



OWL 2 Web Ontology Language: Mapping to RDF Graphs

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Abstract

OWL 2 extends the W3C OWL Web Ontology Language with a small but useful set of features that have been requested by users, for which effective reasoning algorithms are now available, and that OWL tool developers are willing to support. The new features include extra syntactic sugar, additional property and qualified cardinality constructors, extended datatype support, simple metamodeling, and extended annotations.

This document defines a mapping of OWL 2 ontology into the RDF syntax, and vice versa.

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Set of Documents

This document is being published as one of a set of 11 documents:

1. [Structural Specification and Functional-Style Syntax](#)
2. [Direct Semantics](#)
3. [RDF-Based Semantics](#)
4. [Conformance and Test Cases](#)
5. [Mapping to RDF Graphs](#) (this document)
6. [XML Serialization](#)
7. [Profiles](#)
8. [Quick Reference Guide](#)
9. [New Features and Rationale](#)
10. [Manchester Syntax](#)
11. [rdf:text: A Datatype for Internationalized Text](#)

Summary of Changes

This document has been updated to keep in sync with the Syntax document. Apart from that, the biggest change is in the new treatment of *owl:imports*, which is summarized in Section 3.1.

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1 Introduction and Preliminaries

This document defines mappings by means of which every OWL 2 ontology [[OWL 2 Specification](#)] can be mapped into an RDF graph and back. These transformations do not incur any change in the formal meaning of the ontology. More precisely, let O be any OWL 2 ontology, let $T(O)$ be the RDF graph obtained by transforming O as specified in [Section 2](#), and let O' be the OWL 2 ontology obtained by applying the reverse transformation from [Section 3](#) to $T(O)$; then, O and O' are logically equivalent — that is, they have exactly the same set of models.

The mappings presented in this document are backwards-compatible with that of OWL DL: every OWL DL ontology encoded as an RDF graph can be mapped into a valid OWL 2 ontology using the reverse-transformation from [Section 3](#) such that the resulting OWL 2 ontology has exactly the same set of models as the original OWL DL ontology.

The syntax for triples used in this document is the one used in the RDF Semantics [[RDF Semantics](#)]. Full IRIs are abbreviated using the namespaces from the OWL 2 Specification [[OWL 2 Specification](#)]. OWL 2 ontologies mentioned in this document should be understood as instances of the structural specification of OWL 2 [[OWL 2 Specification](#)]; when required, these are written in this document using the functional-style syntax.

The following notation is used throughout this document for referring to parts of RDF graphs:

- $*:x$ denotes an IRI reference;
- $_:x$ denotes a blank node;
- x denotes a blank node or an IRI reference; and
- lit denotes a literal.

The italicized keywords *must*, *must not*, *should*, *should not*, and *may* specify certain aspects of the normative behavior of OWL 2 tools, and are interpreted as specified in RFC 2119 [[RFC 2119](#)].

2 Mapping from the Structural Specification to RDF Graphs

This section defines a mapping of an OWL 2 ontology O into an RDF graph $T(O)$. The mapping is presented in three parts. [Section 2.1](#) shows how to translate axioms that do not contain annotations, [Section 2.2](#) shows how to translate annotations, and [Section 2.3](#) shows how to translate axioms containing annotations.

2.1 Translation of Axioms without Annotations

Table 1 presents the operator T that maps an OWL 2 ontology O into an RDF graph $T(O)$, provided that no axiom in O is annotated. The mapping is defined recursively; that is, the mapping of a construct often depends on the mappings of its subconstructs, but in a slightly unusual way: if the mapping of a construct refers to the mapping of a subconstruct, then the triples generated by the recursive invocation of T are added to the graph under construction, and its *main node* is used in place of the invocation itself.

The definition of the operator T uses the operator $TANN$ in order to translate annotations. The operator $TANN$ is defined in [Section 2.2](#). It takes an annotation and an IRI reference or a blank node and produces the triples that attach the annotation to the supplied object.

In the mapping, each generated blank node (i.e., each blank node that does not correspond to an anonymous individual) is fresh in each application of a mapping rule. Furthermore, the following conventions are used in this section to denote different parts of OWL 2 ontologies:

- OP denotes an object property;
- OPE denotes an object property expression;
- DP denotes a data property;
- DPE denotes a data property expression;
- PE denotes an object or a data property expression;
- AP denotes an annotation property;
- C denotes a class;
- CE denotes a class expression;
- DT denotes a datatype;
- DR denotes a data range;
- U denotes an IRI;
- F denotes a constraining facet;
- a denotes an individual (named or anonymous);
- $*:a$ denotes a named individual;
- lt denotes a literal;
- as denotes an annotation source; and
- av denotes an annotation value.

In this section, $T(SEQ\ y_1\ \dots\ y_n)$ denotes the translation of a sequence of objects from the structural specification into an RDF list, as shown in Table 1.

Table 1. Transformation to Triples

Element E of the Structural Specification	Triples Generated in an Invocation of $T(E)$	Main Node of $T(E)$
SEQ		<i>rdf:nil</i>

SEQ Y ₁ ... Y _n	<code>_:x rdf:first T(y₁)</code> <code>_:x rdf:rest T(SEQ y₂ ... y_n)</code>	<code>_:x</code>
<pre> Ontology(ontologyIRI [versionIRI] Import(importedOntologyIRI₁) ... Import(importedOntologyIRI_k) annotation₁ ... annotation_m axiom₁ ... axiom_n) </pre>	<pre> ontologyIRI rdf:type owl:Ontology [ontologyIRI owl:versionInfo versionIRI] ontologyIRI owl:imports importedOntologyIRI₁ ... ontologyIRI owl:imports importedOntologyIRI_k TANN(annotation₁, ontologyIRI) ... TANN(annotation_m, ontologyIRI) T(axiom₁) ... T(axiom_n) </pre>	ontologyIRI
<pre> Ontology(Import(importedOntologyIRI₁) ... Import(importedOntologyIRI_k) annotation₁ ... annotation_m axiom₁ ... axiom_n) </pre>	<pre> _:x rdf:type owl:Ontology _:x owl:imports importedOntologyIRI₁ ... _:x owl:imports importedOntologyIRI_k TANN(annotation₁, _:x) ... TANN(annotation_m, _:x) T(axiom₁) ... T(axiom_n) </pre>	<code>_:x</code>
C		C
DT		DT
OP		OP
DP		DP
AP		AP
U		U
a		a
lt		lt

Declaration(Datatype(DT))	T(DT) <i>rdf:type rdfs:Datatype</i>	
Declaration(Class(C))	T(C) <i>rdf:type owl:Class</i>	
Declaration(ObjectProperty(OP))	T(OP) <i>rdf:type owl:ObjectProperty</i>	
Declaration(DataProperty(DP))	T(DP) <i>rdf:type owl:DatatypeProperty</i>	
Declaration(AnnotationProperty(AP))	T(AP) <i>rdf:type owl:AnnotationProperty</i>	
Declaration(NamedIndividual(*:a))	T(*:a) <i>rdf:type owl:NamedIndividual</i>	
InverseOf(OP)	<i>_:x owl:inverseOf</i> T(OP)	<i>_:x</i>
IntersectionOf(DR ₁ ... DR _n)	<i>_:x rdf:type rdfs:Datatype</i> <i>_:x owl:intersectionOf</i> T(SEQ DR ₁ ... DR _n)	<i>_:x</i>
UnionOf(DR ₁ ... DR _n)	<i>_:x rdf:type rdfs:Datatype</i> <i>_:x owl:unionOf</i> T(SEQ DR ₁ ... DR _n)	<i>_:x</i>
ComplementOf(DR)	<i>_:x rdf:type rdfs:Datatype</i> <i>_:x owl:datatypeComplementOf</i> T(DR)	<i>_:x</i>
OneOf(lt ₁ ... lt _n)	<i>_:x rdf:type rdfs:Datatype</i> <i>_:x owl:oneOf</i> T(SEQ lt ₁ ... lt _n)	<i>_:x</i>
DatatypeRestriction(DT F ₁ lt ₁ ... F _n lt _n)	<i>_:x rdf:type rdfs:Datatype</i> <i>_:x owl:onDatatype</i> T(DT) <i>_:x owl:withRestrictions</i> T(SEQ <i>_:y</i> ₁ ... <i>_:y</i> _n) <i>_:y</i> ₁ F ₁ lt ₁ ... <i>_:y</i> _n F _n lt _n	<i>_:x</i>
IntersectionOf(CE ₁ ... CE _n)	<i>_:x rdf:type owl:Class</i> <i>_:x owl:intersectionOf</i> T(SEQ CE ₁ ... CE _n)	<i>_:x</i>
UnionOf(CE ₁ ... CE _n)	<i>_:x rdf:type owl:Class</i> <i>_:x owl:unionOf</i> T(SEQ CE ₁ ... CE _n)	<i>_:x</i>

ComplementOf(CE)	<code>_:x rdf:type owl:Class _:x owl:complementOf T(CE)</code>	<code>_:x</code>
OneOf(a ₁ ... a _n)	<code>_:x rdf:type owl:Class _:x owl:oneOf T(SEQ a₁ ... a_n)</code>	<code>_:x</code>
SomeValuesFrom(OPE CE)	<code>_:x rdf:type owl:Restriction _:x owl:onProperty T(OPE) _:x owl:someValuesFrom T(CE)</code>	<code>_:x</code>
AllValuesFrom(OPE CE)	<code>_:x rdf:type owl:Restriction _:x owl:onProperty T(OPE) _:x owl:allValuesFrom T(CE)</code>	<code>_:x</code>
HasValue(OPE a)	<code>_:x rdf:type owl:Restriction _:x owl:onProperty T(OPE) _:x owl:hasValue T(a)</code>	<code>_:x</code>
HasSelf(OPE)	<code>_:x rdf:type owl:Restriction _:x owl:onProperty T(OPE) _:x owl:hasSelf "true"^^xsd:boolean</code>	<code>_:x</code>
MinCardinality(n OPE)	<code>_:x rdf:type owl:Restriction _:x owl:minCardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(OPE)</code>	<code>_:x</code>
MinCardinality(n OPE CE)	<code>_:x rdf:type owl:Restriction _:x owl:minQualifiedCardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(OPE) _:x owl:onClass T(CE)</code>	<code>_:x</code>
MaxCardinality(n OPE)	<code>_:x rdf:type owl:Restriction _:x owl:maxCardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(OPE)</code>	<code>_:x</code>
MaxCardinality(n OPE CE)	<code>_:x rdf:type owl:Restriction _:x owl:maxQualifiedCardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(OPE) _:x owl:onClass T(CE)</code>	<code>_:x</code>
ExactCardinality(n OPE)	<code>_:x rdf:type owl:Restriction _:x owl:cardinality</code>	<code>_:x</code>

	<code>"n"^^xsd:nonNegativeInteger _:x owl:onProperty T(OPE)</code>	
<code>ExactCardinality(n OPE CE)</code>	<code>_:x rdf:type owl:Restriction _:x owl:qualifiedCardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(OPE) _:x owl:onClass T(CE)</code>	<code>_:x</code>
<code>SomeValuesFrom(DPE DR)</code>	<code>_:x rdf:type owl:Restriction _:x owl:onProperty T(DPE) _:x owl:someValuesFrom T(DR)</code>	<code>_:x</code>
<code>SomeValuesFrom(DPE₁ ... DPE_n DR), n ≥ 2</code>	<code>_:x rdf:type owl:Restriction _:x owl:onProperties T(SEQ DPE₁ ... DPE_n) _:x owl:someValuesFrom T(DR)</code>	<code>_:x</code>
<code>AllValuesFrom(DPE DR)</code>	<code>_:x rdf:type owl:Restriction _:x owl:onProperty T(DPE) _:x owl:allValuesFrom T(DR)</code>	<code>_:x</code>
<code>AllValuesFrom(DPE₁ ... DPE_n DR), n ≥ 2</code>	<code>_:x rdf:type owl:Restriction _:x owl:onProperties T(SEQ DPE₁ ... DPE_n) _:x owl:allValuesFrom T(DR)</code>	<code>_:x</code>
<code>HasValue(DPE lt)</code>	<code>_:x rdf:type owl:Restriction _:x owl:onProperty T(DPE) _:x owl:hasValue T(lt)</code>	<code>_:x</code>
<code>MinCardinality(n DPE)</code>	<code>_:x rdf:type owl:Restriction _:x owl:minCardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(DPE)</code>	<code>_:x</code>
<code>MinCardinality(n DPE DR)</code>	<code>_:x rdf:type owl:Restriction _:x owl:minQualifiedCardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(DPE) _:x owl:onDataRange T(DR)</code>	<code>_:x</code>
<code>MaxCardinality(n DPE)</code>	<code>_:x rdf:type owl:Restriction _:x owl:maxCardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(DPE)</code>	<code>_:x</code>
<code>MaxCardinality(n DPE DR)</code>	<code>_:x rdf:type owl:Restriction _:x</code>	<code>_:x</code>

	<pre>owl:maxQualifiedCardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(DPE) _:x owl:onDataRange T(DR)</pre>	
ExactCardinality(n DPE)	<pre>_:x rdf:type owl:Restriction _:x owl:cardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(DPE)</pre>	_:x
ExactCardinality(n DPE DR)	<pre>_:x rdf:type owl:Restriction _:x owl:qualifiedCardinality "n"^^xsd:nonNegativeInteger _:x owl:onProperty T(DPE) _:x owl:onDataRange T(DR)</pre>	_:x
SubClassOf(CE ₁ CE ₂)	T(CE ₁) <i>rdfs:subClassOf</i> T(CE ₂)	
EquivalentClasses(CE ₁ ... CE _n)	<pre>T(CE₁) owl:equivalentClass T(CE₂) ... T(CE_{n-1}) owl:equivalentClass T(CE_n)</pre>	
DisjointClasses(CE ₁ CE ₂)	T(CE ₁) <i>owl:disjointWith</i> T(CE ₂)	
DisjointClasses(CE ₁ ... CE _n), n > 2	<pre>_:x rdf:type owl:AllDisjointClasses _:x owl:members T(SEQ CE₁ ... CE_n)</pre>	
DisjointUnion(C CE ₁ ... CE _n)	T(C) <i>owl:disjointUnionOf</i> T(SEQ CE ₁ ... CE _n)	
SubPropertyOf(OPE ₁ OPE ₂)	T(OPE ₁) <i>rdfs:subPropertyOf</i> T(OPE ₂)	
SubPropertyOf(PropertyChain(OPE ₁ ... OPE _n) OPE)	<pre>_:x rdfs:subPropertyOf T(OPE) _:x owl:propertyChain T(SEQ OPE₁ ... OPE_n)</pre>	
EquivalentProperties(OPE ₁ ... OPE _n)	<pre>T(OPE₁) owl:equivalentProperty T(OPE₂) ... T(OPE_{n-1}) owl:equivalentProperty T(OPE_n)</pre>	

DisjointProperties(OPE ₁ OPE ₂)	T(op ₁) <i>owl:propertyDisjointWith</i> T(op ₂)	
DisjointProperties(OPE ₁ ... OPE _n), n > 2	<i>_:x rdf:type</i> <i>owl:AllDisjointProperties</i> <i>_:x owl:members</i> T(SEQ OPE ₁ ... OPE _n)	
PropertyDomain(OPE CE)	T(OPE) <i>rdfs:domain</i> T(CE)	
PropertyRange(OPE CE)	T(OPE) <i>rdfs:range</i> T(CE)	
InverseProperties(OPE ₁ OPE ₂)	T(OPE ₁) <i>owl:inverseOf</i> T(OPE ₂)	
FunctionalProperty(OPE)	T(OPE) <i>rdf:type</i> <i>owl:FunctionalProperty</i>	
InverseFunctionalProperty(OPE)	T(OPE) <i>rdf:type</i> <i>owl:InverseFunctionalProperty</i>	
ReflexiveProperty(OPE)	T(OPE) <i>rdf:type</i> <i>owl:ReflexiveProperty</i>	
IrreflexiveProperty(OPE)	T(OPE) <i>rdf:type</i> <i>owl:IrreflexiveProperty</i>	
SymmetricProperty(OPE)	T(OPE) <i>rdf:type</i> <i>owl:SymmetricProperty</i>	
AsymmetricProperty(OPE)	T(OPE) <i>rdf:type</i> <i>owl:AsymmetricProperty</i>	
TransitiveProperty(OPE)	T(OPE) <i>rdf:type</i> <i>owl:TransitiveProperty</i>	
SubPropertyOf(DPE ₁ DPE ₂)	T(DPE ₁) <i>rdfs:subPropertyOf</i> T(DPE ₂)	
EquivalentProperties(DPE ₁ ... DPE _n)	T(DPE ₁) <i>owl:equivalentProperty</i> T(DPE ₂) ... T(DPE _{n-1}) <i>owl:equivalentProperty</i> T(DPE _n)	
DisjointProperties(DPE ₁ DPE ₂)	T(DPE ₁) <i>owl:propertyDisjointWith</i> T(DPE ₂)	

DisjointProperties(DPE ₁ ... DPE _n), n > 2	<i>_:x rdf:type owl:AllDisjointProperties</i> <i>_:x owl:members T(SEQ DPE₁ ... DPE_n)</i>	
PropertyDomain(DPE CE)	<i>T(DPE) rdfs:domain T(CE)</i>	
PropertyRange(DPE DR)	<i>T(DPE) rdfs:range T(DR)</i>	
FunctionalProperty(DPE)	<i>T(DPE) rdf:type owl:FunctionalProperty</i>	
HasKey(CE PE ₁ ... PE _n)	<i>T(CE) owl:hasKey T(SEQ PE₁ ... PE_n)</i>	
SameIndividual(a ₁ ... a _n)	<i>T(a₁) owl:sameAs T(a₂)</i> ... <i>T(a_{n-1}) owl:sameAs T(a_n)</i>	
DifferentIndividuals(a ₁ a ₂)	<i>T(a₁) owl:differentFrom T(a₂)</i>	
DifferentIndividuals(a ₁ ... a _n), n > 2	<i>_:x rdf:type owl:AllDifferent</i> <i>_:x owl:members T(SEQ a₁ ... a_n)</i>	
ClassAssertion(CE a)	<i>T(a) rdf:type T(CE)</i>	
PropertyAssertion(OP a ₁ a ₂)	<i>T(a₁) T(OP) T(a₂)</i>	
PropertyAssertion(InverseOf(OP) a ₁ a ₂)	<i>T(a₂) T(OP) T(a₁)</i>	
NegativePropertyAssertion(OPE a ₁ a ₂)	<i>_:x rdf:type owl:NegativePropertyAssertion</i> <i>_:x owl:sourceIndividual T(a₁)</i> <i>_:x owl:assertionProperty T(OPE)</i> <i>_:x owl:targetIndividual T(a₂)</i>	
PropertyAssertion(DPE a lt)	<i>T(a) T(DPE) T(lt)</i>	
NegativePropertyAssertion(DPE a lt)	<i>_:x rdf:type owl:NegativePropertyAssertion</i> <i>_:x owl:sourceIndividual T(a)</i> <i>_:x owl:assertionProperty</i>	

	<code>T(DPE)</code> <code>_:x owl:targetValue T(lt)</code>	
<code>AnnotationAssertion(AP as av)</code>	<code>T(as) T(AP) T(av)</code>	
<code>SubPropertyOf(AP₁ AP₂)</code>	<code>T(AP₁) rdfs:subPropertyOf</code> <code>T(AP₂)</code>	
<code>PropertyDomain(AP U)</code>	<code>T(AP) rdfs:domain T(U)</code>	
<code>PropertyRange(AP U)</code>	<code>T(AP) rdfs:range T(U)</code>	

2.2 Translation of Annotations

The operator *TANN*, which translates annotations and attaches them to an IRI reference or a blank node, is defined in Table 2.

Table 2. Translation of Annotations

Annotation <i>ann</i>	Triples Generated in an Invocation of <i>TANN(ann, y)</i>
<code>Annotation(AP av)</code>	<code>T(y) T(AP) T(av)</code>
<code>Annotation(annotation₁ ... annotation_n AP av)</code>	<code>T(y) T(AP) T(av)</code> <code>_:x rdf:type owl:Annotation</code> <code>_:x owl:subject T(y)</code> <code>_:x owl:predicate T(AP)</code> <code>_:x owl:object T(av)</code> <code>TANN(annotation₁, _:x)</code> <code>...</code> <code>TANN(annotation_n, _:x)</code>

Example:

Consider the following axiom that associates the IRI *a:Peter* with a simple label.

```
AnnotationAssertion( rdfs:label a:Peter "Peter Griffin" )
```

This axiom is translated into the following triple:

```
a:Peter rdfs:label "Peter Griffin"^^xsd:string
```

Example:

Consider the following axiom that associates *a:Peter* with an annotation containing a nested annotation.

```
AnnotationAssertion( a:Peter
  Annotation(
    Annotation( a:author a:Seth_MacFarlane )
    rdfs:label "Peter Griffin"
  )
)
```

This axiom is translated into the following triples:

```
a:Peter rdfs:label "Peter Griffin"^^xsd:string
_:x rdf:type owl:Annotation
_:x owl:subject a:Peter
_:x owl:predicate rdfs:label
_:x owl:object "Peter Griffin"^^xsd:string
_:x a:author a:Seth_MacFarlane
```

2.3 Translation of Axioms with Annotations

If an axiom *ax* contains embedded annotations *annotation₁* ... *annotation_m*, its serialization into RDF depends on the type of the axiom. Let *ax'* be the axiom that is obtained from *ax* by removing all axiom annotations.

2.3.1 Axioms that Generate a Single Triple or that Have a Main Triple

If *ax'* is translated into a single RDF triple *s p o*, then the axiom *ax* is translated into the following triples:

```
s p o
_:x rdf:type owl:Axiom
_:x owl:subject s
_:x owl:predicate p
_:x owl:object o
TANN(annotation1, _:x)
...
TANN(annotationm, _:x)
```

This is the case for the following axioms: **SubClassOf**, **DisjointClasses** with two classes, **SubPropertyOf** without a property chain as the subproperty expression, **PropertyDomain**, **PropertyRange**, **InverseProperties**, **FunctionalProperty**, **InverseFunctionalProperty**, **ReflexiveProperty**, **IrreflexiveProperty**, **SymmetricProperty**, **AsymmetricProperty**, **TransitiveProperty**, **DisjointProperties**

with two properties, **ClassAssertion**, **PropertyAssertion**, **Declaration**, **DifferentIndividuals** with two individuals, and **AnnotationAssertion**.

Example:

Consider the following subclass axiom:

```
SubClassOf( Annotation( rdfs:comment "Children are
people." ) a:Child a:Person )
```

Without the annotation, the axiom would be translated into the following triple:

```
a:Child rdfs:subClassOf a:Person
```

Thus, the annotated axiom is transformed into the following triples:

```
a:Child rdfs:subClassOf a:Person
_:x rdf:type owl:Axiom
_:x owl:subject a:Child
_:x owl:predicate rdfs:subClassOf
_:x owl:object a:Person
_:x rdfs:comment "Children are people."^^xsd:string
```

DisjointUnion, **SubPropertyOf** with a subproperty chain, and **HasKey** axioms are, without annotations, translated into several, and not a single triple. If such axioms are annotated, then the *main* triple is subjected to the transformation described above. The other triples — called *side* triples — are output without any change.

Example:

Consider the following subproperty axiom:

```
SubPropertyOf( Annotation( rdfs:comment "An aunt is a
mother's sister." ) PropertyChain( a:hasMother
a:hasSister ) a:hasAunt ) )
```

Without the annotation, the axiom would be translated into the following triples:

```
_:y rdfs:subPropertyOf a:hasAunt
_:y owl:propertyChain _:z1
_:z1 rdf:first a:hasMother
_:z1 rdf:rest _:z2
_:z2 rdf:first a:hasSister
_:z2 rdf:rest rdf:nil
```

In order to capture the annotation on the axiom, the first triple plays the role of the main triple for the axiom, so it is represented using a fresh blank node `_:x` in order to be able to attach the annotation to it. The original triple is output alongside all other triples as well.

```
_:x rdf:type owl:Axiom
_:x owl:subject _:y
_:x owl:predicate rdfs:subPropertyOf
_:x owl:object a:hasAunt
_:x rdfs:comment "An aunt is a mother's
sister."^^xsd:string

_:y rdfs:subPropertyOf a:hasAunt
_:y owl:propertyChain _:z1
_:z1 rdf:first a:hasMother
_:z1 rdf:rest _:z2
_:z2 rdf:first a:hasSister
_:z2 rdf:rest rdf:nil
```

Example:

Consider the following key axiom:

```
HasKey( Annotation( rdfs:comment "SSN uniquely
determines a person." ) a:Person a:hasSSN )
```

Without the annotation, the axiom would be translated into the following triples:

```
a:Person owl:hasKey _:y
_:y rdf:first a:hasSSN
_:y rdf:rest rdf:nil
```

In order to capture the annotation on the axiom, the first triple plays the role of the main triple for the axiom, so it is represented using a fresh blank node `_:x` in order to be able to attach the annotation to it.

```
_:x rdf:type owl:Axiom
_:x owl:subject a:Person
_:x owl:predicate owl:hasKey
_:x owl:object _:y
_:x rdfs:comment "SSN uniquely determines a
person."^^xsd:string

a:Person owl:hasKey _:y
_:y rdf:first a:hasSSN
_:y rdf:rest rdf:nil
```


2.3.2 Axioms that are Translated to Multiple Triples

If the axiom ax' is of type **EquivalentClasses**, **EquivalentProperties**, or **SameIndividual**, its translation into RDF can be broken up into several RDF triples (because RDF can only represent binary relations). In this case, each of the RDF triples obtained by the translation of ax' is transformed as described in previous section, and the annotations are repeated for each of the triples obtained in the translation.

Example:

Consider the following individual equality axiom:

```
SameIndividual( Annotation( a:source a:Fox ) a:Meg
a:Megan a:Megan_Griffin )
```

This axiom is first split into the following equalities between pairs of individuals, and the annotation is repeated on each axiom obtained in this process:

```
SameIndividual( Annotation( a:source a:Fox ) a:Meg
a:Megan )
SameIndividual( Annotation( a:source a:Fox ) a:Megan
a:Megan_Griffin )
```

Each of these axioms is now transformed into triples as explained in the previous section:

```
a:Meg owl:sameAs a:Megan
_:x1 rdf:type owl:Axiom
_:x1 owl:subject a:Meg
_:x1 owl:predicate owl:sameAs
_:x1 owl:object a:Megan
_:x1 a:source a:Fox

a:Megan owl:sameAs a:Megan_Griffin
_:x2 rdf:type owl:Axiom
_:x2 owl:subject a:Megan
_:x2 owl:predicate owl:sameAs
_:x2 owl:object a:Megan_Griffin
_:x2 a:source a:Fox
```

2.3.3 Axioms Represented by Blank Nodes

If the axiom ax' is of type **NegativePropertyAssertion**, **DisjointClasses** with more than two classes, **DisjointObjectProperties** or **DisjointDataProperties** with more than two properties, or **DifferentIndividuals** with more than two individuals, then its

translation already requires introducing a blank node `_:x`. In such cases, `ax` is translated by first translating `ax'` into `_:x` as shown in Table 1, and then attaching the annotations of `ax` to `_:x`.

Example:

Consider the following negative property assertion:

```
NegativePropertyAssertion( Annotation( a:author
a:Seth_MacFarlane ) a:brotherOf a:Chris a:Stewie )
```

Even without the annotation, this axiom would be represented using a blank node. The annotation can readily be attached to this node, so the axiom is transformed into the following triples:

```
_:x rdf:type owl:NegativePropertyAssertion
_:x owl:sourceIndividual a:Chris
_:x owl:assertionProperty a:brotherOf
_:x owl:targetIndividual a:Stewie
_:x a:author a:Seth_MacFarlane
```

3 Mapping from RDF Graphs to the Structural Specification

This section specifies the results of steps CP-2.2 and CP-3.3 of the canonical parsing process from Section 3.6 of the OWL 2 Specification [[OWL 2 Specification](#)] on an ontology document *D* that can be parsed into an RDF graph *G*. An OWL 2 tool *may* implement these steps in any way it chooses; however, the results *must* be structurally equivalent to the ones defined in the following sections. These steps do not depend on the RDF syntax used to encode the RDF graph in *D*; therefore, the ontology document *D* is identified in this section with the corresponding RDF graph *G*.

An *RDF syntax ontology document* is any sequence of octets accessible from some given IRI that can be parsed into an RDF graph, and that then be transformed into an OWL 2 ontology by the canonical parsing process instantiated as specified in this section.

The following sections contain rules in which triple patterns are matched to *G*. If a triple pattern contains a variable number of triples, the maximal possible subset of *G* *must* be matched. The following notation is used in the patterns:

- The notation `NN_INT (n)` can be matched to any literal whose value *n* is a nonnegative integer.
- Possible conditions on the pattern are enclosed in curly braces `{ }`.
- Some patterns use optional parts, which are enclosed in square brackets `[]`.

- The abbreviation $T(\text{SEQ } Y_1 \dots Y_n)$ denotes the pattern corresponding to RDF lists, as shown in Table 3.

Table 3. Patterns Corresponding to RDF Lists

Sequence S	Triples Corresponding to $T(S)$	Main Node of $T(S)$
SEQ		<i>rdf:nil</i>
SEQ $Y_1 \dots Y_n$	$_ :x \text{ rdf:first } y_1$ $_ :x \text{ rdf:rest } T(\text{SEQ } y_2 \dots y_n)$	$_ :x$

3.1 Extracting Declarations and the IRIs of the Directly Imported Ontology Documents

This section specifies the result of step CP-2.2 of the canonical parsing process on an RDF graph G

3.1.1 Resolving Included RDF Graphs

For backwards compatibility with OWL DL, if G contains an *owl:imports* triple pointing to an RDF graph G' and G' does not have an ontology header, this *owl:imports* triple is interpreted as an *include* rather than an import — that is, the triples of G' are included into G and are not parsed into a separate ontology. To achieve this, the following transformation is applied to G as long as the following rule is applicable to G .

If G contains a pair of triples of the form

```
x rdf:type owl:Ontology
x owl:imports *:y
```

and the values for x and $*:y$ have not already been considered, the following actions are performed:

- The ontology document accessible from the IRI $*:y$ is retrieved as specified in Section 3.2 of the OWL 2 Specification [[OWL 2 Specification](#)].
- The document is parsed into an RDF graph G' using an appropriate RDF syntax.
- If the parsing succeeds and the graph G' does not contain a triple of the form

```
z rdf:type owl:Ontology
```

then G' is merged (as in RDF Semantics [[RDF Semantics](#)]) into G and the triple

```
x owl:imports *:y
```

is removed from G .

3.1.2 Parsing of the Ontology Header and Declarations

Next, the ontology header is extracted from *G* by matching patterns from Table 4 to *G*. It *must* be possible to match exactly one such pattern to *G* in exactly one way. The matched triples are removed from *G*. The set *Imp(G)* of the IRIs of ontology documents that are directly imported into *G* contains exactly all **:z₁*, ..., **:z_k* that are matched in the pattern.

Table 4. Parsing of the Ontology Header

If <i>G</i> contains this pattern...	...then the ontology header has this form.
<pre> *:x rdf:type owl:Ontology [*:x owl:versionInfo *:y] *:x owl:imports *:z₁ ... *:x owl:imports *:z_k { The following triple pattern cannot be matched in <i>G</i>: u w *:x u rdf:type owl:Ontology w rdf:type owl:OntologyProperty } </pre>	<pre> Ontology(*:x [*:y] Import(*:z₁) ... Import(*:z_k) ...) </pre>
<pre> _:x rdf:type owl:Ontology _:x owl:imports *:z₁ ... _:x owl:imports *:z_k { The following triple pattern cannot be matched in <i>G</i>: u w _:x u rdf:type owl:Ontology w rdf:type owl:OntologyProperty } </pre>	<pre> Ontology(Import(*:z₁) ... Import(*:z_k) ...) </pre>

Next, for backwards compatibility with OWL DL, certain redundant triples are removed from *G*. In particular, if the triple pattern from the left-hand side of Table 5 is matched in *G*, then the triples on the right-hand side of Table 5 are removed from *G*.

Table 5. Triples to be Removed for Backwards Compatibility with OWL DL

If <i>G</i> contains this pattern...	...then these triples are removed from <i>G</i> .
<pre> x rdf:type owl:Ontology </pre>	<pre> x rdf:type owl:Ontology </pre>

<pre>x rdf:type owl:Class x rdf:type rdfs:Class</pre>	<pre>x rdf:type rdfs:Class</pre>
<pre>x rdf:type rdfs:Datatype x rdf:type rdfs:Class</pre>	<pre>x rdf:type rdfs:Class</pre>
<pre>x rdf:type owl:DataRange x rdf:type rdfs:Class</pre>	<pre>x rdf:type rdfs:Class</pre>
<pre>x rdf:type owl:Restriction x rdf:type rdfs:Class</pre>	<pre>x rdf:type rdfs:Class</pre>
<pre>x rdf:type owl:Restriction x rdf:type owl:Class</pre>	<pre>x rdf:type owl:Class</pre>
<pre>x rdf:type owl:ObjectProperty x rdf:type rdf:Property</pre>	<pre>x rdf:type rdf:Property</pre>
<pre>x rdf:type owl:FunctionalProperty x rdf:type rdf:Property</pre>	<pre>x rdf:type rdf:Property</pre>
<pre>x rdf:type owl:InverseFunctionalProperty x rdf:type rdf:Property</pre>	<pre>x rdf:type rdf:Property</pre>
<pre>x rdf:type owl:TransitiveProperty x rdf:type rdf:Property</pre>	<pre>x rdf:type rdf:Property</pre>
<pre>x rdf:type owl:DatatypeProperty x rdf:type rdf:Property</pre>	<pre>x rdf:type rdf:Property</pre>
<pre>x rdf:type owl:AnnotationProperty x rdf:type rdf:Property</pre>	<pre>x rdf:type rdf:Property</pre>
<pre>x rdf:type owl:OntologyProperty x rdf:type rdf:Property</pre>	<pre>x rdf:type rdf:Property</pre>
<pre>x rdf:type rdf:List x rdf:first y x rdf:rest z</pre>	<pre>x rdf:type rdf:List</pre>

Next, for backwards compatibility with OWL DL, *G* is modified such that declarations can be properly extracted in the next step. When a triple pattern from the first column of Table 6 is matched in *G*, the matching triples are *replaced in G* with the triples from the second column. This matching phase stops when matching a pattern and replacing it as specified does not change *G*. Note that *G* is a set and

thus cannot contain duplicate triples, so this last condition prevents infinite matches.

Table 6. Additional Declaration Triples

If G contains this pattern...	...then the matched triples are replaced in G with these triples.
*:x <i>rdf:type</i> <i>owl:OntologyProperty</i>	*:x <i>rdf:type</i> <i>owl:AnnotationProperty</i>
*:x <i>rdf:type</i> <i>owl:InverseFunctionalProperty</i>	*:x <i>rdf:type</i> <i>owl:ObjectProperty</i> *:x <i>rdf:type</i> <i>owl:InverseFunctionalProperty</i>
*:x <i>rdf:type</i> <i>owl:TransitiveProperty</i>	*:x <i>rdf:type</i> <i>owl:ObjectProperty</i> *:x <i>rdf:type</i> <i>owl:TransitiveProperty</i>
*:x <i>rdf:type</i> <i>owl:SymmetricProperty</i>	*:x <i>rdf:type</i> <i>owl:ObjectProperty</i> *:x <i>rdf:type</i> <i>owl:SymmetricProperty</i>

Next, the set of declarations *Decl(G)* is extracted from G according to Table 7. The matched triples are not removed from G — the triples from Table 7 can contain annotations so, in order to correctly parse the annotations, they will be matched again in the step described in [Section 3.2.5](#).

Table 7. Parsing Declarations in G

If G contains this pattern...	...then this declaration is added to <i>Decl(G)</i> .
*:x <i>rdf:type owl:Class</i>	Declaration(Class(*:x))
*:x <i>rdf:type rdfs:Datatype</i>	Declaration(Datatype(*:x))
*:x <i>rdf:type owl:ObjectProperty</i>	Declaration(ObjectProperty(*:x))
*:x <i>rdf:type owl:DatatypeProperty</i>	Declaration(DatatypeProperty(*:x))
*:x <i>rdf:type owl:AnnotationProperty</i>	Declaration(AnnotationProperty(*:x))

<i>*:x rdf:type owl:NamedIndividual</i>	Declaration(NamedIndividual(*:x))
<i>_:x rdf:type owl:Axiom _:x owl:subject *:y _:x owl:predicate rdf:type _:x owl:object owl:Class</i>	Declaration(Class(*:y))
<i>_:x rdf:type owl:Axiom _:x owl:subject *:y _:x owl:predicate rdf:type _:x owl:object rdfs:Datatype</i>	Declaration(Datatype(*:y))
<i>_:x rdf:type owl:Axiom _:x owl:subject *:y _:x owl:predicate rdf:type _:x owl:object owl:ObjectProperty</i>	Declaration(ObjectProperty(*:y))
<i>_:x rdf:type owl:Axiom _:x owl:subject *:y _:x owl:predicate rdf:type _:x owl:object owl:DatatypeProperty</i>	Declaration(DataProperty(*:y))
<i>_:x rdf:type owl:Axiom _:x owl:subject *:y _:x owl:predicate rdf:type _:x owl:object owl:AnnotationProperty</i>	Declaration(AnnotationProperty(*:y))
<i>_:x rdf:type owl:Axiom _:x owl:subject *:y _:x owl:predicate rdf:type _:x owl:object owl:NamedIndividual</i>	Declaration(NamedIndividual(*:y))

Finally, the set `RIND` of anonymous individuals used in reification is identified. This is done by initially setting `RIND = ∅` and then applying the patterns shown in Table 8. The matched triples are not deleted from `G`.

Table 8. Identifying Anonymous Individuals in Reification

If <code>G</code> contains this pattern, then <code>_:x</code> is added to <code>RIND</code>.
<i>_:x rdf:type owl:Axiom</i>
<i>_:x rdf:type owl:Annotation</i>

<code>_:x rdf:type owl:AllDisjointClasses</code>
<code>_:x rdf:type owl:AllDisjointProperties</code>
<code>_:x rdf:type owl:AllDifferent</code>
<code>_:x rdf:type owl:NegativePropertyAssertion</code>

3.2 Populating an Ontology

This section specifies the result of step CP-3.3 of the canonical parsing process on an RDF graph G , the corresponding instance O_G of the **Ontology** class, and the set $AllDecl(G)$ of all declarations for G computed as specified in step CP-3.1 of the canonical parsing process.

3.2.1 Analyzing Declarations

The following functions map an IRI reference or a blank node x occurring in G into an object of the structural specification. In particular,

- $CE(x)$ maps x into a class expression,
- $DR(x)$ maps x into a data range,
- $OPE(x)$ maps x into an object property expression,
- $DPE(x)$ maps x into a data property expression, and
- $AP(x)$ maps x into an annotation property.

Initially, these functions are undefined for all IRIs and blank nodes occurring in G ; this is written as $CE(x) = \varepsilon$, $DR(x) = \varepsilon$, $OPE(x) = \varepsilon$, $DPE(x) = \varepsilon$, and $AP(x) = \varepsilon$. The functions are updated as parsing progresses. All of the following conditions *must* be satisfied at any given point in time during parsing.

- For each x , at most one of $OPE(x)$, $DPE(x)$, and $AP(x)$ is defined.
- For each x , at most one of $CE(x)$ and $DR(x)$ is defined.

Furthermore, the value of any of these functions for any x *must not* be redefined during parsing (i.e., if a function is not undefined for x , no attempt should be made to change the function's value for x).

The function $OPE_{or}DPE$ is defined as follows:

- $OPE_{or}DPE(x) = OPE(x)$ if $OPE(x) \neq \varepsilon$;
- $OPE_{or}DPE(x) = DPE(x)$ if $DPE(x) \neq \varepsilon$; and
- $OPE_{or}DPE(x) = \varepsilon$ otherwise.

Functions CE , DR , OPE , DPE , and AP are initialized as shown in Table 9.

Table 9. Initialization of CE, DR, OPE, DPE, and AP

If <i>AllDecl(G)</i> contains this declaration...	...then perform this assignment.
Declaration(Class(*:x))	CE(*:x) := a class with the IRI *:x
Declaration(Datatype(*:x))	DR(*:x) := a datatype with the IRI *:x
Declaration(ObjectProperty(*:x))	OPE(*:x) := an object property with the IRI *:x
Declaration(DataProperty(*:x))	DPE(*:x) := a data property with the IRI *:x
Declaration(AnnotationProperty(*:x))	AP(*:x) := an annotation property with the IRI *:x

3.2.2 Parsing of Annotations

The annotations in *G* are parsed next. The function *ANN* assigns a set of annotations *ANN(x)* to each IRI reference or a blank node *x*. This function is initialized by setting *ANN(x) = ∅* for each each IRI reference or a blank node *x*. Next, the triple patterns from Table 10 are matched in *G* and, for each matched pattern, *ANN(x)* is extended with an annotation from the right column. Each time one of these triple patterns is matched, the matched triples are removed from *G*. This process is repeated until no further matches are possible.

Table 10. Parsing of Annotations

If <i>G</i> contains this pattern...	...then this annotation is added to <i>ANN(x)</i> .
<pre>x *:y z { AP(*:y) ≠ ε, z is an IRI reference or a blank node, and there is no blank node _:w such that G contains the triples _:w rdf:type owl:Annotation _:w owl:subject x _:w owl:predicate *:y _:w owl:object z }</pre>	<pre>Annotation(*:y z)</pre>
<pre>x *:y z _:w rdf:type owl:Annotation _:w owl:subject x</pre>	<pre>Annotation(ANN(_:w) *:y z)</pre>

<pre>_:w owl:predicate *:y _:w owl:object z { AP(*:y) ≠ ε, z is an IRI reference or a blank node, and no other triple in G contains _:w in subject or object position }</pre>	
---	--

3.2.3 Parsing of Ontology Annotations

Let x be the node that was matched in G to $*:x$ or $_:x$ according to the patterns from Table 4; then, $ANN(x)$ determines the set of ontology annotations of O_G .

3.2.4 Parsing of Expressions

Next, functions OPE , DR , and CE are extended as shown in Tables 11, 12, and 13, as well as in Tables 14 and 15. The patterns in the latter two tables are not generated by the mapping from Section 2, but they can be present in RDF graphs that encode OWL DL ontologies. Each time a pattern is matched, the matched triples are removed from G . Pattern matching is repeated until no triple pattern can be matched to G .

Table 11. Parsing Object Property Expressions

If G contains this pattern...	...then $OPE(_:x)$ is set to this object property expression.
<pre>_:x owl:inverseOf *:y { OPE(_:x) = ε and OPE(*:y) ≠ ε }</pre>	<pre>InverseOf(OPE(*:y))</pre>

Table 12. Parsing of Data Ranges

If G contains this pattern...	...then $DR(_:x)$ is set to this data range.
<pre>_:x rdf:type rdfs:Datatype _:x owl:intersectionOf T(SEQ y_1 ... y_n) { $n \geq 2$ and $DR(y_i) \neq \epsilon$ for each $1 \leq i \leq n$ }</pre>	<pre>IntersectionOf(DR(y_1) ... DR(y_n))</pre>
<pre>_:x rdf:type rdfs:Datatype _:x owl:unionOf T(SEQ y_1 ... y_n) { $n \geq 2$ and $DR(y_i) \neq \epsilon$ for each $1 \leq i \leq n$ }</pre>	<pre>UnionOf(DR(y_1) ... DR(y_n))</pre>

<pre> _:x rdf:type rdfs:Datatype _:x owl:datatypeComplementOf y { DR(y) ≠ ε } </pre>	<pre> ComplementOf(DR(y)) </pre>
<pre> _:x rdf:type rdfs:Datatype _:x owl:oneOf T(SEQ lt₁ ... lt_n) { n ≥ 1 } </pre>	<pre> OneOf(lt₁ ... lt_n) </pre>
<pre> _:x rdf:type rdfs:Datatype _:x owl:onDatatype *:y _:x owl:withRestrictions T(SEQ _:z₁ ... _:z_n) _:z₁ *:w₁ lt₁ ... _:z_n *:w_n lt_n { DR(*:y) is a datatype } </pre>	<pre> DatatypeRestriction(DR(*:y) *:w₁ lt₁ ... *:w_n lt_n) </pre>

Table 13. Parsing of Class Expressions

If G contains this pattern...	...then CE(_:x) is set to this class expression.
<pre> _:x rdf:type owl:Class _:x owl:intersectionOf T(SEQ Y₁ ... Y_n) { n ≥ 2 and CE(y_i) ≠ ε for each 1 ≤ i ≤ n } </pre>	<pre> IntersectionOf(CE(y₁) ... CE(y_n)) </pre>
<pre> _:x rdf:type owl:Class _:x owl:unionOf T(SEQ Y₁ ... Y_n) { n ≥ 2 and CE(y_i) ≠ ε for each 1 ≤ i ≤ n } </pre>	<pre> UnionOf(CE(y₁) ... CE(y_n)) </pre>
<pre> _:x rdf:type owl:Class _:x owl:complementOf y { CE(y) ≠ ε } </pre>	<pre> ComplementOf(CE(y)) </pre>
<pre> _:x rdf:type owl:Class _:x owl:oneOf T(SEQ *:y₁ ... *:y_n) { n ≥ 1 } </pre>	<pre> OneOf(*:y₁ ... *:y_n) </pre>
<pre> _:x rdf:type owl:Restriction _:x owl:onProperty y _:x owl:someValuesFrom z { OPE(y) ≠ ε and CE(z) ≠ ε } </pre>	<pre> SomeValuesFrom(OPE(y) CE(z)) </pre>
<pre> _:x rdf:type owl:Restriction _:x owl:onProperty y </pre>	<pre> AllValuesFrom(OPE(y) CE(z)) </pre>

<pre>_:x owl:allValuesFrom z { OPE(y) ≠ ε and CE(z) ≠ ε }</pre>	
<pre>_:x rdf:type owl:Restriction _:x owl:onProperty y _:x owl:hasValue *:z { OPE(y) ≠ ε }</pre>	<pre>HasValue(OPE(y) *:z)</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:onProperty y _:x owl:hasSelf "true"^^xsd:boolean { OPE(y) ≠ ε }</pre>	<pre>HasSelf(OPE(y))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:minQualifiedCardinality NN_INT(n) _:x owl:onProperty y _:x owl:onClass z { OPE(y) ≠ ε and CE(z) ≠ ε }</pre>	<pre>MinCardinality(n OPE(y) CE(z))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:maxQualifiedCardinality NN_INT(n) _:x owl:onProperty y _:x owl:onClass z { OPE(y) ≠ ε and CE(z) ≠ ε }</pre>	<pre>MaxCardinality(n OPE(y) CE(z))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:qualifiedCardinality NN_INT(n) _:x owl:onProperty y _:x owl:onClass z { OPE(y) ≠ ε and CE(z) ≠ ε }</pre>	<pre>ExactCardinality(n OPE(y) CE(z))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:minCardinality NN_INT(n) _:x owl:onProperty y { OPE(y) ≠ ε }</pre>	<pre>MinCardinality(n OPE(y))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:maxCardinality NN_INT(n) _:x owl:onProperty y { OPE(y) ≠ ε }</pre>	<pre>MaxCardinality(n OPE(y))</pre>

<pre>_:x rdf:type owl:Restriction _:x owl:cardinality NN_INT(n) _:x owl:onProperty y { OPE(y) ≠ ε }</pre>	<pre>ExactCardinality(n OPE(y))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:onProperty y _:x owl:hasValue lt { DPE(y) ≠ ε }</pre>	<pre>HasValue(DPE(y) lt)</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:onProperty y _:x owl:someValuesFrom z { DPE(y) ≠ ε and DR(z) ≠ ε }</pre>	<pre>SomeValuesFrom(DPE(y) DR(z))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:onProperties T(SEQ y1 ... Yn) _:x owl:someValuesFrom z { DPE(y_i) ≠ ε for each 1 ≤ i ≤ n and DR(z) ≠ ε }</pre>	<pre>SomeValuesFrom(DPE(y₁) ... DPE(y_n) DR(z))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:onProperty y _:x owl:allValuesFrom z { DPE(y) ≠ ε and DR(z) ≠ ε }</pre>	<pre>AllValuesFrom(DPE(y) DR(z))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:onProperties T(SEQ y1 ... Yn) _:x owl:allValuesFrom z { DPE(y_i) ≠ ε for each 1 ≤ i ≤ n and DR(z) ≠ ε }</pre>	<pre>AllValuesFrom(DPE(y₁) ... DPE(y_n) DR(z))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:minQualifiedCardinality NN_INT(n) _:x owl:onProperty y _:x owl:onDataRange z { DPE(y) ≠ ε and DR(z) ≠ ε }</pre>	<pre>MinCardinality(n DPE(y) DR(z))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:maxQualifiedCardinality NN_INT(n) _:x owl:onProperty y _:x owl:onDataRange z { DPE(y) ≠ ε and DR(z) ≠ ε }</pre>	<pre>MaxCardinality(n DPE(y) DR(z))</pre>

<pre>_:x rdf:type owl:Restriction _:x owl:qualifiedCardinality NN_INT(n) _:x owl:onProperty y _:x owl:onDataRange z { DPE(y) ≠ ε and DR(z) ≠ ε }</pre>	<pre>ExactCardinality(n DPE(y) DR(z))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:minCardinality NN_INT(n) _:x owl:onProperty y { DPE(y) ≠ ε }</pre>	<pre>MinCardinality(n DPE(y))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:maxCardinality NN_INT(n) _:x owl:onProperty y { DPE(y) ≠ ε }</pre>	<pre>MaxCardinality(n DPE(y))</pre>
<pre>_:x rdf:type owl:Restriction _:x owl:cardinality NN_INT(n) _:x owl:onProperty y { DPE(y) ≠ ε }</pre>	<pre>ExactCardinality(n DPE(y))</pre>

Table 14. Parsing of Data Ranges for Compatibility with OWL DL

If G contains this pattern...	...then <i>DR</i> (_:x) is set to this object property expression.
<pre>_:x rdf:type owl:DataRange _:x owl:oneOf T(SEQ lt₁ ... lt_n) { n ≥ 1 }</pre>	<pre>OneOf(lt₁ ... lt_n)</pre>
<pre>_:x rdf:type owl:DataRange _:x owl:oneOf T(SEQ)</pre>	<pre>ComplementOf(rdfs:Literal)</pre>

Table 15. Parsing of Class Expressions for Compatibility with OWL DL

If G contains this pattern...	...then <i>CE</i> (_:x) is set to this class expression.
<pre>_:x rdf:type owl:Class _:x owl:unionOf T(SEQ)</pre>	<pre>owl:Nothing</pre>
<pre>_:x rdf:type owl:Class _:x owl:unionOf T(SEQ y) { CE(y) ≠ ε }</pre>	<pre>CE(y)</pre>

<pre>_:x rdf:type owl:Class _:x owl:intersectionOf T (SEQ)</pre>	<pre>owl:Thing</pre>
<pre>_:x rdf:type owl:Class _:x owl:intersectionOf T (SEQ y) { CE(y) ≠ ε }</pre>	<pre>CE(y)</pre>
<pre>_:x rdf:type owl:Class _:x owl:oneOf T (SEQ)</pre>	<pre>owl:Nothing</pre>

3.2.5 Parsing of Axioms

Next, O_G is populated with axioms. For clarity, the axiom patterns are split into two tables.

- Table 16 presents the patterns for axioms without annotations.
- Annotated axioms are parsed as follows:
 - In case of the patterns for *owl:AllDisjointClasses*, *owl:AllDisjointProperties*, *owl:AllDifferent*, and *owl:NegativePropertyAssertion*, axiom annotations are defined by $ANN(_ : x)$.
 - For all other axioms, axiom annotations are obtained by additionally matching patterns from Table 17 in G during axiom matching.

The axioms in G are parsed as follows:

- All annotated axioms are parsed first.
- Only when no pattern for annotated axioms can be matched in G , then the patterns for axioms without annotations are matched.

In either case, each time a triple pattern is matched, the matched triples are removed from G .

Table 16. Parsing of Axioms without Annotations

If G contains this pattern...	...then the following axiom is added to O_G .
<pre>*:x rdf:type owl:Class</pre>	<pre>Declaration(Class(*:x))</pre>
<pre>*:x rdf:type rdfs:Datatype</pre>	<pre>Declaration(Datatype(*:x))</pre>
<pre>*:x rdf:type owl:ObjectProperty</pre>	<pre>Declaration(ObjectProperty(*:x))</pre>

<i>*:x rdf:type owl:DatatypeProperty</i>	Declaration(DataProperty(*:x))
<i>*:x rdf:type owl:AnnotationProperty</i>	Declaration(AnnotationProperty(*:x))
<i>*:x rdf:type owl:NamedIndividual</i>	Declaration(NamedIndividual(*:x))
<i>x rdfs:subClassOf y { CE(x) ≠ ε and CE(y) ≠ ε }</i>	SubClassOf(CE(x) CE(y))
<i>x owl:equivalentClass y { CE(x) ≠ ε and CE(y) ≠ ε }</i>	EquivalentClasses(CE(x) CE(y))
<i>x owl:disjointWith y { CE(x) ≠ ε and CE(y) ≠ ε }</i>	DisjointClasses(CE(x) CE(y))
<i>_:x rdf:type owl:AllDisjointClasses _:x owl:members T(SEQ y₁ ... Y_n) { n ≥ 2 and CE(y_i) ≠ ε for each 1 ≤ i ≤ n }</i>	DisjointClasses(CE(y ₁) ... CE(y _n))
<i>x owl:disjointUnionOf T(SEQ Y₁ ... Y_n) { n ≥ 2, CE(x) ≠ ε, and CE(y_i) ≠ ε for each 1 ≤ i ≤ n }</i>	DisjointUnion(CE(x) CE(y ₁) ... CE(y _n))
<i>x rdfs:subPropertyOf y { OPE(x) ≠ ε and OPE(y) ≠ ε }</i>	SubPropertyOf(OPE(x) OPE(y))
<i>_:x rdfs:subPropertyOf y _:x owl:propertyChain T(SEQ x₁ ... x_n) { n ≥ 2, OPE(x_i) ≠ ε for each 1 ≤ i ≤ n, and OPE(y) ≠ ε }</i>	SubPropertyOf(PropertyChain(OPE(x ₁) ... OPE(x _n)) OPE(y))
<i>x owl:equivalentProperty y { OPE(x) ≠ ε and OPE(y) ≠ ε }</i>	EquivalentProperties(OPE(x) OPE(y))
<i>x owl:propertyDisjointWith y { OPE(x) ≠ ε and OPE(y) ≠ ε }</i>	DisjointProperties(OPE(x) OPE(y))

<pre>_:x rdfs:type owl:AllDisjointProperties _:x owl:members T (SEQ Y1 ... Yn) { n ≥ 2 and OPE(y_i) ≠ ε for each 1 ≤ i ≤ n }</pre>	DisjointProperties(OPE(y ₁) ... OPE(y _n))
<pre>x rdfs:domain y { OPE(x) ≠ ε and CE(y) ≠ ε }</pre>	PropertyDomain(OPE(x) CE(y))
<pre>x rdfs:range y { OPE(x) ≠ ε and CE(y) ≠ ε }</pre>	PropertyRange(OPE(x) CE(y))
<pre>x owl:inverseOf y { OPE(x) ≠ ε and OPE(y) ≠ ε }</pre>	InverseProperties(OPE(x) OPE(y))
<pre>x rdfs:type owl:FunctionalProperty { OPE(x) ≠ ε }</pre>	FunctionalProperty(OPE(x))
<pre>x rdfs:type owl:InverseFunctionalProperty { OPE(x) ≠ ε }</pre>	InverseFunctionalProperty(OPE(x))
<pre>x rdfs:type owl:ReflexiveProperty { OPE(x) ≠ ε }</pre>	ReflexiveProperty(OPE(x))
<pre>x rdfs:type owl:IrreflexiveProperty { OPE(x) ≠ ε }</pre>	IrreflexiveProperty(OPE(x))
<pre>x rdfs:type owl:SymmetricProperty { OPE(x) ≠ ε }</pre>	SymmetricProperty(OPE(x))
<pre>x rdfs:type owl:AsymmetricProperty { OPE(x) ≠ ε }</pre>	AsymmetricProperty(OPE(x))
<pre>x rdfs:type owl:TransitiveProperty { OPE(x) ≠ ε }</pre>	TransitiveProperty(OPE(x))
<pre>x rdfs:subPropertyOf y { DPE(x) ≠ ε and DPE(y) ≠ ε }</pre>	SubPropertyOf(DPE(x) DPE(y))
<pre>x owl:equivalentProperty y { DPE(x) ≠ ε and DPE(y) ≠ ε }</pre>	EquivalentProperties(DPE(x) DPE(y))

<code>x owl:propertyDisjointWith y</code> { <code>DPE(x) ≠ ε</code> and <code>DPE(y) ≠ ε</code> }	<code>DisjointProperties(DPE(x)</code> <code>DPE(y))</code>
<code>_:x rdf:type</code> <code>owl:AllDisjointProperties</code> <code>_:x owl:members T(SEQ y1 ...</code> <code>Yn)</code> { <code>n ≥ 2</code> and <code>DPE(y_i) ≠ ε</code> for each <code>1 ≤ i ≤ n</code> }	<code>DisjointProperties(DPE(y₁)</code> <code>... DPE(y_n))</code>
<code>x rdfs:domain y</code> { <code>DPE(x) ≠ ε</code> and <code>CE(y) ≠ ε</code> }	<code>PropertyDomain(DPE(x) CE(y)</code> <code>)</code>
<code>x rdfs:range y</code> { <code>DPE(x) ≠ ε</code> and <code>DR(y) ≠ ε</code> }	<code>PropertyRange(DPE(x) DR(y)</code> <code>)</code>
<code>x rdf:type</code> <code>owl:FunctionalProperty</code> { <code>DPE(x) ≠ ε</code> }	<code>FunctionalProperty(DPE(x))</code>
<code>x owl:hasKey T(SEQ y1 ... Yn)</code> { <code>n ≥ 1</code> , <code>CE(x) ≠ ε</code> , and <code>OPEorDPE(y_i) ≠ ε</code> for each <code>1</code> <code>≤ i ≤ n</code> }	<code>HasKey(CE(x) OPEorDPE(y₁)</code> <code>... OPEorDPE(y_n))</code>
<code>x owl:sameAs y</code>	<code>SameIndividual(x y)</code>
<code>x owl:differentFrom y</code>	<code>DifferentIndividuals(x y)</code>
<code>_:x rdf:type owl:AllDifferent</code> <code>_:x owl:members T(SEQ x1 ...</code> <code>x_n)</code> { <code>n ≥ 2</code> }	<code>DifferentIndividuals(x₁ ...</code> <code>x_n)</code>
<code>_:x rdf:type owl:AllDifferent</code> <code>_:x owl:distinctMembers T(SEQ</code> <code>x1 ... x_n)</code> { <code>n ≥ 2</code> }	<code>DifferentIndividuals(x₁ ...</code> <code>x_n)</code>
<code>x rdf:type y</code> { <code>CE(y) ≠ ε</code> }	<code>ClassAssertion(x CE(y))</code>
<code>x *:y z</code> { <code>OPE(*:y) ≠ ε</code> }	<code>PropertyAssertion(OPE(*:y)</code> <code>x z)</code>
<code>_:x rdf:type</code> <code>owl:NegativePropertyAssertion</code> <code>_:x owl:sourceIndividual w</code> <code>_:x owl:assertionProperty y</code>	<code>NegativePropertyAssertion(</code> <code>OPE(y) w z)</code>

<code>_:x owl:targetIndividual z { OPE(y) ≠ ε }</code>	
<code>x *:y lt { DPE(*:y) ≠ ε }</code>	<code>PropertyAssertion(DPE(*:y) x lt)</code>
<code>_:x rdf:type owl:NegativePropertyAssertion _:x owl:sourceIndividual w _:x owl:assertionProperty y _:x owl:targetValue lt { DPE(y) ≠ ε }</code>	<code>NegativePropertyAssertion(DPE(y) w lt)</code>
<code>*:x rdf:type owl:DeprecatedClass</code>	<code>AnnotationAssertion(owl:deprecated *:x "true"^^xsd:boolean)</code>
<code>*:x rdf:type owl:DeprecatedProperty</code>	<code>AnnotationAssertion(owl:deprecated *:x "true"^^xsd:boolean)</code>
<code>*:x rdfs:subPropertyOf *:y { AP(*:x) ≠ ε and AP(*:y) ≠ ε }</code>	<code>SubPropertyOf(AP(*:x) AP(*:y))</code>
<code>*:x rdfs:domain *:y { AP(*:x) ≠ ε }</code>	<code>PropertyDomain(AP(*:x) *:y)</code>
<code>*:x rdfs:range *:y { AP(*:x) ≠ ε }</code>	<code>PropertyRange(AP(*:x) *:y)</code>

Table 17. Parsing of Annotated Axioms

If G contains this pattern...	...then the following axiom is added to O_G.
<pre>s *:p o _:x rdf:type owl:Axiom _:x owl:subject s _:x owl:predicate *:p _:x owl:object o { s *:p o is the main triple for an axiom according to Table 17 and G contains possible necessary side triples for the axiom }</pre>	<p>The result is the axiom corresponding to <code>s *:p o</code> (and possible side triples) that additionally contains the annotations <code>ANN(_:x)</code>.</p>

Next, for each blank node or IRI reference `x` such that `x ∉ RIND`, and for each annotation `Annotation(annotation1 ... annotationn AP y) ∈`

ANN(x) with n possibly being equal to zero, the following annotation assertion is added to O_G:

```
AnnotationAssertion( annotation1 ... annotationn AP x y
)
```

Finally, the patterns from Table 18 are matched in G, the resulting axioms are added to O_G. These patterns are not generated by the mapping from Section 2, but they can be present in RDF graphs that encode OWL DL ontologies. (Note that the patterns from the table do not contain triples of the form **:x rdf:type owl:Class* because such triples are removed while parsing the entity declarations, as specified in Section 3.1.2.) Each time a triple pattern is matched, the matched triples are removed from G.

Table 18. Parsing of Axioms for Compatibility with OWL DL

If G contains this pattern...	...then the following axiom is added to O _G .
<pre>*:x owl:complementOf Y { CE(*:x) ≠ ε and CE(Y) ≠ ε }</pre>	<pre>EquivalentClasses(CE(*:x) ComplementOf(CE(Y)))</pre>
<pre>*:x owl:unionOf T(SEQ) { CE(*:x) ≠ ε }</pre>	<pre>EquivalentClasses(CE(*:x) owl:Nothing)</pre>
<pre>*:x owl:unionOf T(SEQ Y₁) { CE(*:x) ≠ ε and CE(Y₁) ≠ ε }</pre>	<pre>EquivalentClasses(CE(*:x) CE(Y₁))</pre>
<pre>*:x owl:unionOf T(SEQ Y₁ ... Y_n) { n ≥ 2, CE(*:x) ≠ ε, and CE(Y_i) ≠ ε for each 1 ≤ i ≤ n }</pre>	<pre>EquivalentClasses(CE(*:x) UnionOf(CE(Y₁) ... CE(Y_n)))</pre>
<pre>*:x owl:intersectionOf T(SEQ) { CE(*:x) ≠ ε }</pre>	<pre>EquivalentClasses(CE(*:x) owl:Thing)</pre>
<pre>*:x owl:intersectionOf T(SEQ Y₁) { CE(*:x) ≠ ε and CE(Y₁) ≠ ε }</pre>	<pre>EquivalentClasses(CE(*:x) CE(Y₁))</pre>

<pre> *:x owl:intersectionOf T(SEQ Y1 ... Yn) { n ≥ 2, CE(*:x) ≠ ε, and CE(Yi) ≠ ε for each 1 ≤ i ≤ n } </pre>	<pre> EquivalentClasses(CE(*:x) IntersectionOf(CE(Y1) ... CE(Yn))) </pre>
<pre> *:x owl:oneOf T(SEQ { CE(*:x) ≠ ε } </pre>	<pre> EquivalentClasses(CE(*:x) owl:Nothing) </pre>
<pre> *:x owl:oneOf T(SEQ *:Y1 ... *:Yn) { CE(*:x) ≠ ε } </pre>	<pre> EquivalentClasses(CE(*:x) OneOf(*:Y1 ... *:Yn)) </pre>

At the end of this process, the graph *G* *must* be empty.

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