

➤ FAIR metabolomics e-resources in web components

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Séminaire INRAE “Semantic Linked Data” – 2021

- ¹ Plateau de Profilage Métabolique et Métabolomique (P2M2, IGEPP, Rennes)
- ² PlateForme Exploration du Métabolisme (PFEM, Clermont-Ferrand)

Plan

I. Contexte

II. Projet FORUM

III. Metabolomic Semantic Datalake [management des ressources RDF]

IV. Discovery / Web Component [utilisation des ressources RDF]



Context



MetaboHUB 2.0 (2021 - 2025)

Infrastructure nationale de métabolomique et fluxomique

➔ a pour objectif de fournir des outils technologiques de pointe et des services en métabolomique et fluxomique aux équipes de recherche académiques et à des partenaires industriels dans les domaines de la santé, de la nutrition, de l'agriculture, de l'environnement et des biotechnologies.

WP5 "Creating FAIR e-resources for knowledge mining"

- T.1 MetaboHUB Data management and stewardship
- T.2 Ensure MTH2.0 e-resources sustainability
- **T.3 Interoperability between e-resources: creating study specific e-resources**
- **T.4 Linked data for advanced knowledge extraction**

FORUM / CATI EMPREINTE (F. Giacomoni, C. Frainay)

2019 d'un financement de la part du copil Schéma Directeur du Numérique (SDN)



=> **Preuve de concept de l'apport des technologies du web sémantique dans l'ouverture, la diffusion et l'exploitation d'empreintes métaboliques et de réseaux métaboliques autour de questions scientifiques touchant à la Nutrition et à la Santé**

Portail <http://semantic-metabolomics.org/>

FORUM - Constat

- **Problématique production** (Utilisation dans les SI/IHM)
 - RDFstore versus base relationnelle
 - Interopérabilité / robustesse
 - API / maintenabilité
- **Problématique recherche/intégration/inférence**
 - Gestion bases de connaissances massives PubCHEM ~ 8 Milliards de triplets
 - Accessibilité/Updates des bases de connaissances externes (NCBI/EBI/...)
 - ➡ Update des bases de connaissances internes
 - Intégration des bases non RDF (Metabolights, Global Natural Products Social Molecular Networking, Golm Metabolome Database, etc...)

2 exemples



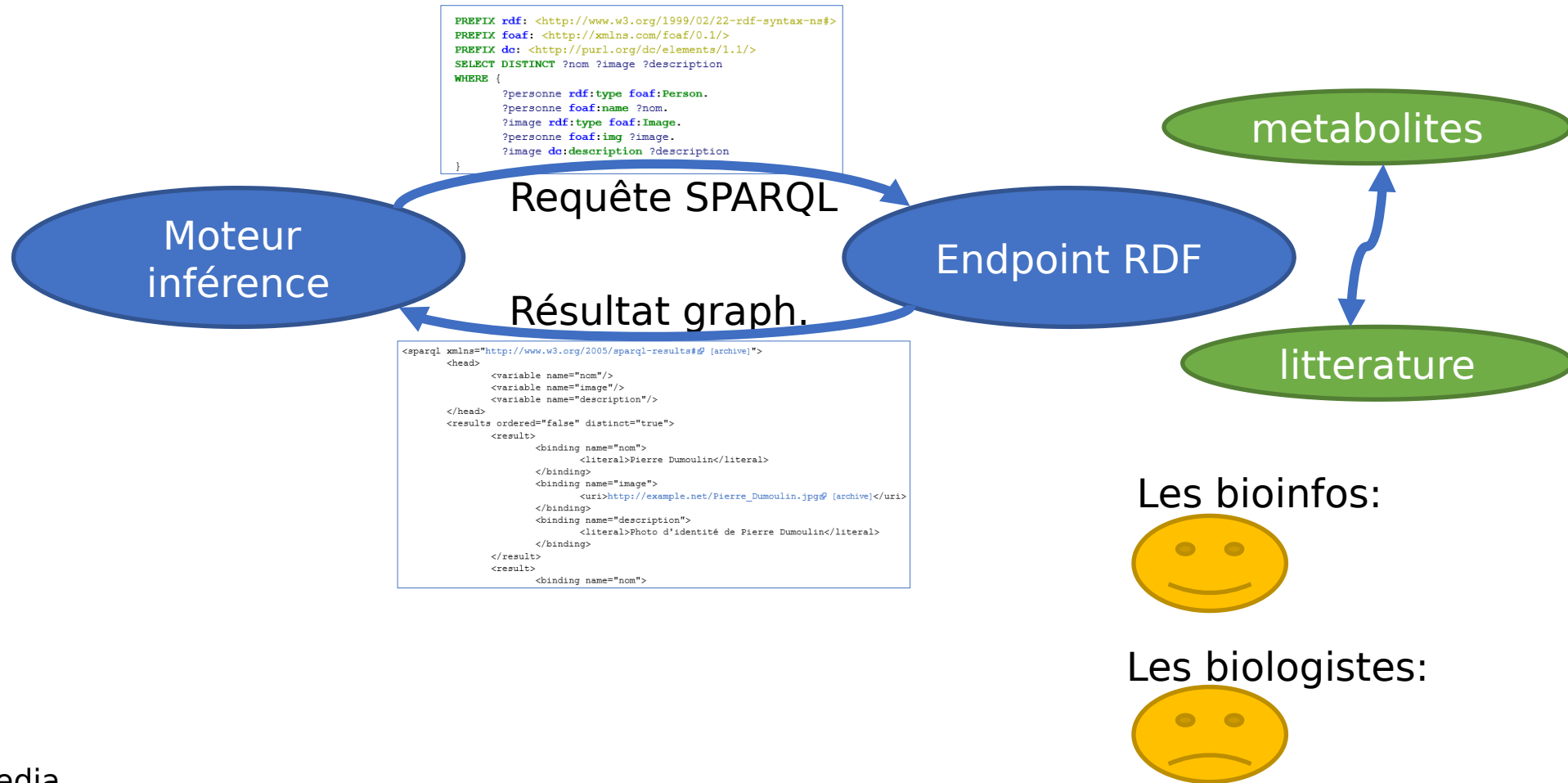
Mise à disposition des résultats du projet (relations entre des composés et des concepts biomédicaux) via un site web



Retour d'exp. mise à disposition d'un RDF store (8 Milliards triplets)

Forum - Problématique 1 / utilisation

Web sémantique et bioinformatique



Les bioinfos:



Les biologistes:



Source: Wikipedia

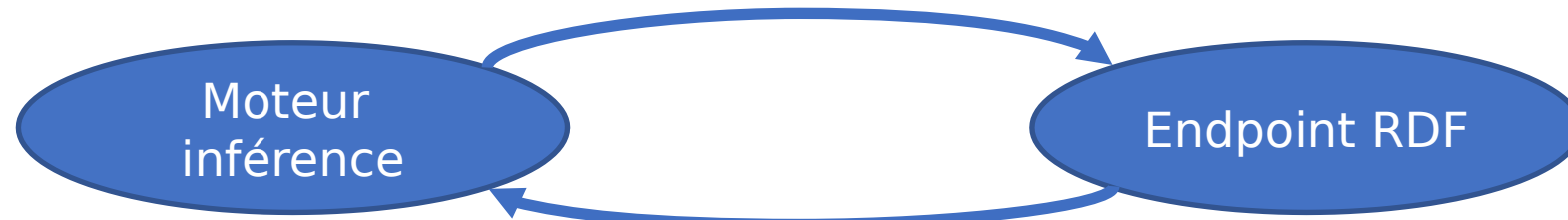


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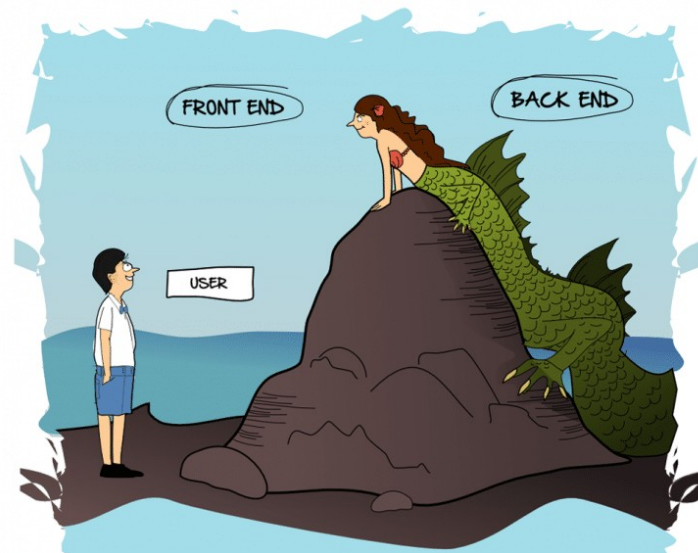
Forum - Problématique 1 / utilisation

Web sémantique et bioinformatique



The screenshot shows the FORUM web interface. At the top, it says "FORUM Metabolism Knowledge Network Portal" with navigation links for "About", "Find Associations", and "Ask anything". Below is a search bar with the text "Find..." and two radio buttons: "a chemical compound/class" (selected) and "a medical concept". A search input field contains "Glucose-6-P" and a link "Glucose-6-Phosphate" is shown below it. Underneath, there is a section titled "... get associated medical concepts" with a table of results.

Name	p.value	odd ratio	papers	score
Metabolic Syndrome	1.456e-24	0.84	1245	★★★★☆
...
...
...

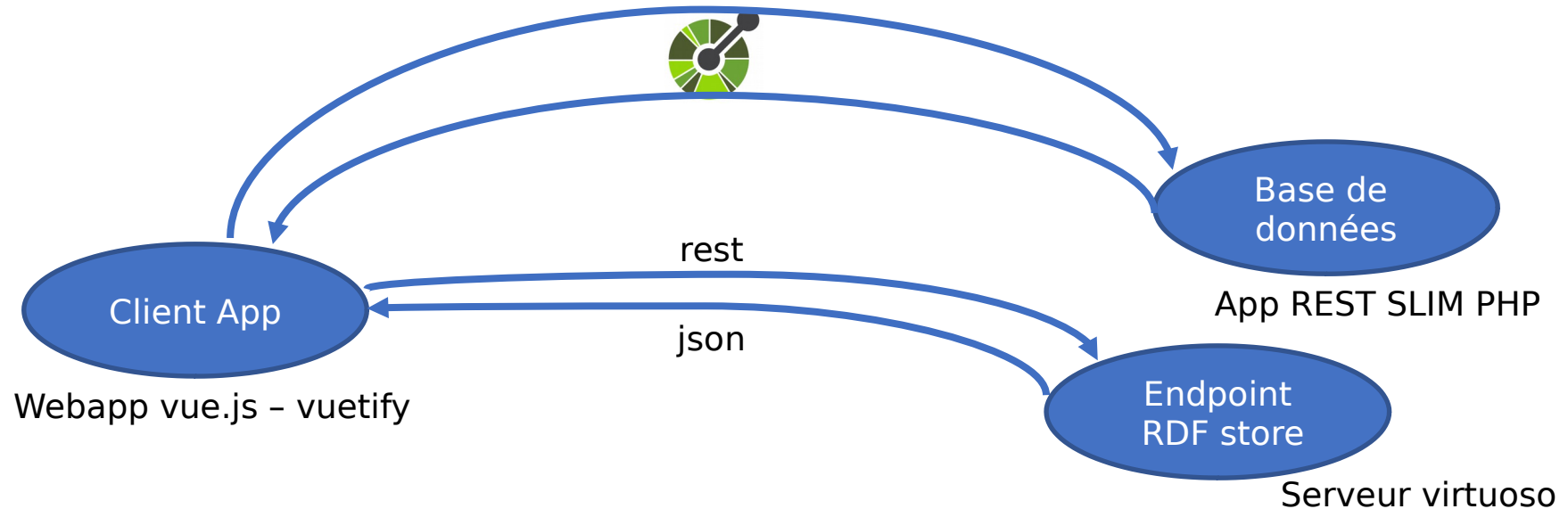
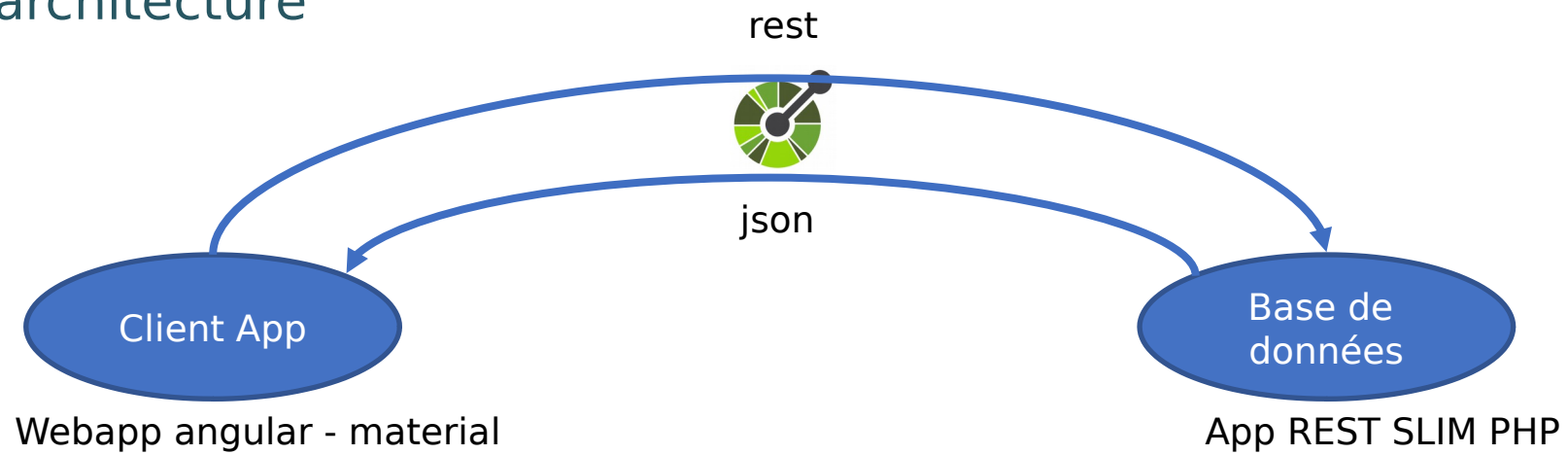


Les biologistes:



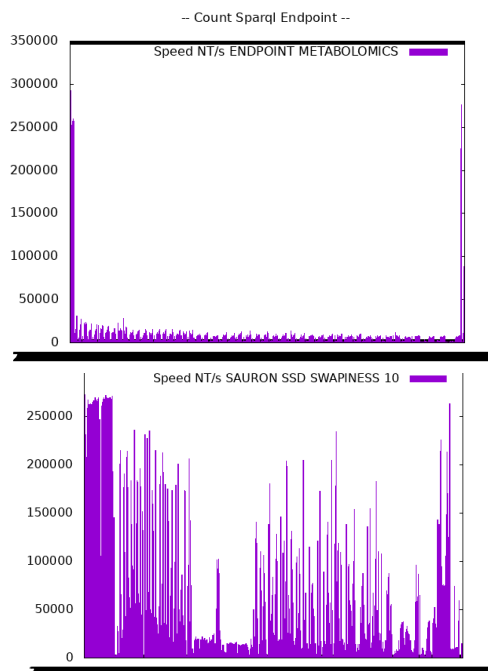
Forum - Problématique 1 / utilisation

« Meta » architecture



Forum - Problématique 2 / mise à disposition

- Bases : PubChem, ChEBI, Enrichment
- 8 Milliards de triplets (8,256,324,376)
- Virtuoso



	ENDPOINT-METABOLOMICS	SAURON (DEV)
CORE	16	48
MEM	128Go	192Go
Env Test	Disque Local(SSD)/RBD-SATA	RBD-SATA/RBD-SSD/NetAPP

	EM - LOCAL(SSD)	EM - RBD-SATA	SAURON-RBD-SATA	SAURON-RBD-SSD	SAURON-RBD-SSD (swapiness10)	SAURON-NETAPP
vitesse moy(T/sec)	40996.4	7189.96	12428.9	71366.2	64883.3	20243.3
vitesse std	63130.8	25868.6	37922.2	82599	75743.8	47900
durée	~2,8j	~22j	~12,4j	~1,74j	~1,81j	~5,57j

Metabolomic Semantic Datalake

Évaluation d'une infrastructure BIG Data pour la gestion et l'inférence de ressources RDF

• Financement

- AAP DiPSO 2021 « Soutien à Projets Innovants et Structurants sur le numérique » (20 k€)
- MetaboHUB (1k€)
- ALIMH (1k€)
- Plateforme Métabolomique P2M2 (1k€)

• Matériel

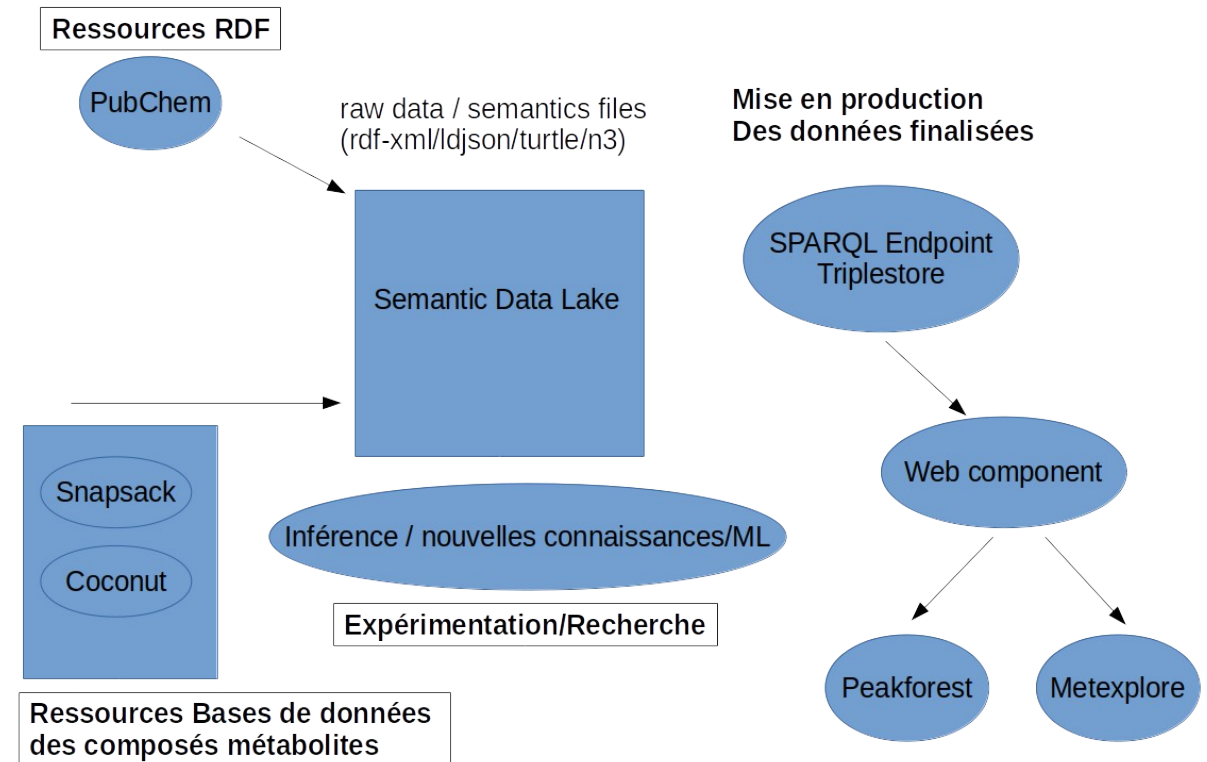
- 1 Namenode (VM, 4 CPU, 250 Go)
- 4 Datanodes
 - Serveur PowerEdge C6525 (2CPU,64 RAM, 2x1To SSD)

• Formations

- Big Data / Administration d'un cluster SPARK 4 ½j - Septembre 2021
- **Big Data / Spark env. / Scala – 6 ½ j Janvier-Février 2022**

- **PROSODie** : C. Duperier (PFEM), D. Benaben (PMB)
- **BARIC** : M. Boudet (IGEPP)
- **EMPREINTE** : F. Giacomoni (PFEM), O. Filangi (IGEPP)

Architecture Metabolomic Semantic Data Lake



Metabolomic Semantic Datalake / Technologies

Gestion / Création de ressources



Management des ressources sémantiques



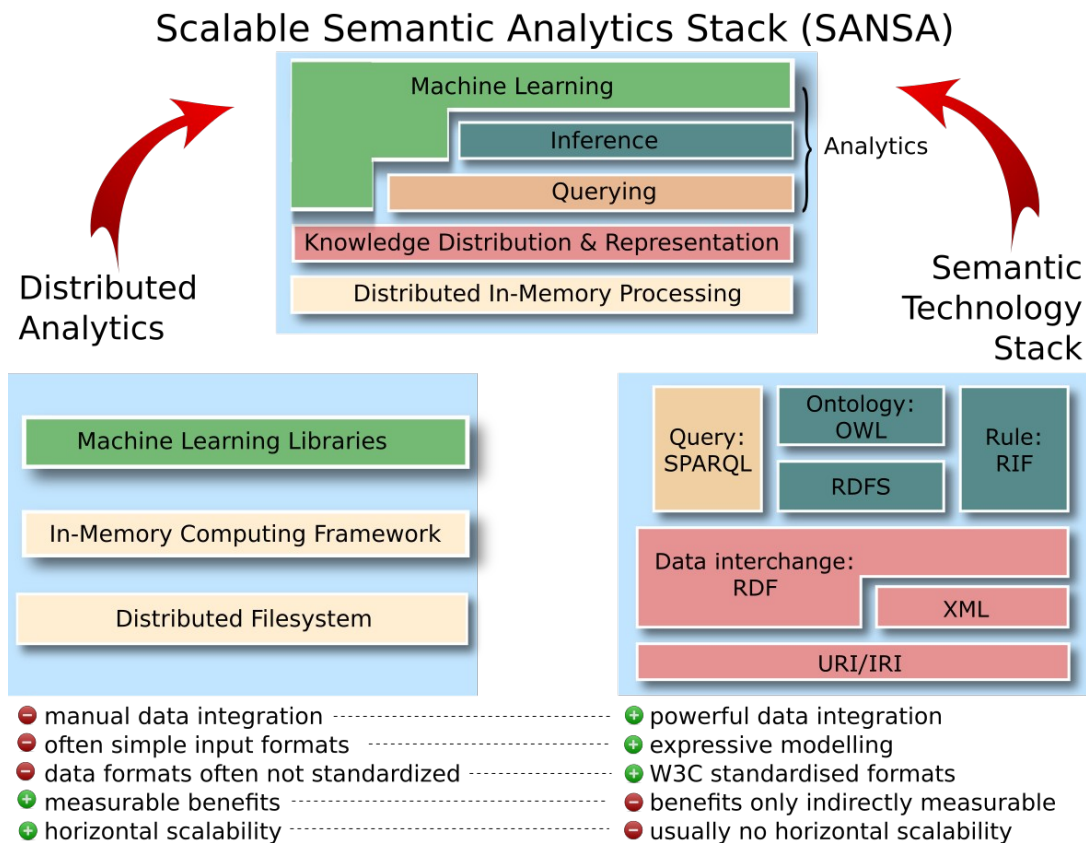
AskOmic

Utilisation des ressources RDF

Discovery



Vue.js

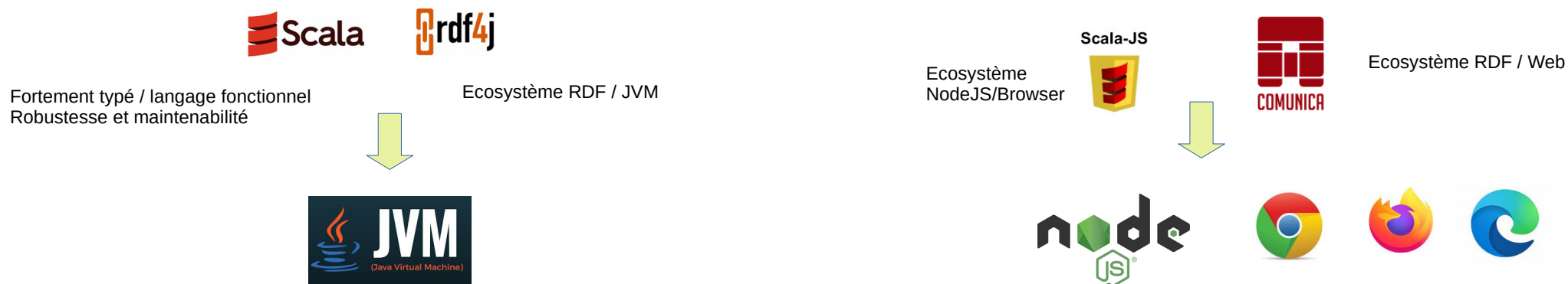


SANSa-Stack : <http://sansa-stack.net/>

Smart Data Analytics (SDA) research group

DSL (Domain Specific language) pour faciliter l'utilisation des ressources RDF et l'implémentation de fonctionnalités dans les SI MetaboHUB. La construction se base sur les concepts de **navigation à facette** (notion de focus et de contexte)

```
SWDiscovery(config)
  .something("chebild")
  .set(URI("http://purl.obolibrary.org/obo/CHEBI_4167"))
  .isObjectOf(URI("https://www.ebi.ac.uk/metabolights/property#Xref"),"study")
  .datatype(URI("http://www.w3.org/2000/01/rdf-schema#label"),"labelStudy")
  .focus("chebild")
  .datatype(URI("http://www.w3.org/2000/01/rdf-schema#label"),"labelChebild")
  .select("study","labelStudy","labelChebild")
```



COMUNICA : Flexible SPARQL and GraphQL over decentralized RDF on the Web.
Ghent University, <https://comunica.dev/>

Discovery / exemple HTML / 1

```
1 <script type="text/javascript" src="https://cdn.jsdelivr.net/gh/p2m2/discovery@0.2.0/dist/discovery-web.min.js"> </script>
2 <script>
3   let config = SWDiscoveryConfiguration.setConfigString(`
4     {
5       "sources" : [{
6         "id"      : "file_metabo",
7         "url"     : "https://raw.githubusercontent.com/p2m2/discovery/develop/shared/src/test/resources/metabo.ttl",
8         "mimetype" : "text/turtle"
9       }],
10      "settings" : {
11        "logLevel" : "info"
12      }
13    }
14  `)
15  SWDiscovery(config)
16    .prefix("pp", "https://metabohub.p2m2.org/ontology/property/")
17    .something("compound")
18    .isSubjectOf("pp:InChIKey")
19    .filter.contains("MIYGQTFETY")
20    .focus("compound")
21    .console()
22    .helper() // display information on the web page and propose new building block
23    .select("compound")
24    .commit().raw().then((response) => {
25
26      for (let i=0;i<response.results.bindings.length;i++) {
27        let iValue =response.results.bindings[i]["compound"].value;
28        console.log(iValue );
29      }
30
31    }).catch( (error) => {
32      console.error(" -- catch exception --")
33      console.error(error)
34    } );
35 </script>
```

Discovery

- build : build 2021-03-24

New step on focus

- target node : Something@compound - [List(SubjectOf@object0 - [List(false Contains ("MIYGQTFETY"))])]
- regex :
- Number of values : 1

Values 10 .set(value) .setList(value1,value1,..)

- {"compound":{"value":"https://foodb.ca/compounds/FDB000013","type":"uri"}}

Classes .isA("uri")

- <https://metabohub.p2m2.org/ontology/class/Compound>

Forward property .isSubjectOf("uri", "myreferencevar")

[X]

Datatype property .datatype("uri", "myreferencevar")

- https://metabohub.p2m2.org/ontology/property/db_source
- https://metabohub.p2m2.org/ontology/property/cas_number
- <https://metabohub.p2m2.org/ontology/property/InChI>
- https://metabohub.p2m2.org/ontology/property/iupac_name
- https://metabohub.p2m2.org/ontology/property/mass_minush
- https://metabohub.p2m2.org/ontology/property/mass_plush
- https://metabohub.p2m2.org/ontology/property/exact_mass
- <https://metabohub.p2m2.org/ontology/property/InChIKey>
- https://metabohub.p2m2.org/ontology/property/can_smiles

Backward property .isObjectOf("uri", "myreferencevar")

```
Group similar messages in console Evaluate triggers us
2021-10-06T09:49:17.004Z info [ ] ..... [SN013cn]
2021-10-06T09:49:17.009Z info [ ] --- Discovery : build 2021-03-24 ..... [SN011]
2021-10-06T09:49:17.009Z info [ ] ..... [SN013cn]
https://raw.githubusercontent.com/p2m2/discovery/develop/shared/src/test/resources/metabo.ttl
USER REQUEST
[ ] Root
[ ] |--- Something (compound)
[ ] | |--- SubjectOf (pp:InChIKey , object0)
[ ] | | |--- FILTER false Contains ("MIYGQTFETY")
---- SOURCESNODE ----
---- DATATYPE ----
---- Solution Modifier ----
---- Expression ----
FOCUS NODE: compound
ENDPOINT: undefined
-- SPARQL Request --
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> discovery-web.min.js:1570
PREFIX owl: <http://www.w3.org/2002/07/owl#> discovery-web.min.js:1570
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> discovery-web.min.js:1570
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> discovery-web.min.js:1570
PREFIX pp: <https://metabohub.p2m2.org/ontology/property/> discovery-web.min.js:1570
----
-- SPARQL Request -- discovery-web.min.js:1570
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> discovery-web.min.js:1570
PREFIX owl: <http://www.w3.org/2002/07/owl#> discovery-web.min.js:1570
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#> discovery-web.min.js:1570
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#> discovery-web.min.js:1570
PREFIX pp: <https://metabohub.p2m2.org/ontology/property/> discovery-web.min.js:1570
SELECT discovery-web.min.js:1570
WHERE { discovery-web.min.js:1570
?compound pp:InChIKey ?object0 . discovery-web.min.js:1570
FILTER ( contains(str(?object0), "MIYGQTFETY") ) discovery-web.min.js:1570
} discovery-web.min.js:1570
https://foodb.ca/compounds/FDB000013 discovery-web.min.js:1570
example_with_urlfile.html:28
```

https://p2m2.github.io/discovery/user_docs_file_example.html

Discovery / exemple Scala / ChEBI Discovery

ScalaJs functional implementation based of the ontology based matching describe in the "Improving lipid mapping in Genome Scale Metabolic Networks using ontologies." Poupin et al - 2020 using the Chemical Entities of Biological Interest (ChEBI)
<https://doi.org/10.1007/s11306-020-01663-5>

<https://github.com/eMetaboHUB/ChEBI-discovery>

```
@JSImportTopLevel(name="ChebiDiscovery")
case class ChebiDiscovery(
  config_discovery : String = ""{
    "sources" : [{
      "id" : "Forum-Desease-Chem",
      "url" : "https://forum.semantic-metabolomics.fr/sparql"
    }],
    "settings" : {
      "logLevel" : "off"
    }
  }.stripMargin

  ,groupBySize : Int = 1000) {

val instDiscovery =
  SWDiscovery(StatementConfiguration.setConfigString(config_discovery))
  .prefix("c", "http://purl.obolibrary.org/obo/")
  .prefix("cp", "http://purl.obolibrary.org/obo/chebi#")
```

```
def get_has_role(chebi: URI)
: Future[Seq[URI]] = {

  instDiscovery
    .something()
    .set(chebi)
    .isSubjectOf(URI("rdfs:subClassOf"), "ac")
    .isSubjectOf(URI("owl:onProperty"))
    .set(URI("http://purl.obolibrary.org/obo/RO_0000087"))
    .focus("ac")
    .isSubjectOf(URI("owl:someValuesFrom"), "idChebi_role")
    .select(List("idChebi_role"))
    .commit()
    .raw
    .map(json =>
      json("results")("bindings").arr.map(row => SparqlBuilder.createUri(row("idChebi_role")))
    ).toSeq
  }
}
```

```
sbt:chebi-discovery> testOnly com.github.inrae.metabohub.Metabolites2NetworkTest
----- Running Tests -----
2021-10-07T13:23:25.232Z info [] ----- (SWDiscovery.scala:26)
2021-10-07T13:23:25.233Z info [] ---- Discovery : build 2021-05-25 ----- (SWDiscovery.scala:27)
2021-10-07T13:23:25.233Z info [] ----- (SWDiscovery.scala:28)
Map(<http://purl.obolibrary.org/obo/CHEBI_15756> -> Map(is_conjugate_acid_of -> <http://purl.obolibrary.org/obo/CHEBI_7896>), <http://purl.obolibrary.org/obo/CHEBI_7896> -> Map(is_conjugate_b
ase_of -> <http://purl.obolibrary.org/obo/CHEBI_15756>))
Map(<http://purl.obolibrary.org/obo/CHEBI_90488> -> Map(is_conjugate_acid_of -> <http://purl.obolibrary.org/obo/CHEBI_57880>))
Map(<http://purl.obolibrary.org/obo/CHEBI_30828> -> Map(is_conjugate_base_of -> <http://purl.obolibrary.org/obo/CHEBI_36023>))
Vector(<http://purl.obolibrary.org/obo/CHEBI_7896>, is_conjugate_acid_of, 0.1), (<http://purl.obolibrary.org/obo/CHEBI_7896>, is_conjugate_base_of, -0.1))
Vector(<http://purl.obolibrary.org/obo/CHEBI_57880>, is_conjugate_acid_of, 1.1))
Vector(<http://purl.obolibrary.org/obo/CHEBI_30828>, is_conjugate_base_of, -1.1))
- com.github.inrae.metabohub.Metabolites2NetworkTest.chebi - Metabolites2NetworkTest examples 1097ms
[Info] Tests: 1, Passed: 1, Failed: 0
[success] Total time: 3 s, completed 7 oct. 2021 à 15:23:26
sbt:chebi-discovery>
```



> Discovery - POC avec PeakForest

Implémentation de Discovery dans PeakForest - actuel & futur

Requête: « recherche toute les publication liées à un ChEBI id »

```
1 function listMetabolightsStudies(chebiid) {
2   // init
3   const config = SWDiscoveryConfiguration.setConfigString('
4     {
5       "sources": [{
6         "id": "metabolights",
7         "url": "https://metabolights.semantic-metabolomics.fr/sparql"
8       }];
9     }
10  );
11  const query = new SWDiscovery(config);
12  // let chebiid = "CHEBI:4167";
13  chebiid = chebiid + "";
14  chebiid = chebiid.toLowerCase().indexOf("chebi") < 0 ? "CHEBI:" + chebiid : chebiid;
15  let chebi = chebiid.replace(' ', '_');
16  let r = SWDiscovery(config).something()
17    .set("http://purl.obolibrary.org/obo/" + chebi)
18    .isObjectOf("https://www.ebi.ac.uk/metabolights/property#study")
19    .filter(contains("MTBLS"))
20    .focus("study")
21    .datatype("http://www.w3.org/2000/01/rdf-schema#label", "label")
22    .datatype("https://www.ebi.ac.uk/metabolights/property#technology_type", "technology_type")
23    .datatype("https://www.ebi.ac.uk/metabolights/property#comment", "comment")
24    .datatype("https://www.ebi.ac.uk/metabolights/property#instrument_platform", "instrument_platform")
25    .datatype("https://www.ebi.ac.uk/metabolights/property#organism_part", "organism_part")
26    .datatype("https://www.ebi.ac.uk/metabolights/property#study_design", "study_design")
27    .datatype("https://www.ebi.ac.uk/metabolights/property#study_factor", "study_factor")
28    .datatype("https://www.ebi.ac.uk/metabolights/property#organism", "organism")
29    .datatype("https://www.ebi.ac.uk/metabolights/property#omics_type", "omics_type")
30    .datatype("https://www.ebi.ac.uk/metabolights/property#publication", "publication")
31    .select("study", "label", "technology_type", "comment", "instrument_platform",
32           "organism_part", "study_design", "study_factor", "organism"); // "omics_type", "publication",
33
34  // run
35  r.commit().raw().then((response) => {
36    let strData = "";
37    for (let i = 0; i < response.results.bindings.length; i++) {
38      let study = response.results.bindings[i]["study"].value;
39      let label = response.results.datatypes["label"][study][0].value;
40      let technology_type = response.results.datatypes["technology_type"][study][0].value;
41      let comment = response.results.datatypes["comment"][study][0].value;
42      let instrument_platform = response.results.datatypes["instrument_platform"][study][0].value;
43      let organism_part = response.results.datatypes["organism_part"][study][0].value;
44      let organism = "";
45      if (Object.prototype.hasOwnProperty.call(response.results.datatypes["organism"], study)) {
46        organism = response.results.datatypes["organism"][study][0].value;
```

Appel du endpoint

Appel à l'endpoint

```
51 let study_factor = "";
52 if (Object.prototype.hasOwnProperty.call(response.results.datatypes["study_factor"], study)) {
53   study_factor = response.results.datatypes["study_factor"][study][0].value;
54 }
55 // console.log(label, "=>", study, ";", comment);
56 comment = $.parseHTML(comment); //parseHTML return HTMLCollection
57 comment = $(comment).text(); //use $( ) to get .text() method
58 // new line
59 strData += '<li class="list-group-item">' +
60 '<a href="#" + study + " target="blank"><i class="fa fa-link"></i></a>' +
61 '<span class="mtbls-technology-type">' + technology_type + '</span>' +
62 '<span class="mtbls-label" title="' + comment + "'>' + label + '</span>' +
63 // organism part
64 if (organism_part !== "") {
65   strData += '<span class="mtbls-organism-part">' + organism_part + '</span>' +
66 }
67 // organism
68 if (organism !== "") {
69   let shortOrga = organism.replace('http://purl.obolibrary.org/obo/NCBITaxon:', '');
70   strData += '<a class="mtbls-organism" href="#" + organism + " target="blank" + shortOrga + '</a>' +
71 }
72 // study_design
73 if (study_design !== "") {
74   strData += '<span class="mtbls-keyword">' + study_design + '</span>' +
75 }
76 // study_factor
77 if (study_factor !== "") {
78   strData += '<span class="mtbls-keyword">' + study_factor + '</span>' +
79 }
80 strData += '<span class="mtbls-keyword">' + instrument_platform + '</span>' +
81 '</li>';
82
83 // display or hide
84 if (strData !== "") {
85   document.getElementById('cardSheet_metabolights').innerHTML += '<ul class="list-group">' + strData + '</ul>';
86 } else {
87   $('#panel-metabolights-studies').hide();
88 }
89 });
```

Construction rendu HTML

Metabolights Studies

- NMR spectroscopy The Human Saliva Metabolome *saliva* NCBITaxon:9606 untargeted metabolites control sample group Agilent
- mass spectrometry Creating a Reliable Mass Spectral-Retention Time Library for All Ion Fragmentation-Based Metabolomics *pure substance* tandem mass spectrometry Amount Liquid Chromatography MS-Positive ESI-MS (Reactive)
- mass spectrometry Integration of whole-body [18F]FDG PET/MI with non-targeted metabolomics can provide new insights on tissue-specific insulin resistance in type 2 diabetes *Blood Plasma* NCBITaxon:9606 untargeted metabolites WHR Liquid Chromatography MS-
- mass spectrometry In Vitro and In Vivo Metabolomic Profiling after Infection with Virulent Newcastle Disease Virus *UMNSAH/DF-1 Cell* NCBITaxon:9031 ultra-performance liquid chromatography-mass spectrometry Viral exposure

Rendu HTML



INRAE

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Source: https://developer.mozilla.org/fr/docs/Web/Web_Components

> MetaboHUB & webcomponents

Groupe de travail – partage de composants applicatifs

Qu'est ce qu'un webcomponents?

- Ensemble de technologies permettant de créer des composants d'interface graphique **personnalisés** et **réutilisables**.
- Ces éléments sont **encapsulés**, **versatiles** et **sans risquer une collision avec d'autres morceaux de code**

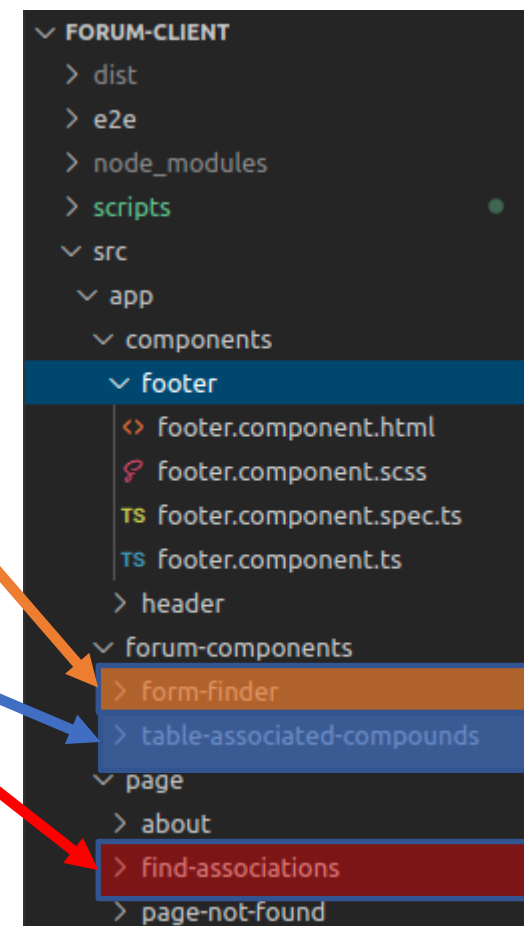
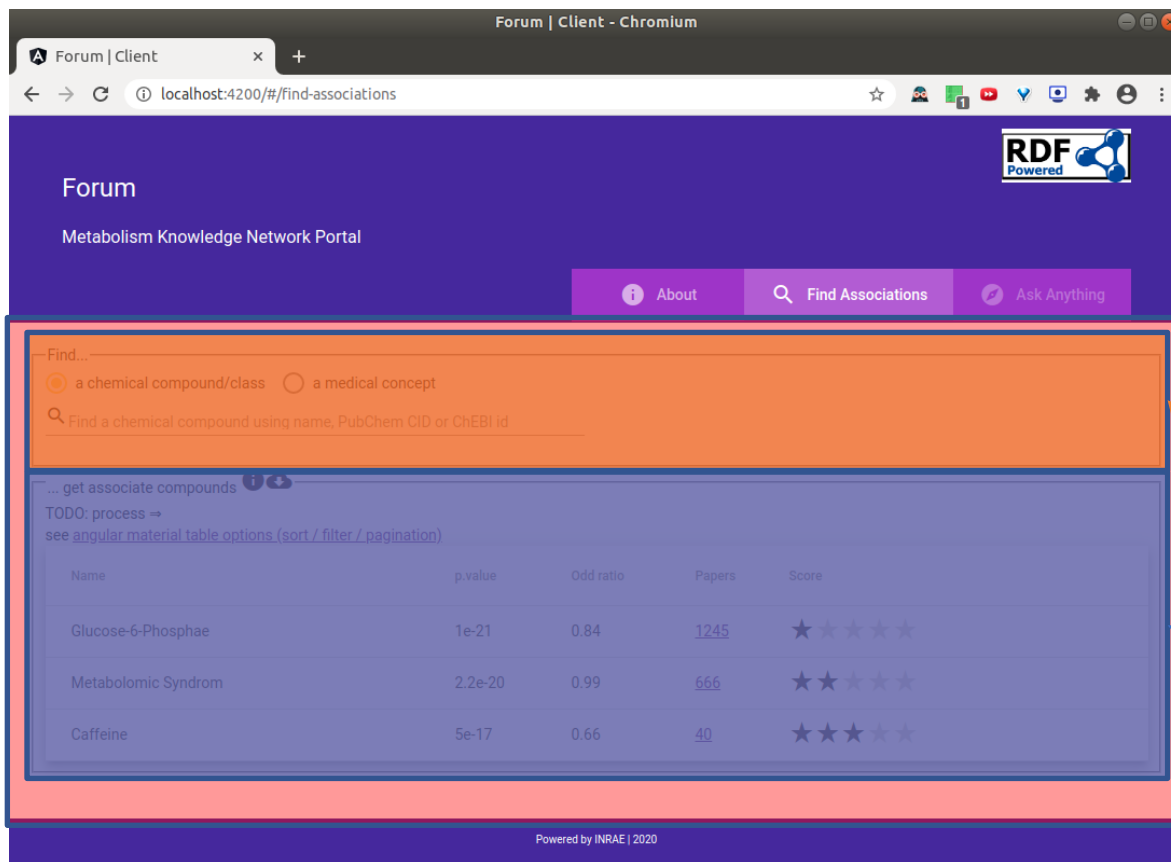
Problématiques posées:

- Uniformisation des choix technologiques (vue3, typescript, **OpenAPI**)
- Uniformisation des pratiques de dev. / framework graphiques (vuetify3)
- Autre (licences, repo de partage, ...)

	Pros	Cons
jQuery & ...	Bien connu des dev	Conflits de lib; « lourd »;
webcomponents	Réutilisable; TS; archi micro-api;	Transpliage JS; incompatibilité vue/angular/reac

➤ Projet Forum - Architecture

« App » architecture



INRAE

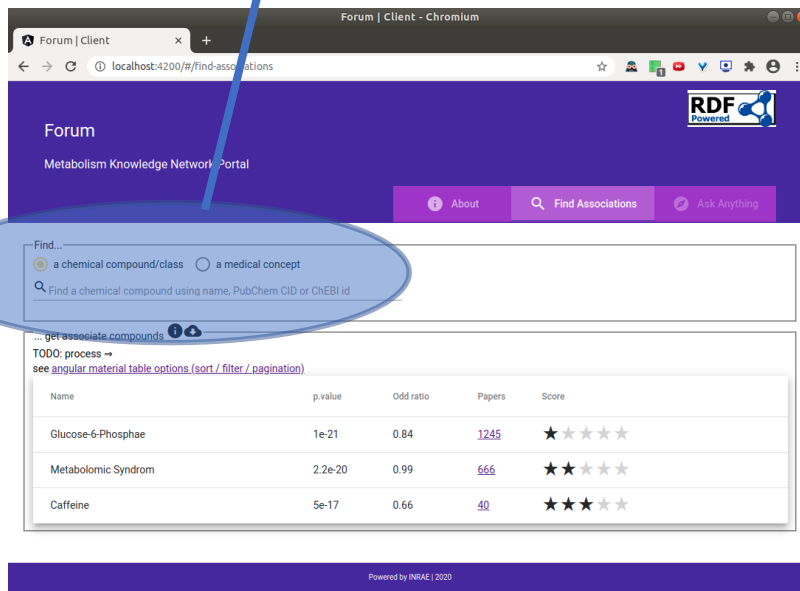
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➤ Forum Client - Code

Web Components

```
find-associations.component.html x
src > app > page > find-associations > find-associations.component.html > div#main-div
1 <div id="main-div">
2
3 <forum-form-finder (searchQuery)="onSearchQuery($event)"></forum-form-finder>
4
5 <forum-table-associated-compounds [searchResults]="dataSearchResults"></forum-table-associated-compounds>
6
7 </div>
```

```
TS form-finder.component.ts x
src > app > forum-components > form-finder > TS form-finder.component.ts > FormFinderComponent
1 import { Component, EventEmitter, OnInit, Output } from '@angular/core';
2
3 import { FormControl, FormGroup } from '@angular/forms';
4 import { Observable } from 'rxjs';
5 import { startWith, map } from 'rxjs/operators';
6
7 import { EndpointSearchQuery, SearchEntityType } from '../endpoint-search-query';
8
9 @Component({
10   selector: 'forum-form-finder',
11   templateUrl: './form-finder.component.html',
12   styleUrls: ['./form-finder.component.scss']
13 })
14 export class FormFinderComponent implements OnInit {
15
16   // data to send to parent
17   searchFormData: EndpointSearchQuery = new EndpointSearchQuery();
```



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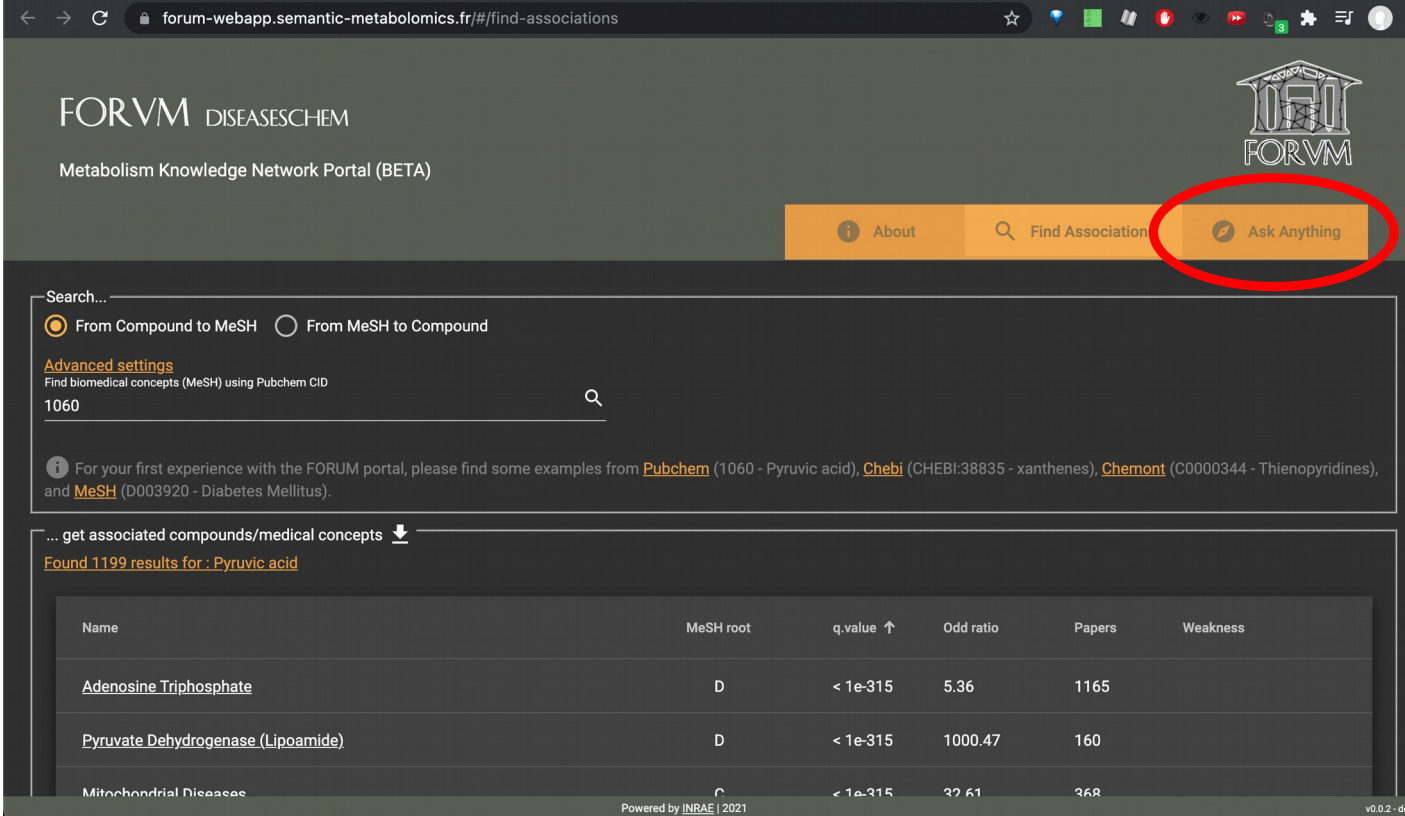
➤ Projet Forum - Perspectives

Done

- ✓ Fuzzy search

TODO

- Afficher version base
- « Ask anything »
 - YASGUI ?
 - <https://yasgui.triply.cc/>
 - AskOmics ?
 - <https://askomics.org/>
 - Sparklis ?
 - <http://www.irisa.fr/LIS/ferre/sparklis>



FORVM DISEASESCHEM
Metabolism Knowledge Network Portal (BETA)

Search...
 From Compound to MeSH From MeSH to Compound
[Advanced settings](#)
Find biomedical concepts (MeSH) using Pubchem CID
1060

For your first experience with the FORUM portal, please find some examples from [Pubchem](#) (1060 - Pyruvic acid), [Chebi](#) (CHEBI:38835 - xanthenes), [Chemont](#) (C0000344 - Thienopyridines), and [MeSH](#) (D003920 - Diabetes Mellitus).

... get associated compounds/medical concepts ↓
Found 1199 results for : Pyruvic acid

Name	MeSH root	q.value ↑	Odd ratio	Papers	Weakness
Adenosine Triphosphate	D	< 1e-315	5.36	1165	
Pyruvate Dehydrogenase (Lipoamide)	D	< 1e-315	1000.47	160	
Mitochondrial Diseases		< 1e-315	32.61	368	

Powered by INRAE | 2021 v0.0.2 - dev

<https://forum-webapp.semantic-metabolomics.fr>
<https://doi.org/10.1093/bioinformatics/btab627>



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Questions

- **FORUM**

- <http://semantic-metabolomics.org/>
- « *FORUM: Building a Knowledge Graph from public databases and scientific literature to extract associations between chemicals and diseases* » M.Delmas et al
<https://doi.org/10.1093/bioinformatics/btab627>
- Contact : clement.frainay@inrae.fr

- **Metabolomics Semantic Datalake**

- **Janvier/Février 2022 : formation Big Data (Spark/Scala) 6 demi-journée en visio**
- Contact : olivier.filangi@inrae.fr, franck.giacomoni@inrae.fr

- **Discovery**

- <https://p2m2.github.io/discovery> : (doc/tutoriels/templates/exemples d'application)
- Contact : olivier.filangi@inrae.fr

- **Web Component**

- Contact : nils.paulhe@inrae.fr

- **SPARQL Endpoints**

- <https://peakforest.semantic-metabolomics.fr/sparql/>
- <https://metabolights.semantic-metabolomics.fr/sparql/>
- <https://forum.semantic-metabolomics.fr/sparql/>

