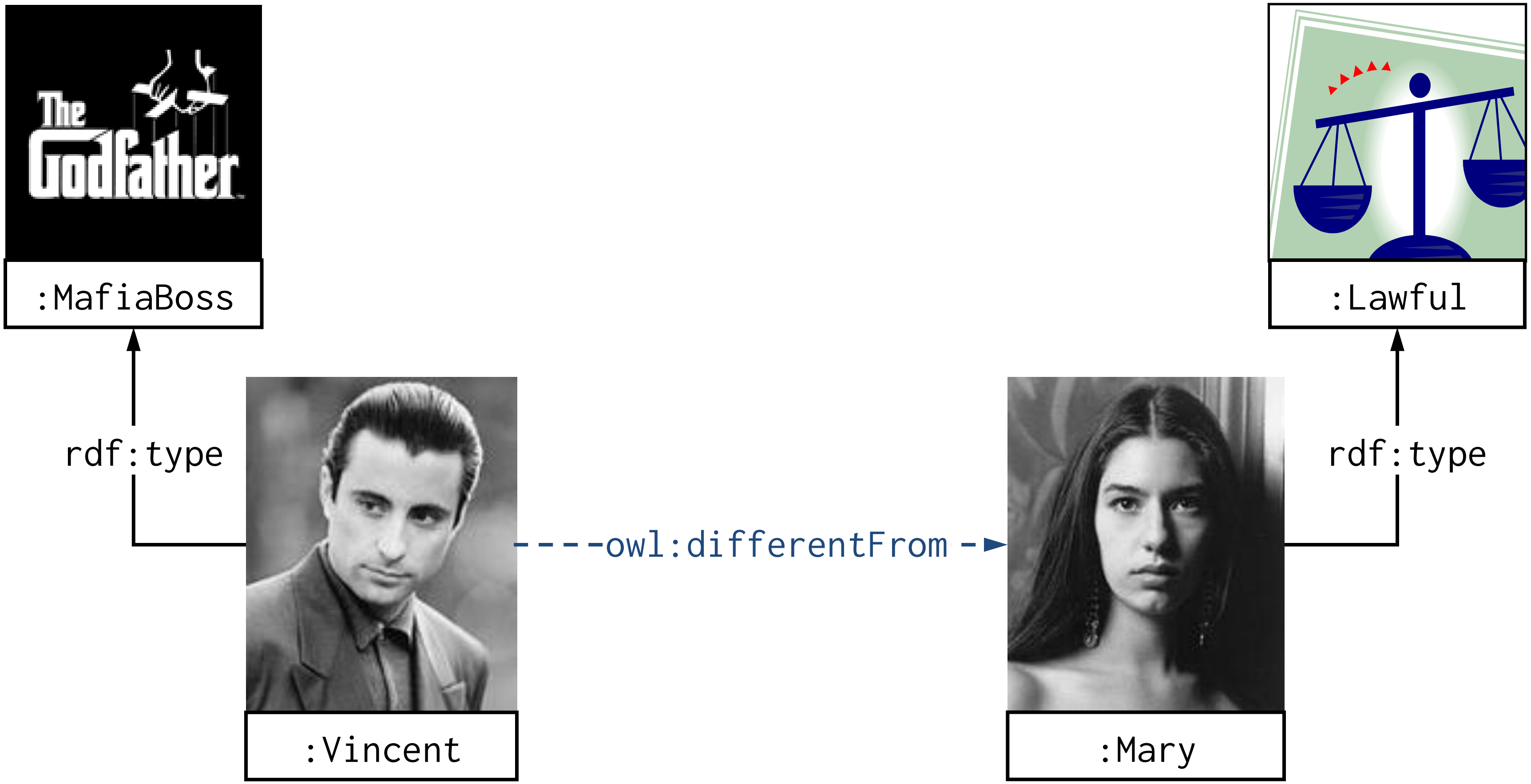


:Vincent rdf:type :MafiaBoss , :Lawful .

:MafiaBoss owl:disjointWith :Lawful .

⇒ FALSE

owl:disjointWith (II)



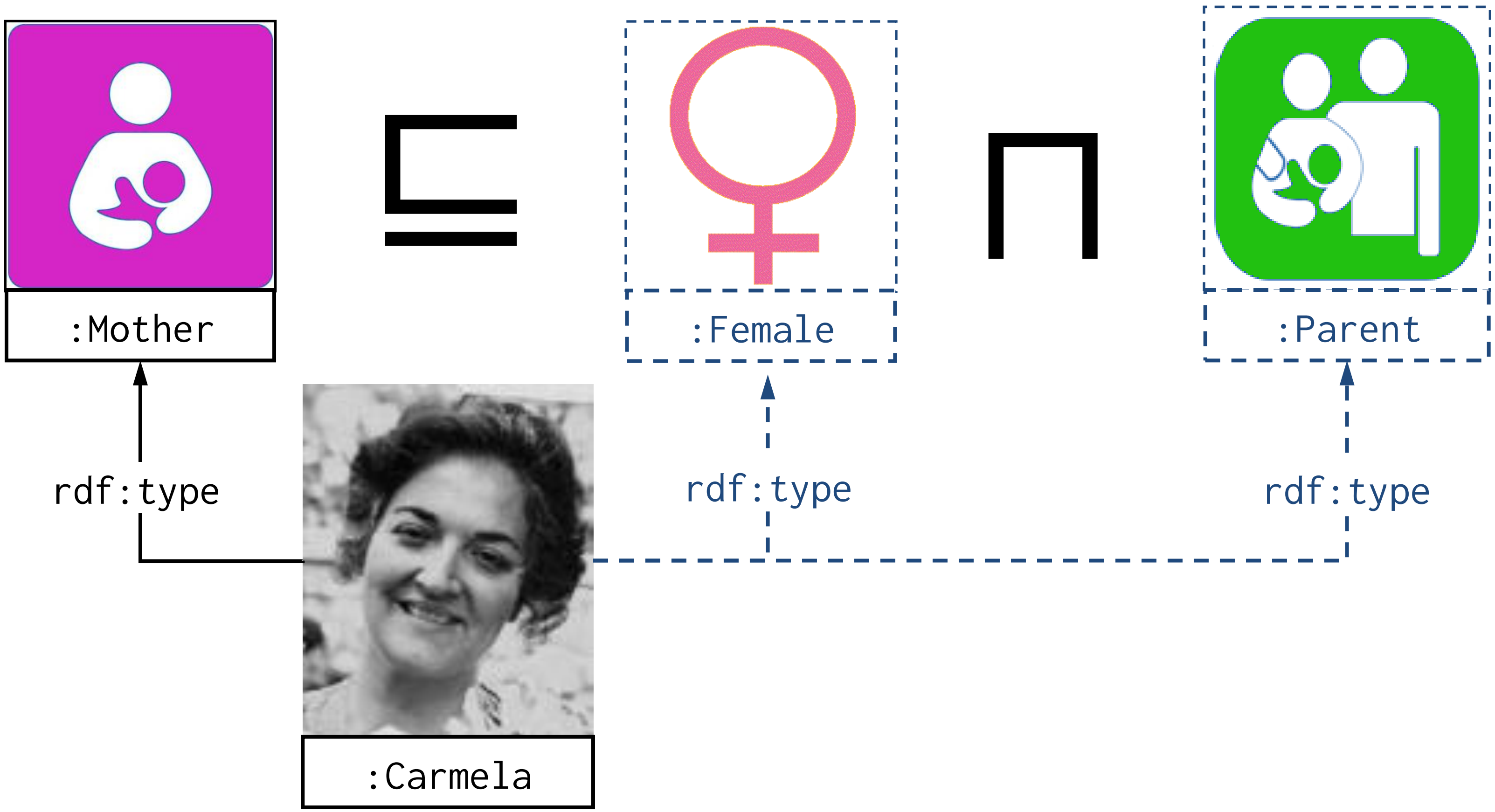

```
:Vincent rdf:type :MafiaBoss .
:Mary rdf:type :Lawful .
:MafiaBoss owl:disjointWith :Lawful .
⇒ :Vincent owl:differentFrom :Mary
```

Class Definitions in OWL

Description Logics

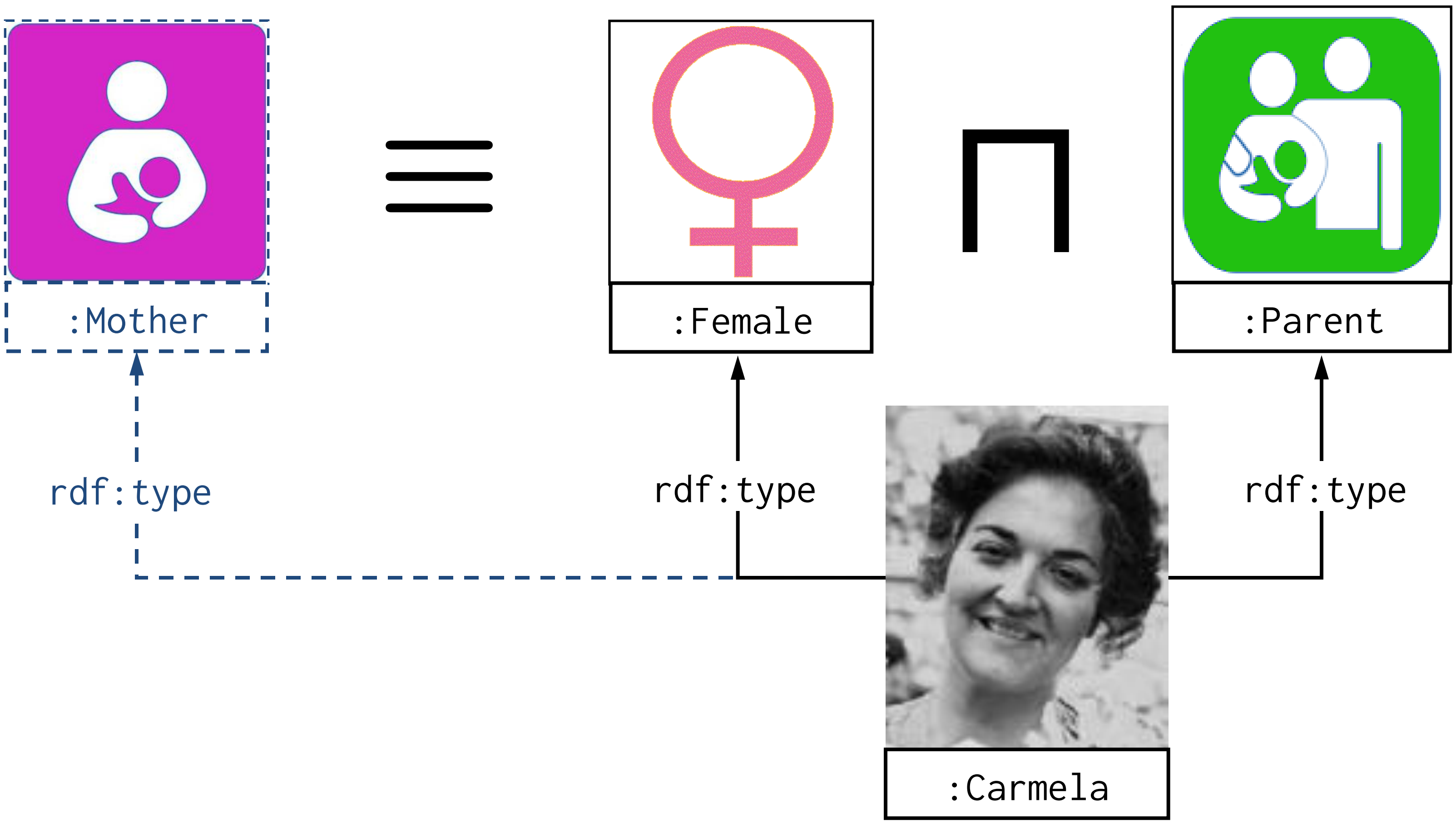
Name	Syntax	OWL key-term	DL
		Concept Definitions	
Atomic Concept	A	`owl:Class`	$\mathcal{ALC}$
Top Concept	$\top$	`owl:Thing`	$\mathcal{ALC}$
Bottom Concept	$\bot$	`owl:Nothing`	$\mathcal{ALC}$
Concept Negation	$\neg C$	`owl:complementOf`	$\mathcal{ALC}$
Concept Intersection	$C \sqcap D$	`owl:intersectionOf`	$\mathcal{ALC}$
Concept Union	$C \sqcup D$	`owl:unionOf`	$\mathcal{ALC}$
Nominal	$\{a_1, ..., a_n\}$	`owl:oneOf`	$\mathcal{O}$
Existential Restriction	$\exists R.C$	`owl:someValuesFrom`	$\mathcal{ALC}$
Universal Restriction	$\forall R.C$	`owl:allValuesFrom`	$\mathcal{ALC}$
Self Restriction	$\exists R.\mathsf{Self}$	`owl:hasSelf`	$\mathcal{R}$
Number Restriction	$\leq n\,R, \geq n\,R, = n\,R$	`owl:*cardinality`	$\mathcal{N}$
Qualified Number Restriction	$\leq n\,R.C, \geq n\,R.C, = n\,R.C$	`owl:*qualifiedCardinality`	$\mathcal{Q}$
		Concept Axioms (T-Box)	
Concept Inclusion	$C \sqsubseteq D$	`rdfs:subClassOf`	$\mathcal{ALC}$
		Role Definitions	
Role	R	`owl:*Property`	$\mathcal{ALC}$
Inverse Role	R^-	`owl:inverseOf`	$\mathcal{I}$
Universal Role	U	`owl:top*Property`	$\mathcal{R}$
		Role Axioms (R-Box)	
Role Inclusion	$R \sqsubseteq S$	`rdfs:subPropertyOf`	$\mathcal{H}$
Complex Role Inclusion	$R_1 \circ ... \circ R_n \sqsubseteq S$	`owl:propertyChainAxiom`	$\mathcal{R}$
Transitive Roles	$\mathsf{Trans}(R)$	`owl:TransitiveProperty`	$\mathcal{S}$
Functional Roles	$\mathsf{Func}(R)$	`owl:FunctionalProperty`	$\mathcal{F}$
Reflexive Roles	$\mathsf{Ref}(R)$	`owl:ReflexiveProperty`	$\mathcal{R}$
Irreflexive Roles	$\mathsf{Irref}(R)$	`owl:IrreflexiveProperty`	$\mathcal{R}$
Symmetric Roles	$\mathsf{Sym}(R)$	`owl:SymmetricProperty`	$\mathcal{I}$
Asymmetric Roles	$\mathsf{Asym}(R)$	`owl:AsymmetricProperty`	$\mathcal{R}$
Disjoint Roles	$\mathsf{Disj}(R, S)$	`owl:disjointPropertyWith`	$\mathcal{R}$
		Assertional Definitions	
(Named) Individual	a	*(RDF IRI or Literal)*	$\mathcal{ALC}$
		Assertional Axioms (A-Box)	
Role Assertion	$R(a, b)$	*(RDF triple)*	$\mathcal{ALC}$
Negative Role Assertion	$\neg R(a, b)$	`owl:NegativePropertyAssertion`	$\mathcal{ALC}$
Concept Assertion	$C(a)$	`rdf:type`	$\mathcal{ALC}$
Equality	$a = b$	`owl:sameAs`	$\mathcal{ALC}$
Inequality	$a \neq b$	`owl:differentFrom`	$\mathcal{ALC}$

owl:intersectionOf (⊓) [I]



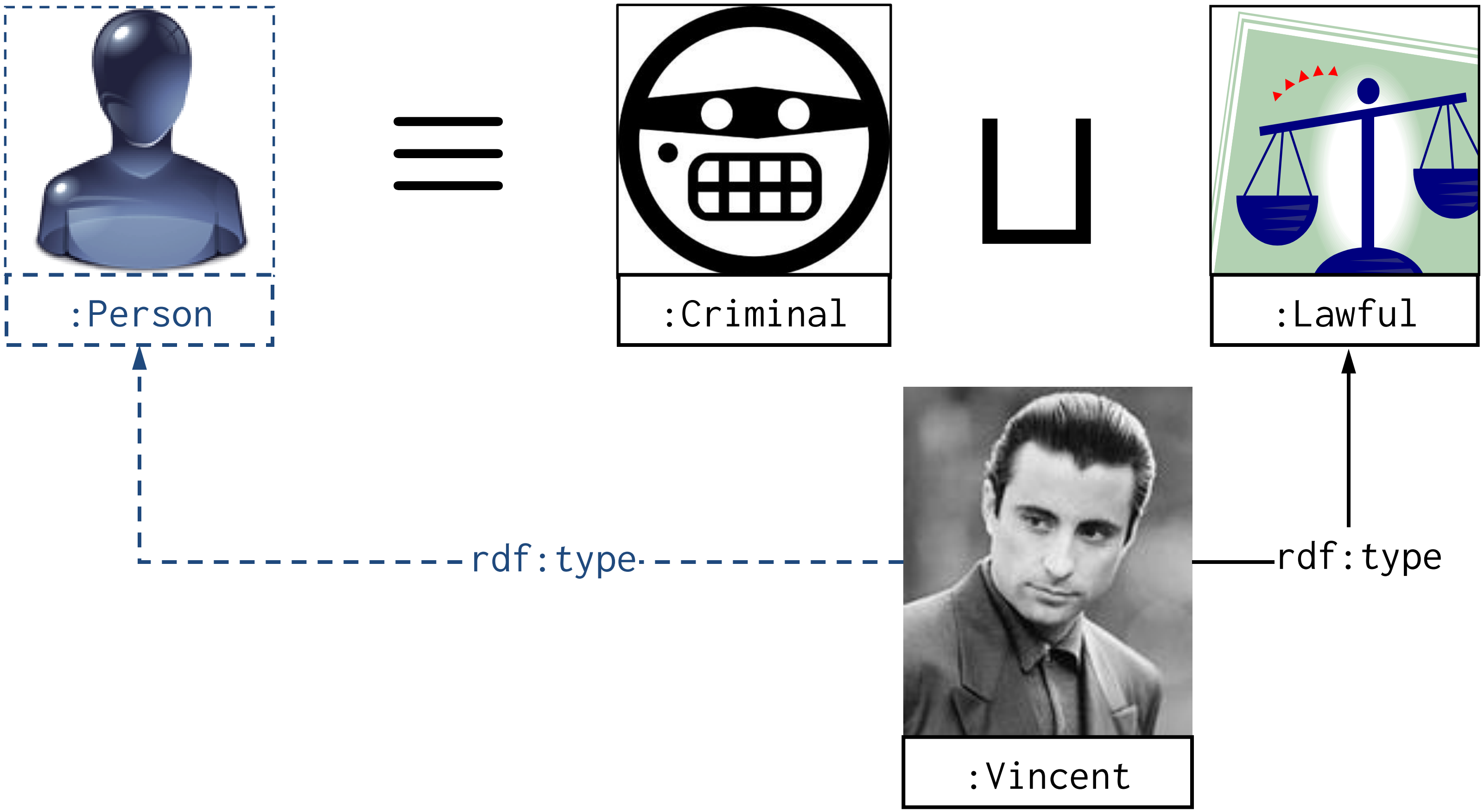

```
:Carmela rdf:type :Mother .
:Mother rdfs:subClassOf [ owl:intersectionOf ( :Female :Parent ) ]
⇒ :Carmela rdf:type :Female , :Parent .
```

owl:intersectionOf (⊓) [II]



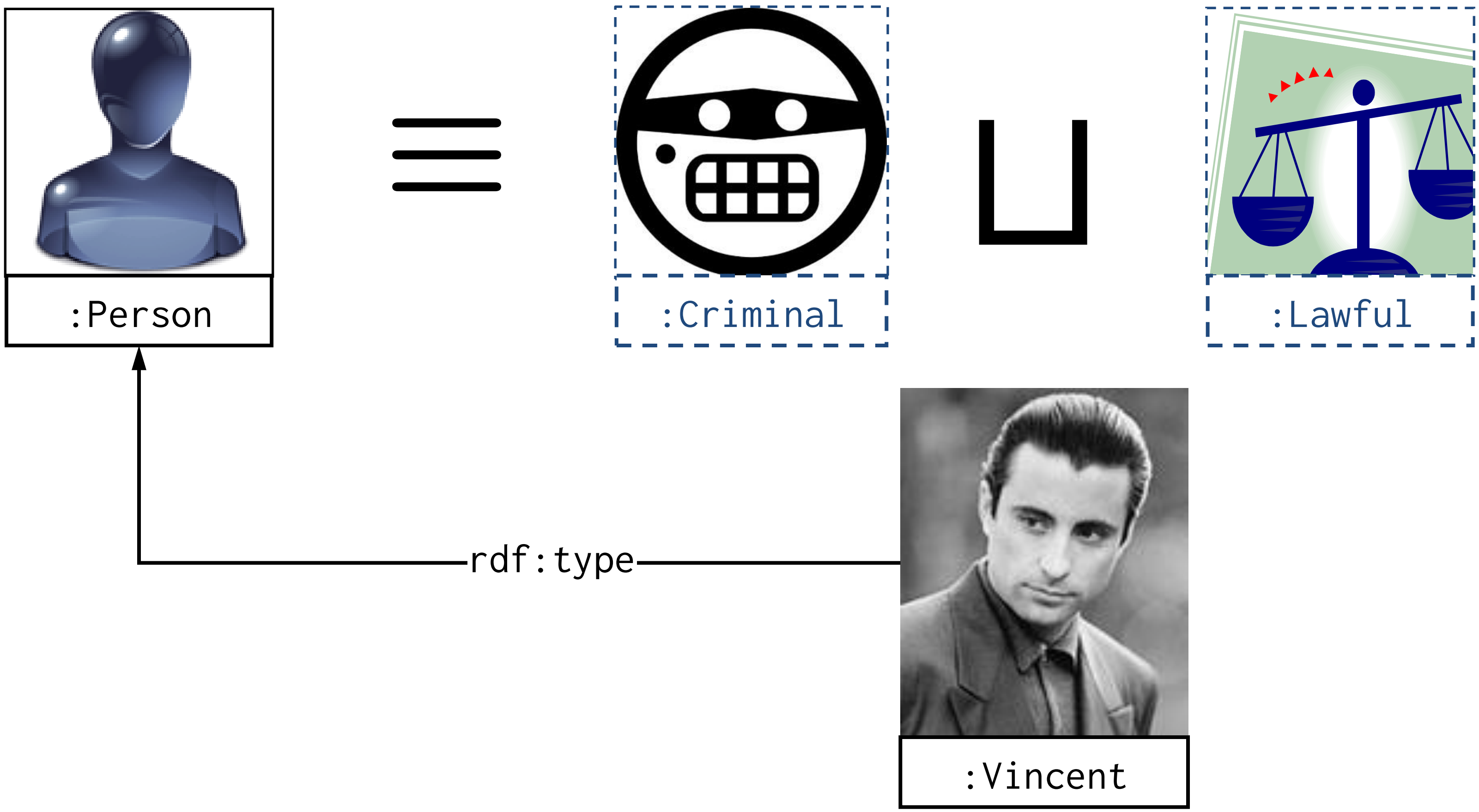

```
:Carmela rdf:type :Female , :Parent .
:Mother owl:equivalentClass [ owl:intersectionOf ( :Female :Parent ) ]
⇒ :Carmela rdf:type :Mother .
```

owl:unionOf (⊔) [I]




```
:Vincent rdf:type :Lawful .
:Person owl:equivalentClass [ owl:unionOf ( :Criminal :Lawful ) ]
⇒  :Vincent rdf:type :Person .
```

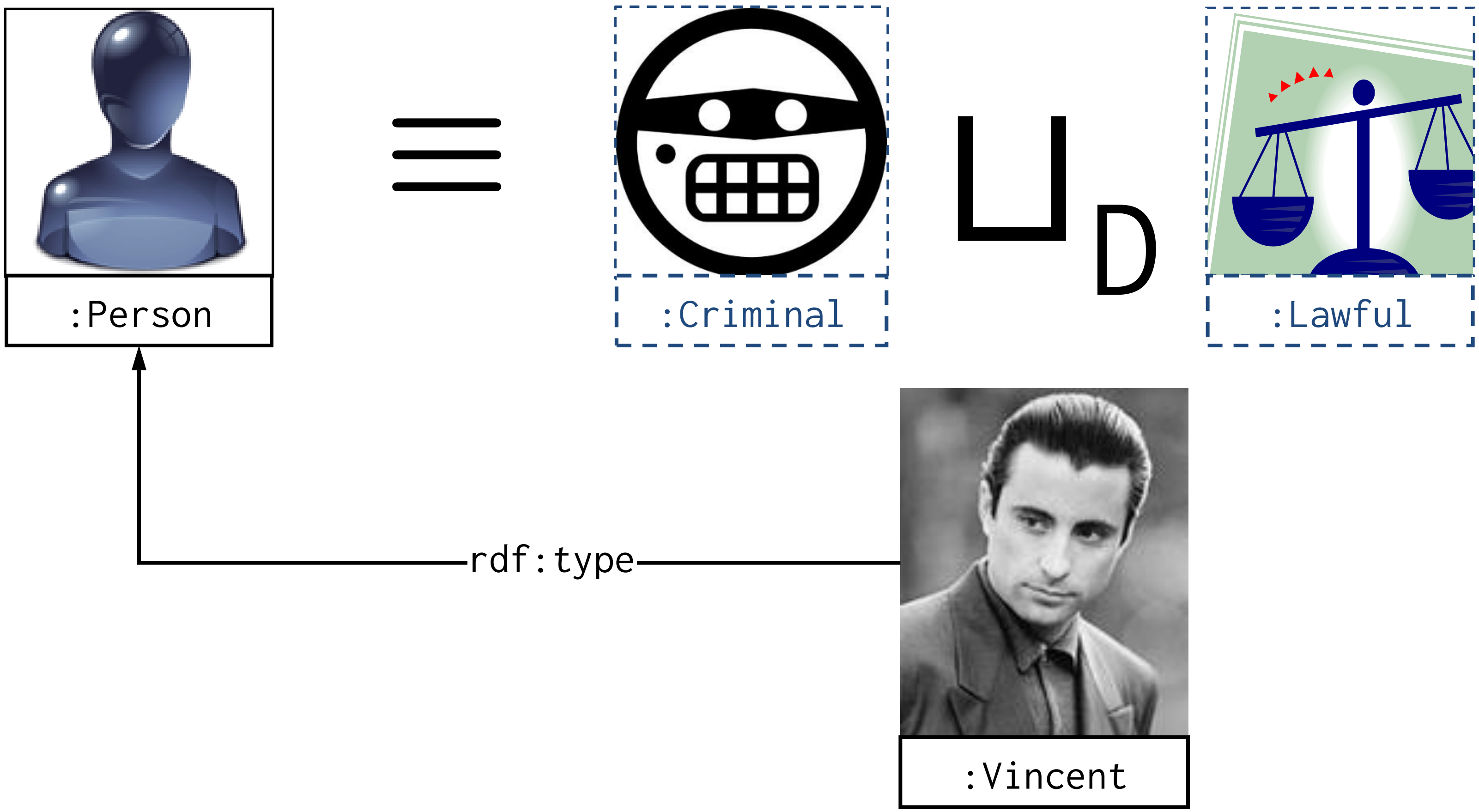
owl:unionOf (⊔) [II]




```
:Vincent rdf:type :Person .
:Person owl:equivalentClass [ owl:unionOf ( :Criminal :Lawful ) ]
```

⇒ # :Vincent must be either :Lawful or :Criminal (or both)

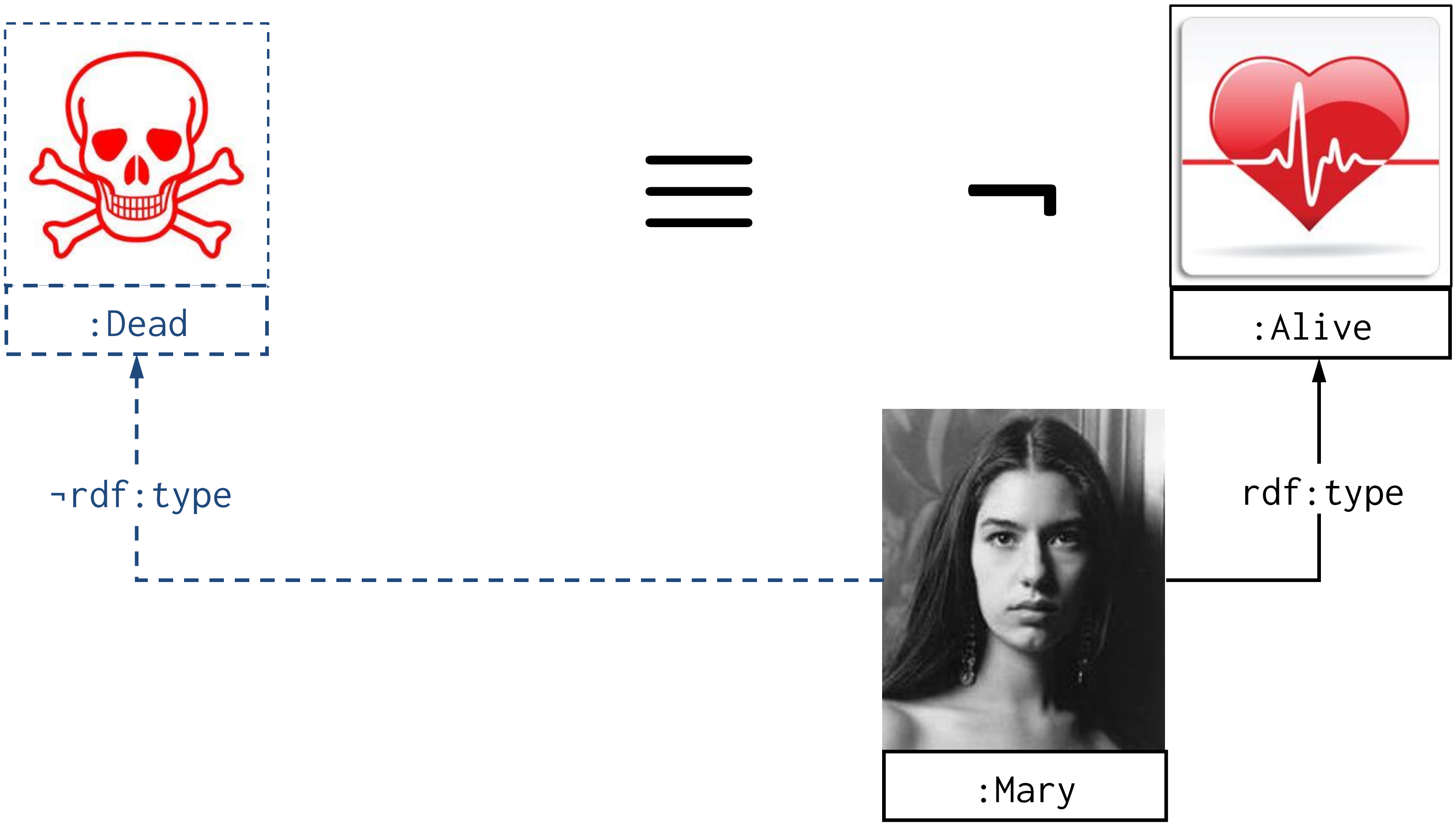
owl:disjointUnionOf ($\sqcup_D$)




```
:Vincent rdf:type :Person .
:Person owl:equivalentClass
     [ owl:disjointUnionOf ( :Criminal :Lawful ) ]
```

⇒ # :Vincent must be either :Lawful or :Criminal (not both)

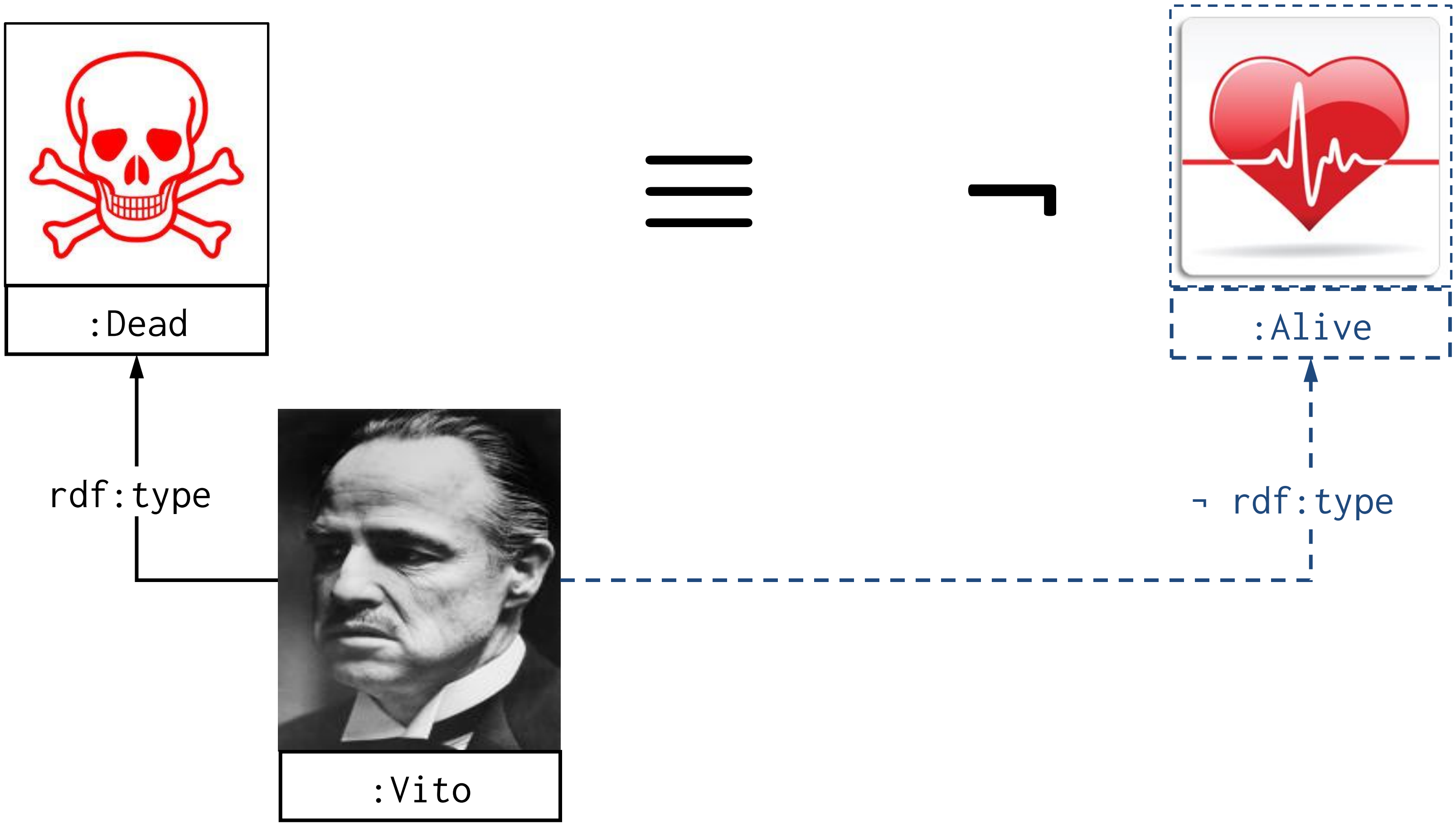
owl:complementOf (¬) [I]




```
:Mary rdf:type :Alive .
:Dead owl:equivalentClass [ owl:complementOf :Alive ]
⇒ [] owl:sourceIndividual :Mary ; owl:targetProperty rdf:type ;
       owl:targetIndividual :Dead .
```


WARNING
SPOILER
ALERT

owl:complementOf (¬) [II]

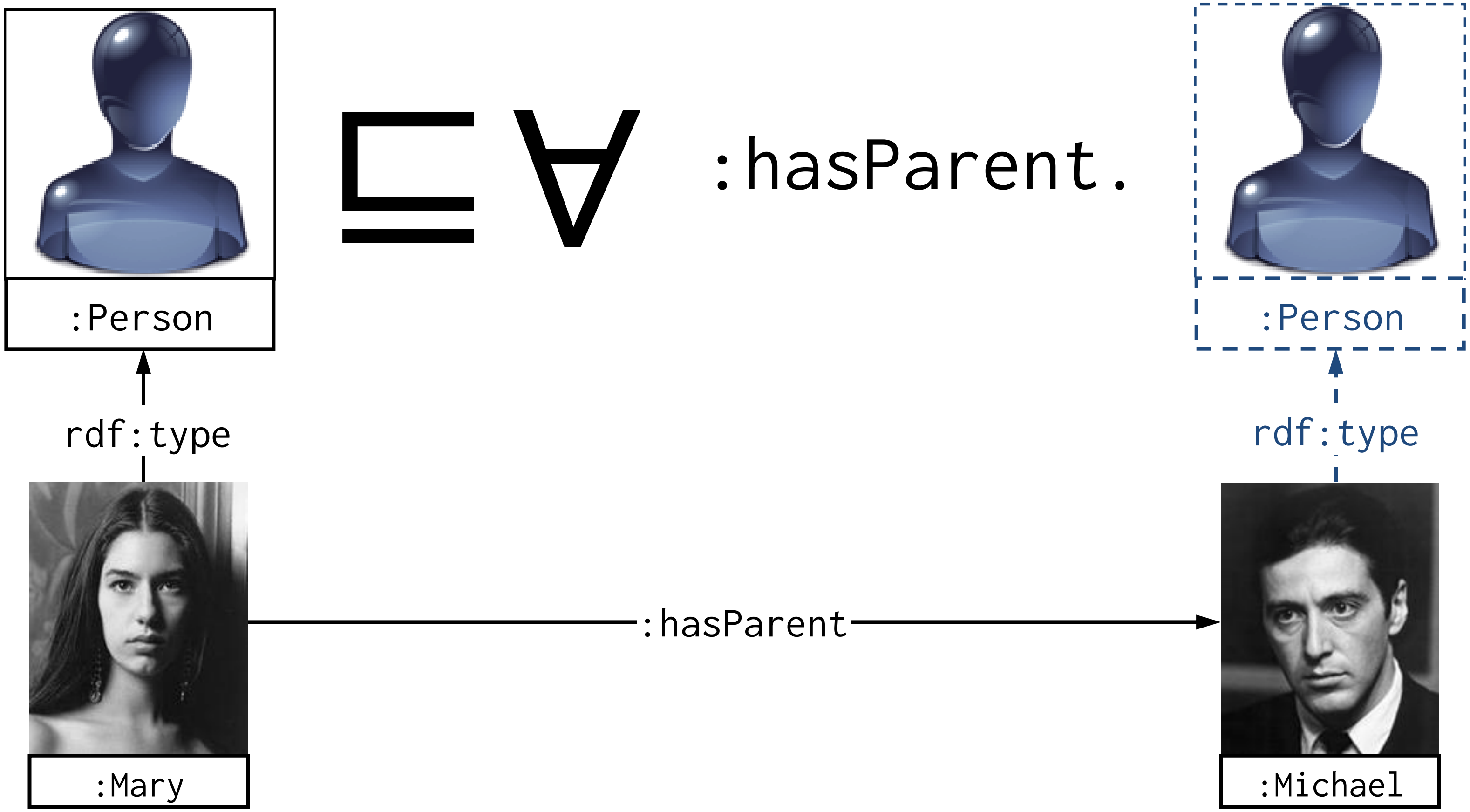



```
:Vito rdf:type :Dead .
:Dead owl:equivalentClass [ owl:complementOf :Alive ]
⇒ [] owl:sourceIndividual :Vito ; owl:targetProperty rdf:type ;
       owl:targetIndividual :Alive .
```

owl:oneOf ({})

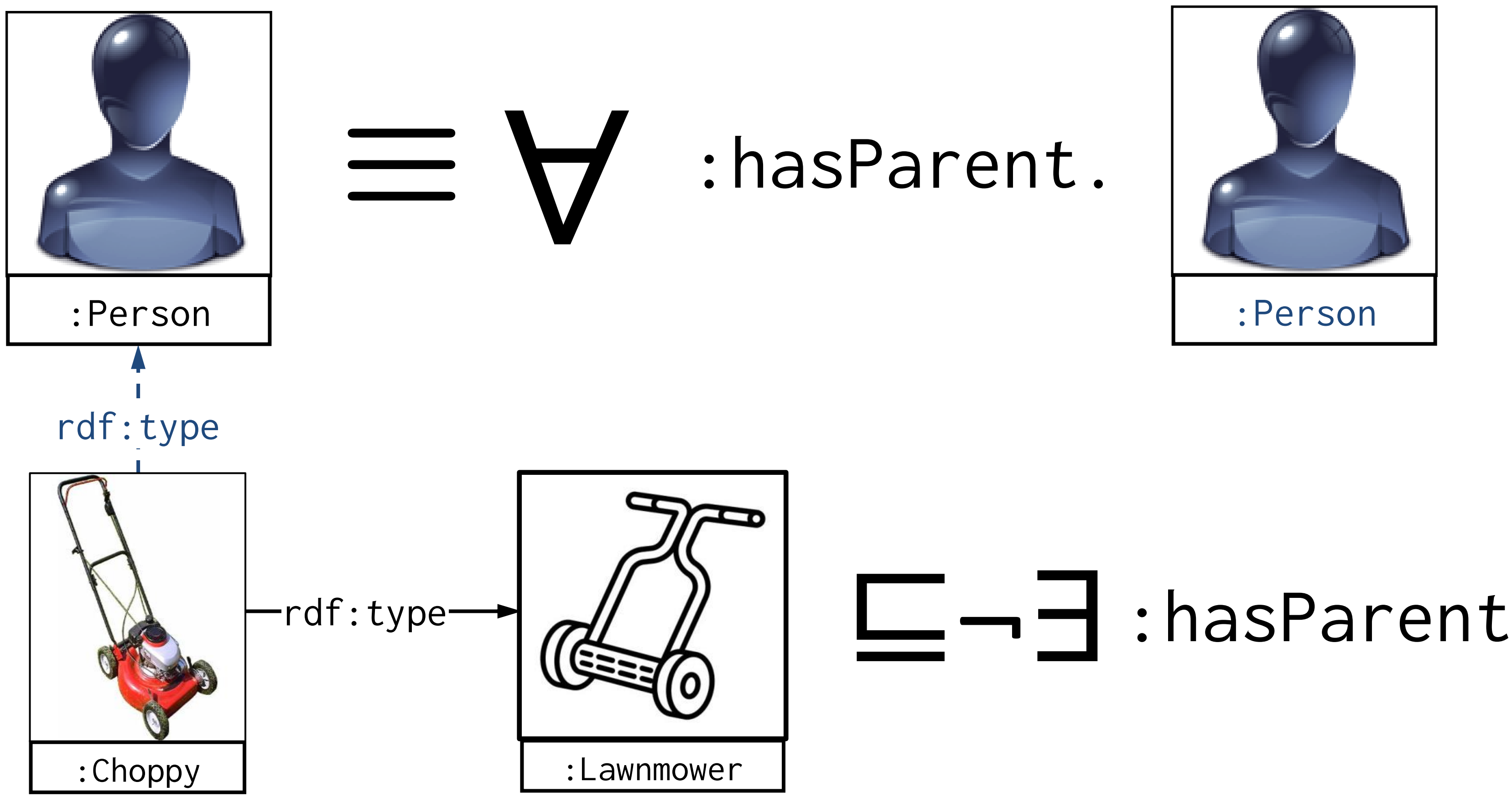

```
:Godfather owl:equivalentClass
   [ owl:oneOf (:Vito :Michael :Vincent) ]
⇒ :Vito rdf:type :Godfather .
⇒ :Michael rdf:type :Godfather .
⇒ :Vincent rdf:type :Godfather .
```

owl:allValuesFrom (∀) [I]




```
:Mary rdf:type :Person ; :hasParent :Michael .
:Person rdfs:subClassOf
  [ owl:allValuesFrom :Person ; owl:onProperty :hasParent ]
⇒  :Michael rdf:type :Person .
```

`owl:allValuesFrom` (∀) [II]



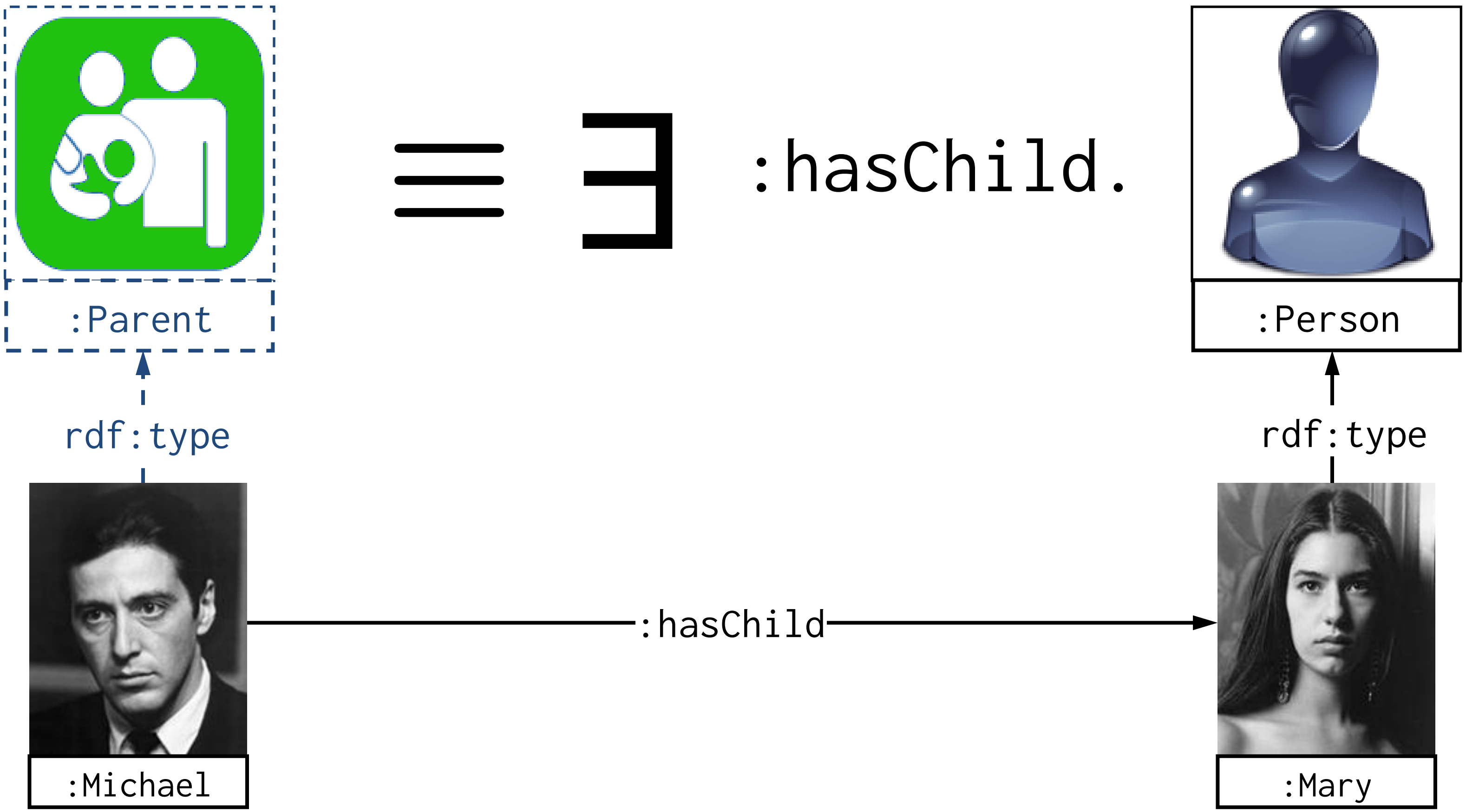
Need to be careful using ≡ with `owl:allValuesFrom`!

If all of X's parents are `:Person`s, X is a `:Person`.

But `:Choppy` does not have parents, so all its parents are trivially anything!

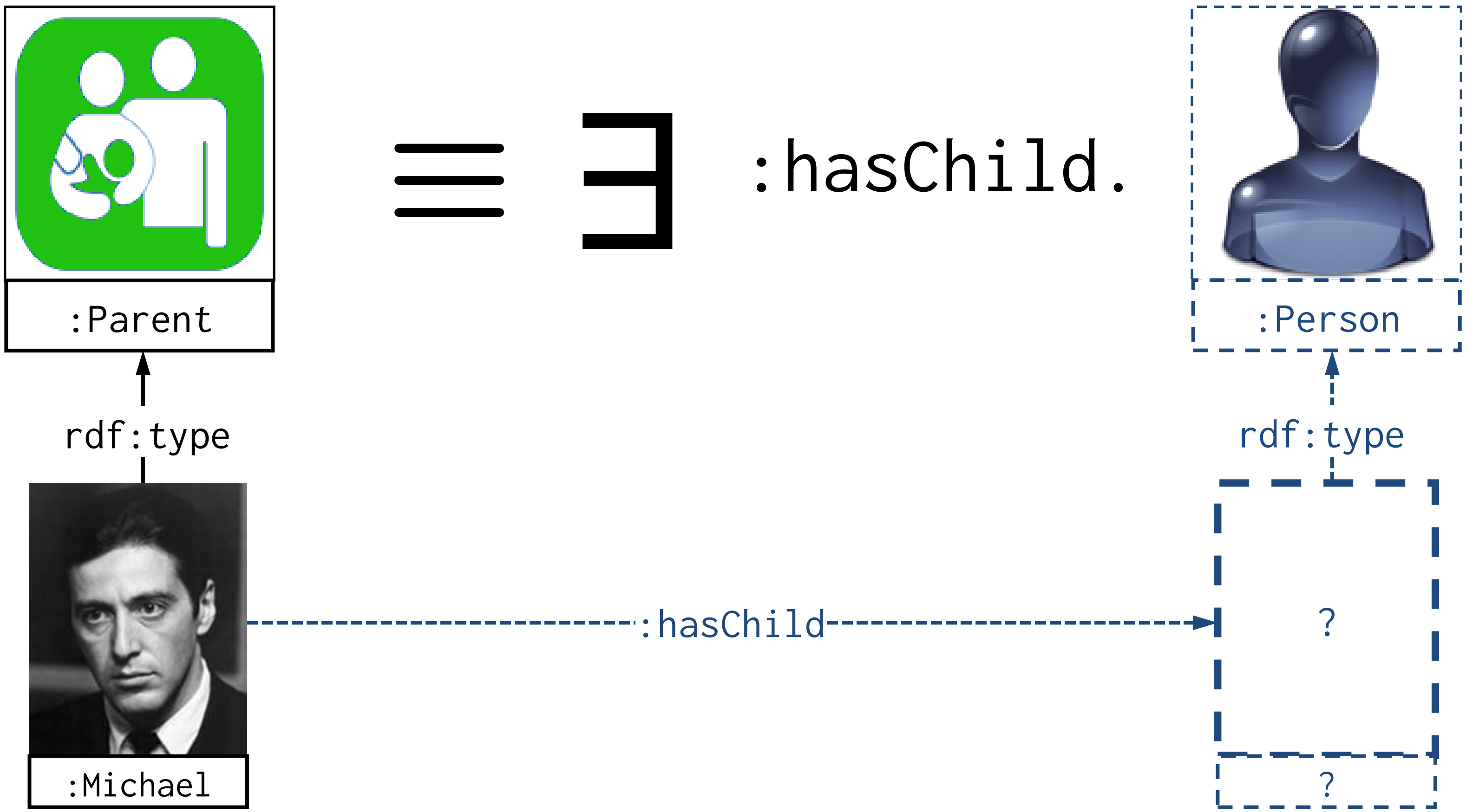
Thus `:Choppy` must be a `:Person`!

owl:someValuesFrom (∃) [I]




```
:Michael :hasChild :Mary . :Mary rdf:type :Person .
:Parent owl:equivalentClass
  [ owl:someValuesFrom :Person ; owl:onProperty :hasChild ]
⇒  :Michael rdf:type :Parent .
```

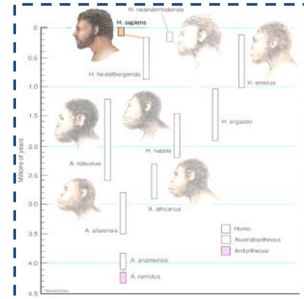
owl:someValuesFrom (∃) [II]




```
:Michael rdf:type :Parent .
:Parent owl:equivalentClass
  [ owl:someValuesFrom :Person ; owl:onProperty :hasChild ]
⇒  :Michael :hasChild _:someone . _:someone rdf:type :Person .
```

owl:hasValue ($\exists P.\{x\}$) [I]

:Person

$\sqsubseteq \exists$:species.{  }

:H.Sapiens

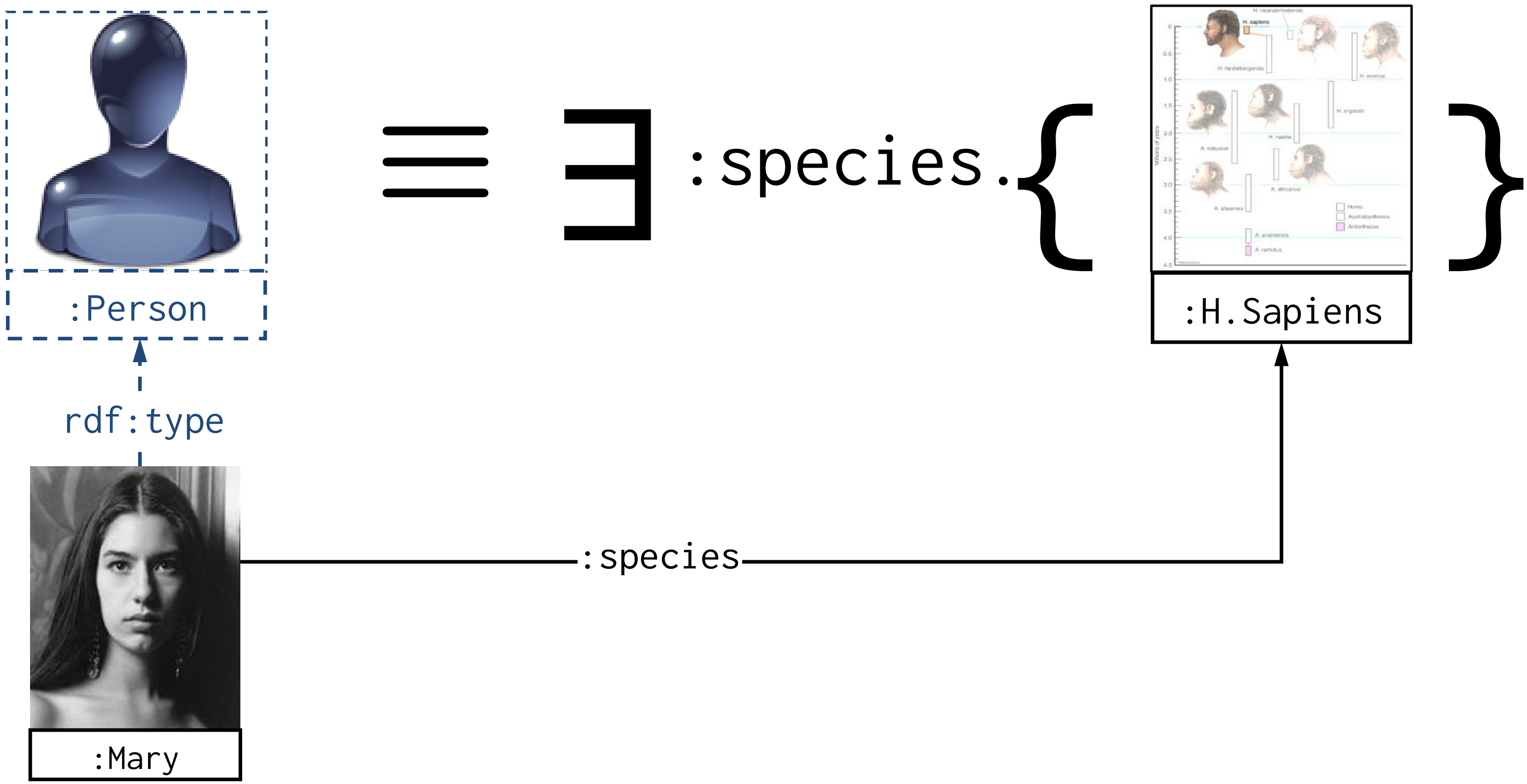
rdf:type

:Mary

:species

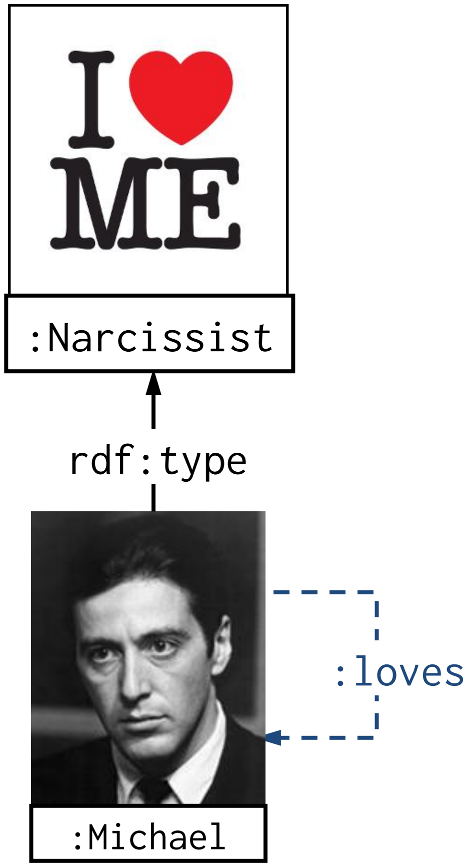
```
:Mary rdf:type :Person .
:Person rdfs:subClassOf
  [ owl:hasValue :H.Sapiens ; owl:onProperty :species ]
⇒  :Mary :species :H.Sapiens .
```

owl:hasValue ($\exists P.\{x\}$) [I]




```
:Mary :species :H.Sapiens .
:Person owl:equivalentClass
  [ owl:hasValue :H.Sapiens ; owl:onProperty :species ]
⇒  :Mary rdf:type :Person .
```

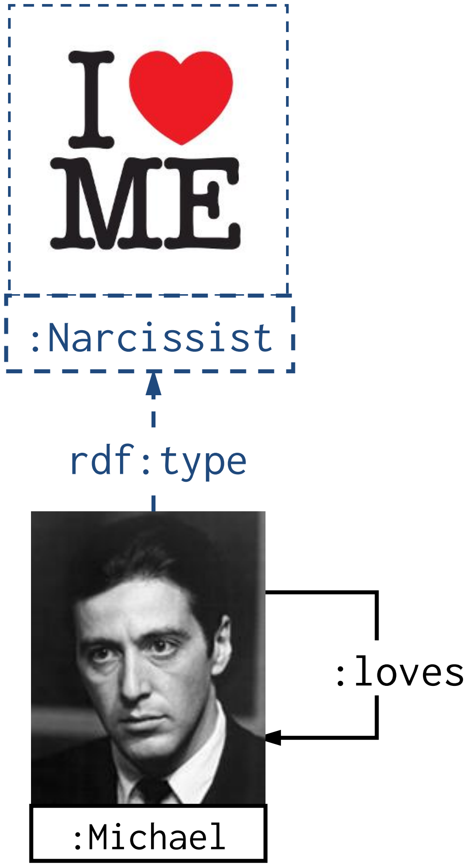
owl:hasSelf (Self) [I]



$\sqsubseteq$ Self(*:loves*)

```
:Michael rdf:type :Narcissist .
:Narcissist rdfs:subClassOf
  [ owl:hasSelf true ; owl:onProperty :loves ]
⇒  :Michael :loves :Michael .
```

owl:hasSelf (Self) [II]



$\equiv$ Self(:loves)

```
:Michael :loves :Michael .
:Narcissist owl:equivalentClass
  [ owl:hasSelf true ; owl:onProperty :loves ]
⇒  :Michael rdf:type Narcissist .
```

Cardinality restrictions ($\geq$, $\leq$, $=$)

- Define a class with a given number of values for a property:
  - Exact: :Person $\sqsubseteq$ = 2 (:hasBioParent)

```
:Person rdfs:subClassOf [ owl:cardinality 2 ;
                          owl:onProperty :hasBioParent ] .
```

  - Max: :Monogamist $\sqsubseteq$ ≤ 1 (:hasCurrentSpouse)

```
:Monogamist rdfs:subClassOf [ owl:maxCardinality 1 ;
                              owl:onProperty :hasCurrentSpouse ] .
```

  - Min: :Parent $\equiv$ ≥ 1 (:hasChild)

```
:Parent owl:equivalentClass [ owl:minCardinality 1 ;
                              owl:onProperty :hasChild ] .
```

QUALIFIED CARDINALITY RESTRICTIONS (≥, ≤,=)

- Define a class with a given number of values from a given class for a property:
  - Exact: $\texttt{:Biped} \equiv {=2}\ (\texttt{:hasLimb.Leg})$

```
:Biped owl:equivalentClass [ owl:qualifiedCardinality 2 ;
                             owl:onProperty :hasLimb ;
                             owl:onClass :Leg ] .
```

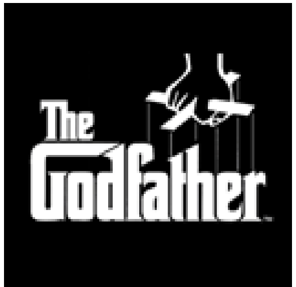
  - Max: $\texttt{:Mafia} \sqsubseteq\ \leq 1\ (\texttt{:hasCurrentMember.Godfather})$

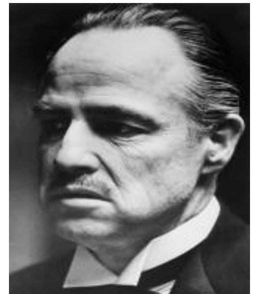
```
:Mafia rdfs:subClassOf [ owl:maxQualifiedCardinality 1 ;
                         owl:onProperty :hasCurrentMember ;
                         owl:onClass :Godfather ] .
```

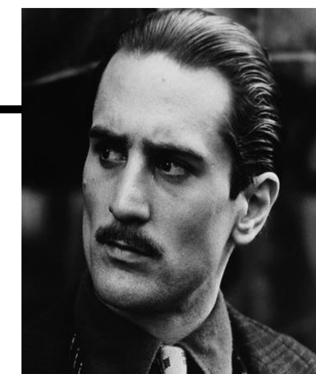
  - Min: $\texttt{:Twin} \sqsubseteq\ \geq 1\ (\texttt{:sibling.Twin})$

```
:Twin rdfs:subClassOf [ owl:minQualifiedCardinality 1 ;
                        owl:onProperty :sibling ;
                        owl:onClass :Twin ] .
```

Slides are examples, not definitions



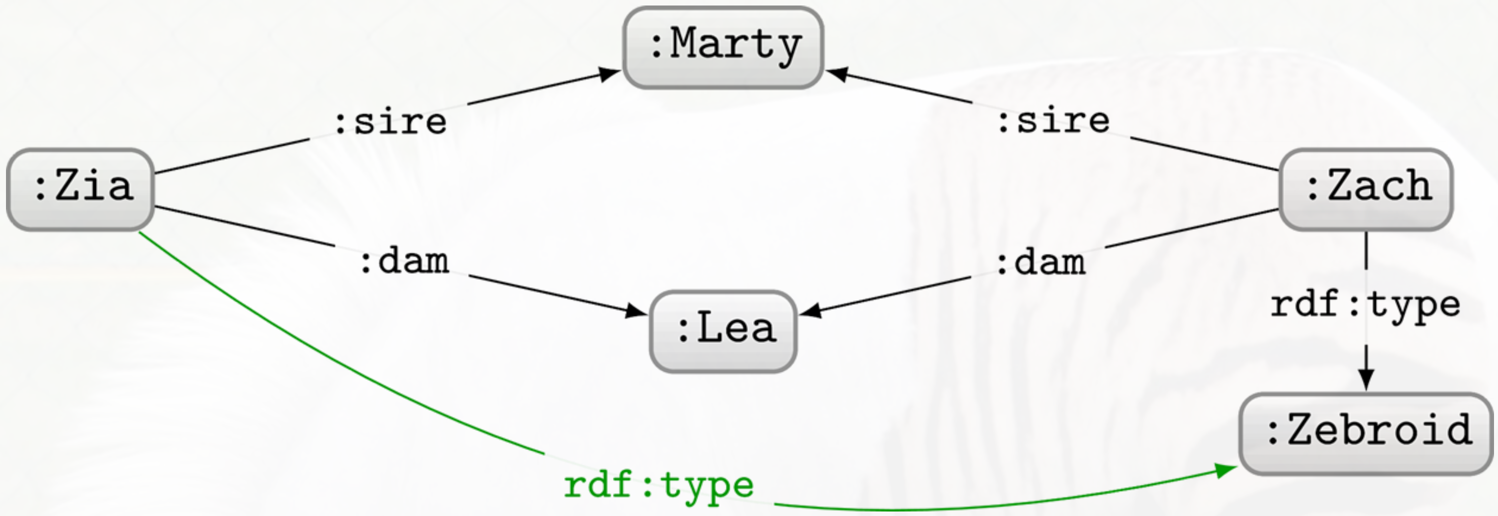
:Godfather ≡ {  :Vito ,  :Michael ,  :Vincent }



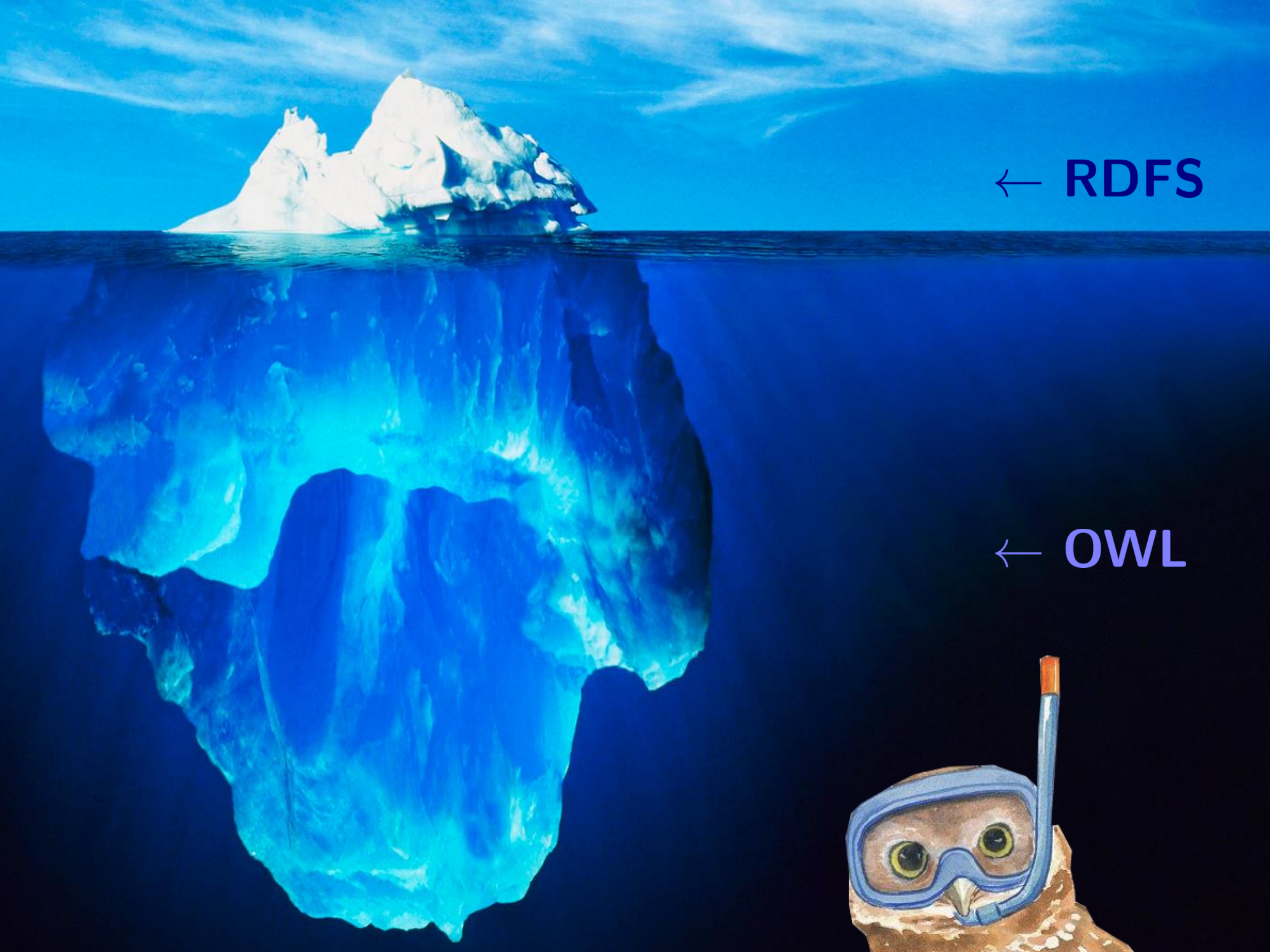
:VitoYoung

rdf:type

⇒ :VitoYoung must be owl:sameAs :Vito or :Michael or :Vincent



- sire is a sub-property of parent
- dam is a sub-property of parent
- A Zebroid has exactly one parent a Zebra
- A Zebroid has exactly one parent a (¬Zebra and a Equine)
- A Zebroid is a sub-class of Equine
- An Equine has exactly two parents
- Two things cannot be related by sire and dam at the same time


← RDFS
← OWL

Questions?