GA4GH Metadata & Beyond

Implementing the GA4GH schema specifications on top of the arrayMap cancer genome resource

Michael Baudis | ELIXIR All Hands 2017 | 21-23 March | Rome | Italy

University of Zurich[UZH]

arrayMap

EMBL-EBI

Global Alliance for Genomics & Health

SIB

GA4GH API promotes sharing

GENOMICS

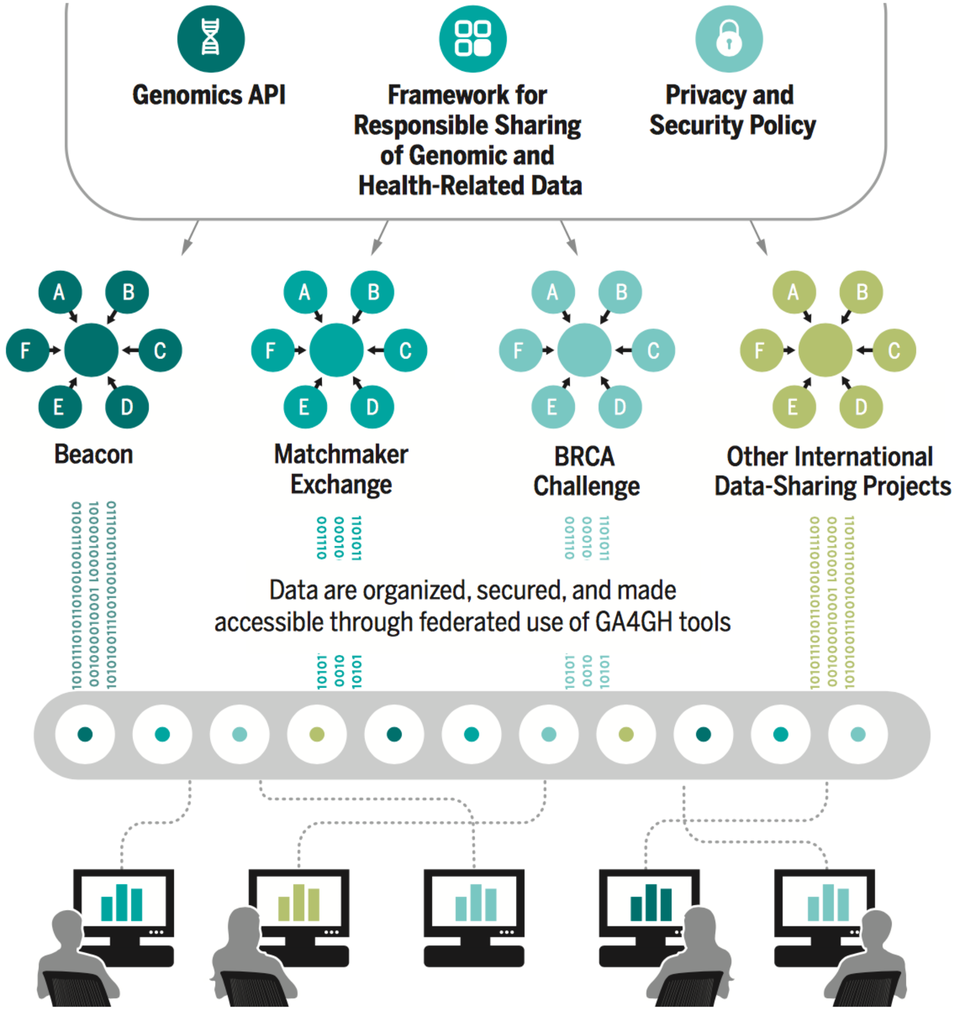
A federated ecosystem for sharing genomic, clinical data

Silos of genome data collection are being transformed into seamlessly connected, independent systems

The Global Alliance for Genomics and Health*

SCIENCE 10 JUNE 2016 • VOL 352 ISSUE 6291

A federated data ecosystem. To share genomic data globally, this approach furthers medical research without requiring compatible data sets or compromising patient identity.



Global Alliance for Genomics & Health

ga4gh / schemas

Work on data models and APIs for Genomic data. http://ga4gh.org/#/api

1,102 commits 17 branches 16 releases 46 contributors Apache-2.0

Branch: metadata-integ... New pull request Create new file Upload files Find file Clone or download

This branch is 15 commits ahead, 3 commits behind master. Pull request Compare

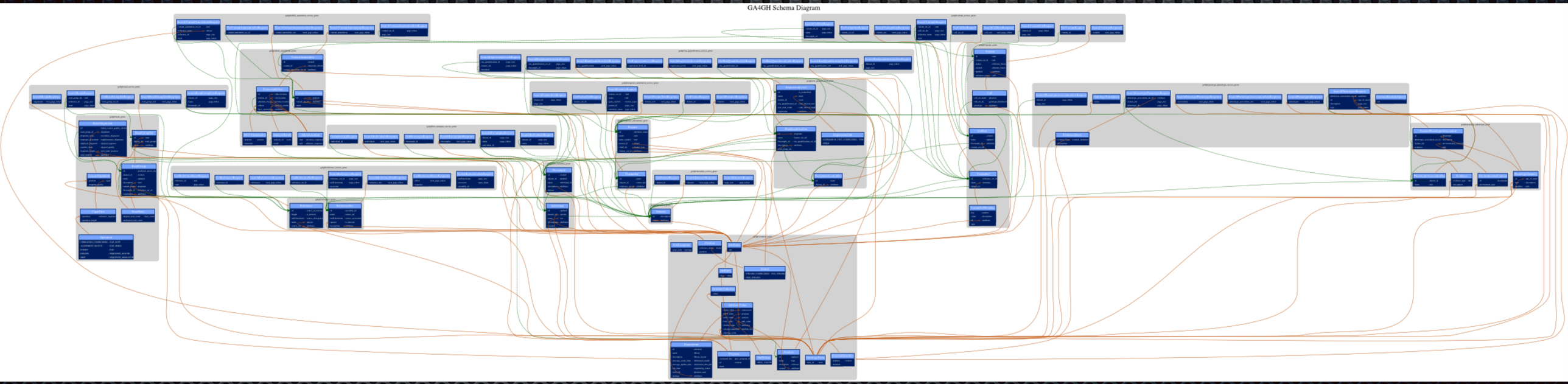
mbaudis Merge branch 'master' into metadata-integration Latest commit 077c2c7 2 days ago

doc	Merge branch 'master' into metadata-integration	2 days ago
python	Add constraints file	2 days ago
scripts	Utilize new common methods in schemas	2 days ago
src/main/proto	Merge branch 'master' into metadata-integration	13 days ago
tests	Utilize new common methods in schemas	2 days ago
tools	Merge branch 'master' into metadata-integration	13 days ago
.gitignore	Remove protoc call from install path (#781)	7 days ago
.travis.yml	Add constraints file	2 days ago
CONTRIBUTING.rst	Convert Avro -> proto3.	10 months ago

The State of the Schema, Feb 2017

Global Alliance
for Genomics & Health

Collaborate. Innovate. Accelerate.



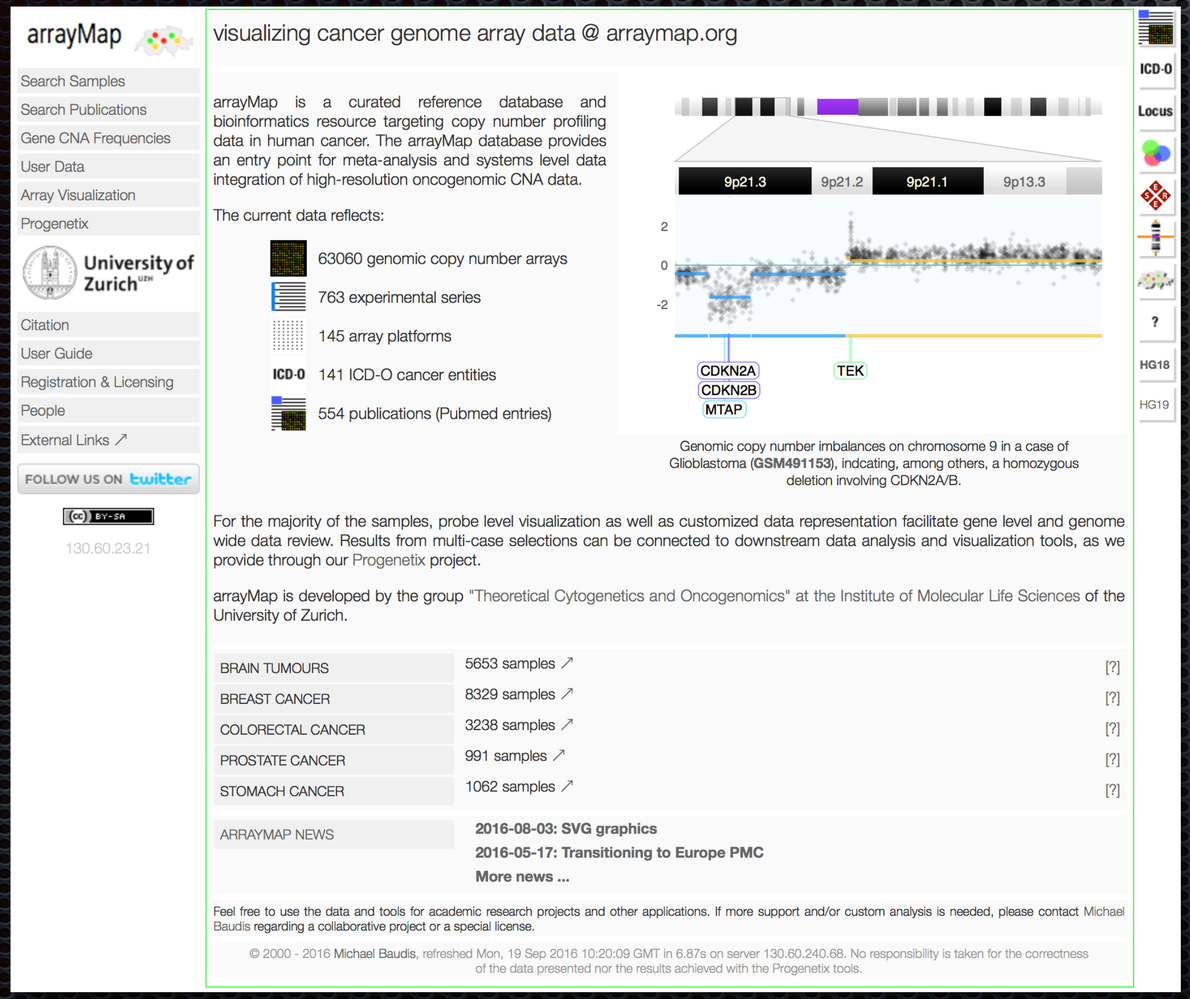
Reference Resources for Cancer Genome Profiling

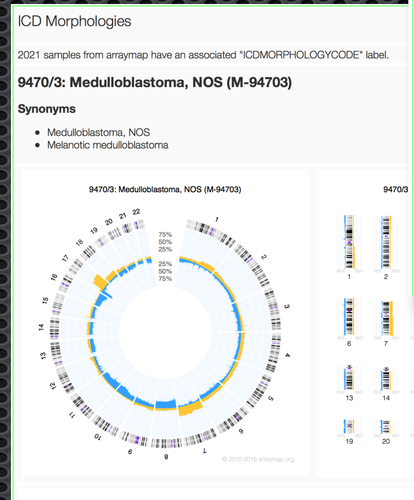
- curated reference resources for cancer genome profiling data and related information
- basis for own research activities, collaborative projects and external use
- structured information serves for implementing GA4GH concepts

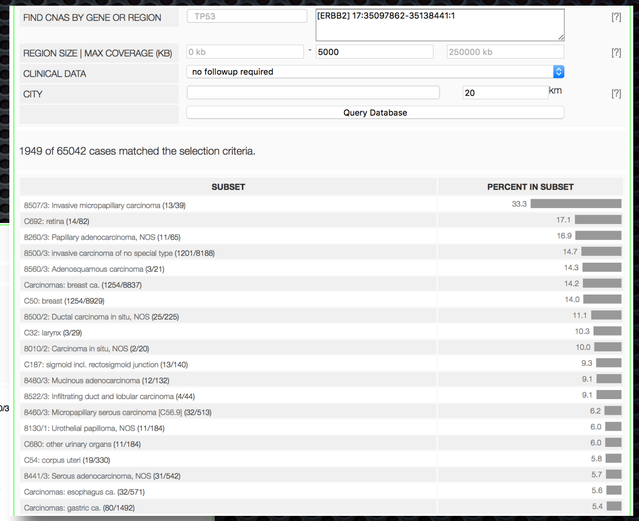
	progenetix	arrayMap
techniques	cCGH, aCGH, WES, WGS	aCGH (+?)
scope	sample (e.g. combination of several experiments)	experiment
content	**>31000** samples	**>60000** arrays
raw data presentation	no (link to sources if available)	yes (raw, log2, segmentation if available)
per sample re-analysis	no; supervised result (mostly as provided through publication)	yes (re-segmentation, thresholding, size filters ...)
final data	annotated/interpreted CN status for GP and cytogenetic regions	unsupervised CN status for GP and cytogenetic regions
main purposes	• Distribution of CNA target regions in most tumor types (>350 ICD-O) • Cancer classification	• Gene specific hits • Genome feature correlation (fragile sites ...)

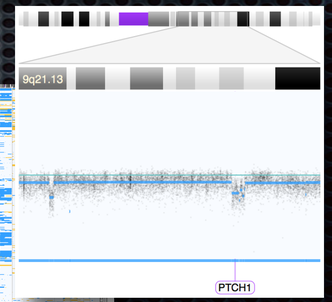
arrayMap

Resource for copy number variation data in cancer





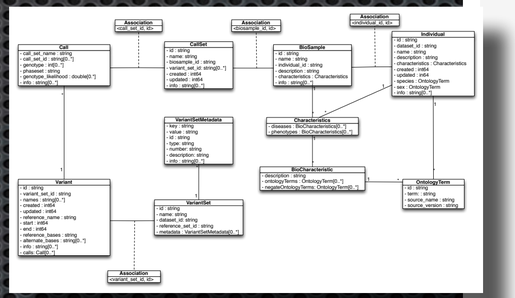




UID	SERIESID	PMID	ICDMORPHOLOGYCODE	ICDTOPOGRAPHYCODE
GSM1000061	GSE36942	23457519	8070/3	C10
GSM1000062	GSE36942	23457519	8070/3	C10
GSM1001316	GSE40777	23571474	8070/3	C53
GSM1001317	GSE40777	23571474	8010/3	C34
GSM1001318	GSE40777	23571474	8070/3	C09
GSM1001319	GSE40777	23571474	8010/3	C34
GSM1002668	GSE40834	24047479	9823/3	C42
GSM1002669	GSE40834	24047479	9823/3	C42
GSM1002670	GSE40834	24047479	9823/3	C42
GSM1002671	GSE40834	24047479	9823/3	C42
GSM1002672	GSE40834	24047479	9823/3	C42
GSM1002673	GSE40834	24047479	9823/3	C42
GSM1002674	GSE40834	24047479	9823/3	C42
GSM1002675	GSE40834	24047479	9823/3	C42
GSM1002676	GSE40834	24047479	9823/3	C42
GSM1002677	GSE40834	24047479	9823/3	C42
GSM1002678	GSE40834	24047479	9823/3	C42
GSM1002679	GSE40834	24047479	9823/3	C42
GSM1002680	GSE40834	24047479	9823/3	C42

Developing the GA4GH **Metadata** Schema

- arrayMap for GA4GH
  - metadata schema development through implementation of arrayMap resource data
  - OntologyTerm objects for biodata
  - implementation w/ ontology services



Driving **Beacon** Development

- Beacon+
  - CNV/CNA as first type of structural variants
  - disease specific queries
  - quantitative reporting

Global Alliance for Genomics & Health

EMBL-EBI

arrayMap

elixir

SIB Swiss Institute of Bioinformatics


```
{
        "_id" : ObjectId("58297ca32ca4591e5a0df054"),
        "id" : "AM_V_1778741",
        "variant_set_id" : "AM_VS_HG18",
        "reference_name" : "10"
        "start" : 579049,
        "end" : 17236099,
        "alternate_bases" : "DUP",
        "reference_bases" : ".",
        "info" : {
          "svlen":16657050,
          "cipos":[
              -1000,
              1000
          ],
          "ciend":[
              -1000,
              1000
          ]
        },
        "calls" : [
                {
                        "genotype" : [
                                ".",
                                "."
                        ],
                        "call_set_id" : "AM_CS_TCGA-61-1917-01A-01D-0648-01",
                        "info" : {
                                "segvalue" : 0.5491
                        }
                }
        ],
        "created" : ISODate("2016-11-14T08:33:58.202Z"),
        "updated" : ISODate("2016-11-14T08:33:58.202Z"),
}
```

Meta Data: Everything but the sequence

Global Alliance for Genomics & Health

May 2014 — Formation

August 2014 — Specification document

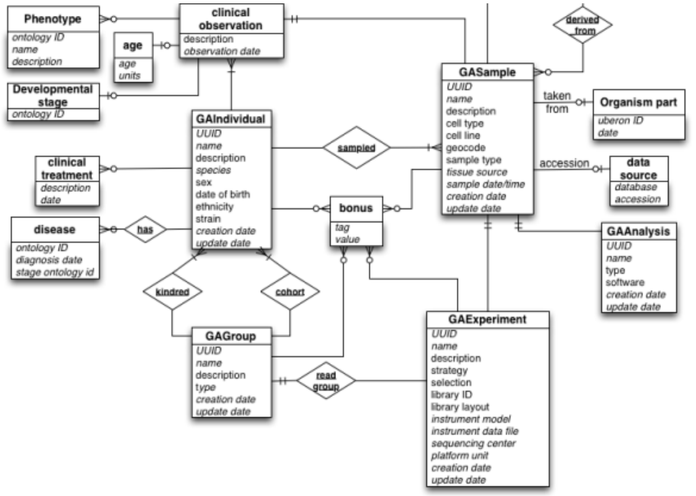
September 2014 — Draft Avro schema

October 2014 — Merged Schema

Frameworks for consistent description of annotated data domains:

- *GAExperiment* Technical data - bridge to Reads Task Team
- *GAIndividual* Clinical data - bridge to Clinical and Regulatory & Ethics
- *GAIndividualGroup* Static or dynamically generated semantic collections
- *GAAnalysis* Interpretation & methodology of one or more
- *GASample* Biological information using common ontologies

- Species neutral but focus on human use cases
- Standardised ontologies for feature annotations
- Next steps:
  - ontology recommendations (with CWG)
  - model refinement through implementation
  - validation and data transformation tools



Meta Data: Everything but the sequence

Global Alliance for Genomics & Health

May 2014 — Formation

August 2014 — Specification document

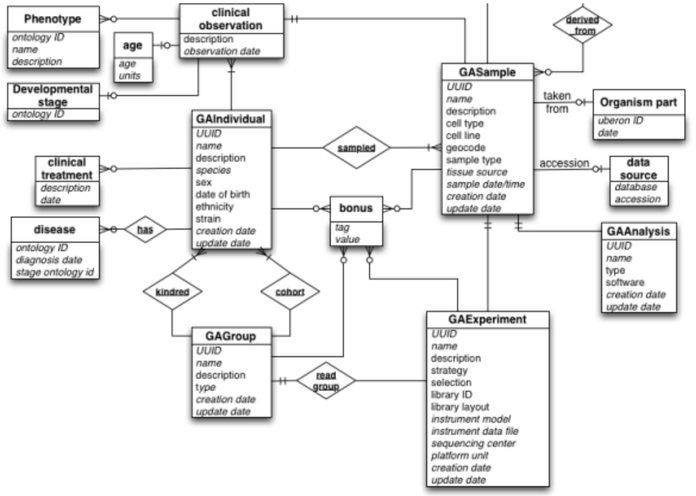
September 2014 — Draft Avro schema

October 2014 — Merged Schema

Frameworks for consistent description of annotated data domains:

- *GAExperiment* Technical data - bridge to Reads Task Team
- *GAIndividual* Clinical data - bridge to Clinical and Regulatory & Ethics
- *GAIndividualGroup* Static or dynamically generated semantic collections
- *GAAnalysis* Interpretation & methodology of one or more
- *GASample* Biological information using common ontologies

- Species neutral but focus on human use cases
- Standardised ontologies for feature annotations
- Next steps:
  - ontology recommendations (with CWG)
  - model refinement through implementation
  - validation and data transformation tools



“Metadata” Objects

metadata branch, December 2015

Individual
accessions
dateOfBirth
description
developmentalStage
diseases
ethnicity
geographicLocation
guid
id
info
interventions
name
observations
phenotypes
recordCreateTime
recordUpdateTime
sex
species
strain

BioSample
accessions
ageAtSampling
cellLine
cellType
description
geographicLocation
guid
id
individualIds
info
interventions
name
observations
organismPart
preservationMethod
recordCreateTime
recordUpdateTime
samplingDate
sex
species
specimenType

Experiment
description
id
info
instrumentDataFile
instrumentModel
molecule
name
platformId
platformName
preparationId
processingFacility
recordCreateTime
recordUpdateTime
runTime
selection
strategy

```
record OntologyTerm {
    union { null, string } ontologySourceID = null;
    union { null, string } ontologySourceName = null;
    union { null, string } ontologySourceVersion = null;
}
```

```
record GeographicLocation {
    union { null, string } description = null;
    union { null, float } elevation = null;
    union { null, float } latitude = null;
    union { null, float } longitude = null;
```

```
record Observation {
    union { null, string } ageAtObservation = null;
    union { null, string } dateTimeObserved = null;
    union { null, string } id = null;
    OntologyTerm observation;
    union { null, string } unit = null;
    OntologyTerm value;
}
```

```
record Evidence {
    union { null, string } description = null;
    OntologyTerm evidenceType;
```

```
record Dataset {
    array<string> accessions;
    union { null, string } description = null;
    union { null, string } guid = null;
    string id;
    array<string> memberIds;
    union { null, string } name = null;
}
```

```
record Disease {
    union { null, string } ageOfOnset = null;
    union { null, string } dateTimeDiagnosis = null;
    OntologyTerm disease;
    union { null, OntologyTerm } stageAtDiagnosis = null;
}
```

State of the schema

Biosample from arrayMap 2017-02-17


```
{
        "_id" : ObjectId("589dfa5109d374e4f3655aee"),
        "name" : "AM_BS_GSM322223",
        "individual_id" : "PGIND_GSM322223",
        "id" : "AM_BS_GSM322223",
        "characteristics" : {
                "diseases" : [
                        {
                                "ontologyTerms" : [
                                        {
                                                "termLabel" : "Chronic Lymphocytic Leukemia",
                                                "termId" : "NCIT:C3163"
                                        },
                                        {
                                                "termLabel" : "B-cell chronic lymphocytic leukemia/small lymphocytic lymphoma",
                                                "termId" : "SNMI:M-98233"
                                        },
                                        {
                                                "termLabel" : "B-cell chronic lymphocytic leukemia/small lymphocytic lymphoma",
                                                "termId" : "ICDOM:9823_3"
                                        },
                                        {
                                                "termLabel" : "hematopoietic and reticuloendothelial systems",
                                                "termId" : "ICDOT:C42"
                                        }
                                ],
                                "negatedOntologyTerms" : [ ],
                                "description" : "Chronic Lymphocytic Leukemia"
                        }
                ],
                "phenotypes" : [ ]
        },
        "description" : "Chronic Lymphocytic Leukemia",
        "info" : {
                "tnm" : "T1",
                "death" : "0",
                "country" : "Sweden",
                "geo_long" : 17.64,
                "redirected_to" : "null",
                "followup_months" : 68,
                "geo_lat" : 59.86,
                "pubmed_id" : "18484635",
                "sex" : "female",
                "age" : 59,
                "city" : "uppsala"
        },
        "updated" : ISODate("2017-02-10T17:15:02.380Z"),
        "created" : ISODate("2017-02-10T17:15:02.380Z")
}
```

- object model instead of named attributes
- referencing of ontologies instead of text descriptors

- need for ontologies & mappings
- these are no "real" open ontologies

- curating phenotypic data into ontologies

- fallback to key:value map for
- unassigned data; this should disappear over time


```
"_id" : ObjectId("589dfa5109d374e4f3655aee"),
"name" : "AM_BS_GSM322223",
"individual_id" : "PGIND_GSM322223",
"id" : "AM_BS_GSM322223",
"characteristics" : {
        "diseases" : [
                {
                        "ontologyTerms" : [
                                {
                                        "termLabel" : "B-cell chronic lymphocytic leukemia/small lymphocytic lymphoma",
                                        "termId" : "SNMI:M-98233"
                                },
                                {
                                        "termLabel" : "B-cell chronic lymphocytic leukemia/small lymphocytic lymphoma",
                                        "termId" : "ICDOM:9823_3"
                                },
                                {
                                        "termLabel" : "hematopoietic and reticuloendothelial systems",
                                        "termId" : "ICDOT:C42"
                                }
                        ],
                        "negatedOntologyTerms" : [ ],
                        "description" : "Chronic Lymphocytic Leukemia"
                }
        ],
        "phenotypes" : [ ]
},
"description" : "Chronic Lymphocytic Leukemia",
"info" : {
        "tnm" : "T1",
        "death" : "0",
        "country" : "Sweden",
        "geo_long" : 17.64,
        "redirected_to" : "null",
        "followup_months" : 68,
        "geo_lat" : 59.86,
        "pubmed_id" : "18484635",
        "sex" : "female",
        "age" : 59,
        "city" : "uppsala"
},
"updated" : ISODate("2017-02-10T17:15:02.380Z"),
"created" : ISODate("2017-02-10T17:15:02.380Z")
```

Working towards ontologies: Mapping >55'000 samples from ICD-O to NCIt (neoplasm core)

example_dx	ICDMORPHOLOGY	ICDOM	ICDTOPOGRAPHY	ICDOT	NCIT:CODE
malignant melanoma [metastatic cell line MaMel19]	Malignant melanoma NOS	8720/3	skin	C44	C3224
malignant melanoma [vagina]	Malignant melanoma NOS	8720/3	vagina and labia	C510	C3224
malignant melanoma [uvea metastasized]	Malignant melanoma NOS	8720/3	retina	C692	C3224
meningioma	Meningioma NOS	9530/0	meninges cerebral spinal	C700	C3230
mesothelioma	Mesothelioma NOS	9050/3	lung and bronchus	C34	C3234
pleural mesothelioma	Mesothelioma NOS	9050/3	pleura	C384	C3234
mesothelioma	Mesothelioma NOS	9050/3	connective and soft tissue NOS	C499	C3234
multiple myeloma	Plasma cell myeloma	9732/3	hematopoietic and reticuloendothelial syste	C42	C3242
Mycosis fungoides	Mycosis fungoides	9700/3	skin	C44	C3246
Myelodysplastic syndrome	Myelodysplastic syndrome NOS	9989/3	hematopoietic and reticuloendothelial syste	C42	C3247
Acute myeloblastic leukemia with maturation [FAB M2]	Acute myeloblastic leukemia with maturation [FAB M2]	9874/3	hematopoietic and reticuloendothelial syste	C42	C3250
neuroblastoma	Neuroblastoma NOS	9500/3	peripheral nervs incl. autonomous	C47	C3270
Cerebral neuroblastoma [cerebral region midline frontal lobe]	Neuroblastoma NOS	9500/3	cerebrum	C710	C3270
neuroblastoma [adrenal gland cell line]	Neuroblastoma NOS	9500/3	adrenal gland	C76	C3270
Cutaneous neurofibroma	Neurofibroma NOS	9540/0	skin	C44	C3272
Plexiform neurofibroma	Neurofibroma NOS	9540/0	Nervous system NOS	C729	C3272
Oligodendroglioma [Supratentorial Frontal Lobe]	Oligodendroglioma NOS	9450/3	cerebrum	C710	C3288
oilgodendroglioma	Oligodendroglioma NOS	9450/3	Brain NOS	C719	C3288
oligodendroglioma	Oligodendroglioma NOS	9450/3	brain nos	c719	C3288
Paraganglioma	Paraganglioma NOS	8680/1	Nervous system NOS	C729	C3308
paraganglioma	paraganglioma NOS	8680/1	adrenal cortex	C740	C3308
Pheochromocytoma	Pheochromocytoma NOS	8700/0	adrenal cortex	C740	C3326
polycythemia vera	Polycythemia vera	9950/3	hematopoietic and reticuloendothelial syste	C42	C3336
pediatric rhabdomyosarcoma	Rhabdomyosarcoma NOS	8900/3	connective and soft tissue NOS	C499	C3359
Sezary syndrome	Sezary syndrome	9701/3	hematopoietic and reticuloendothelial syste	C42	C3366
sezary syndrome	sezary syndrome	9701/3	skin	C44	C3366
Synovial sarcoma	Synovial sarcoma NOS	9040/3	connective and soft tissue NOS	C499	C3400
essential thrombocythemia	Essential thrombocythemia	9962/3	hematopoietic and reticuloendothelial syste	C42	C3407
carcinosarcoma	Carcinosarcoma NOS	8980/3	connective and soft tissue NOS	C499	C34448
Carcinosarcoma [breast cell line HS578T]	Carcinosarcoma NOS	8980/3	breast	C50	C34448
acute monocytic leukemia	Monocytic leukemia NOS	9860/3	hematopoietic and reticuloendothelial syste	C42	C3171
leiomyoblastoma	Epithelioid leiomyoma	8891/0	kidney	C649	C3157
colon mucosa [low grade dysplastic tumor; myhmut]	atypical adenoma	8140/1	large intestine excl. rectum and rectosigmoi	C189	C7559

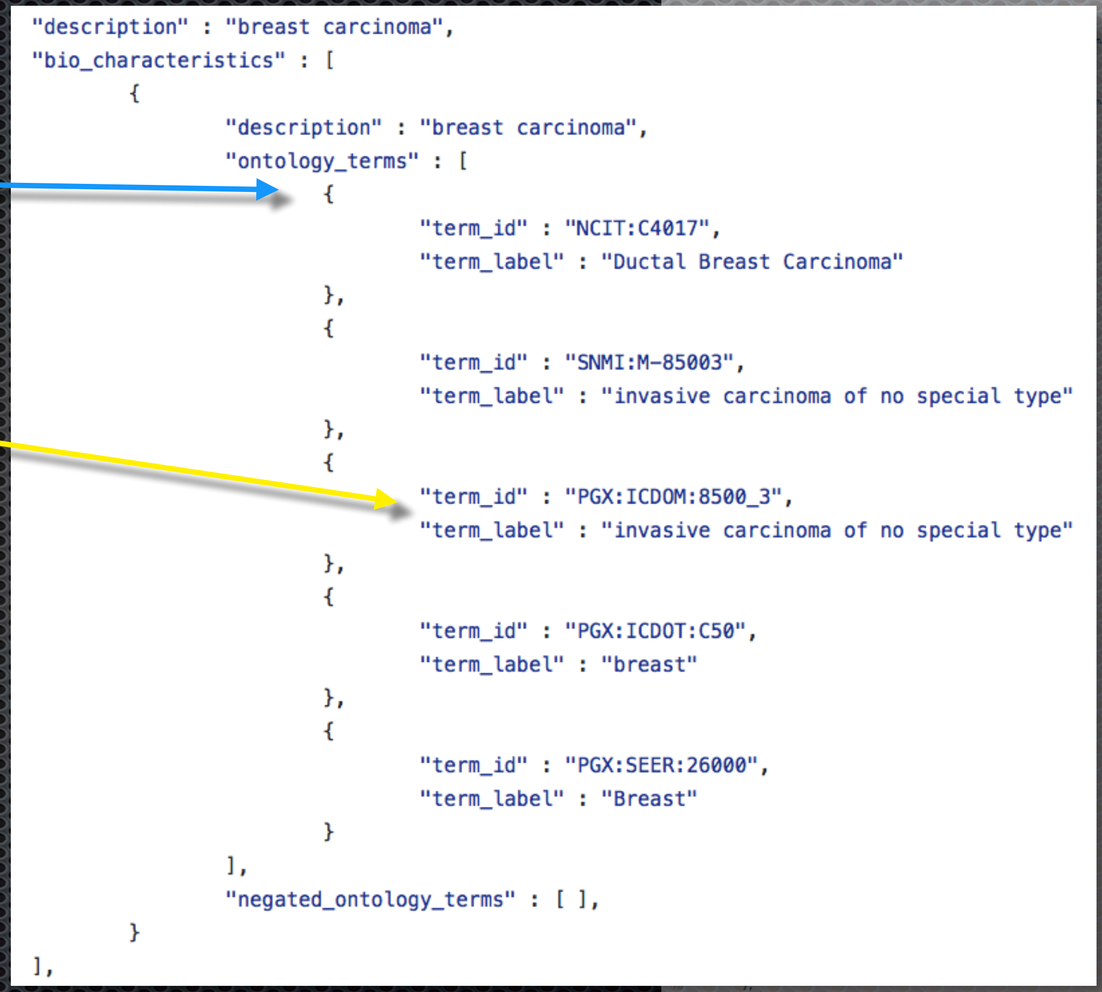
State of the schema

Biosample from arrayMap

2017-03-20

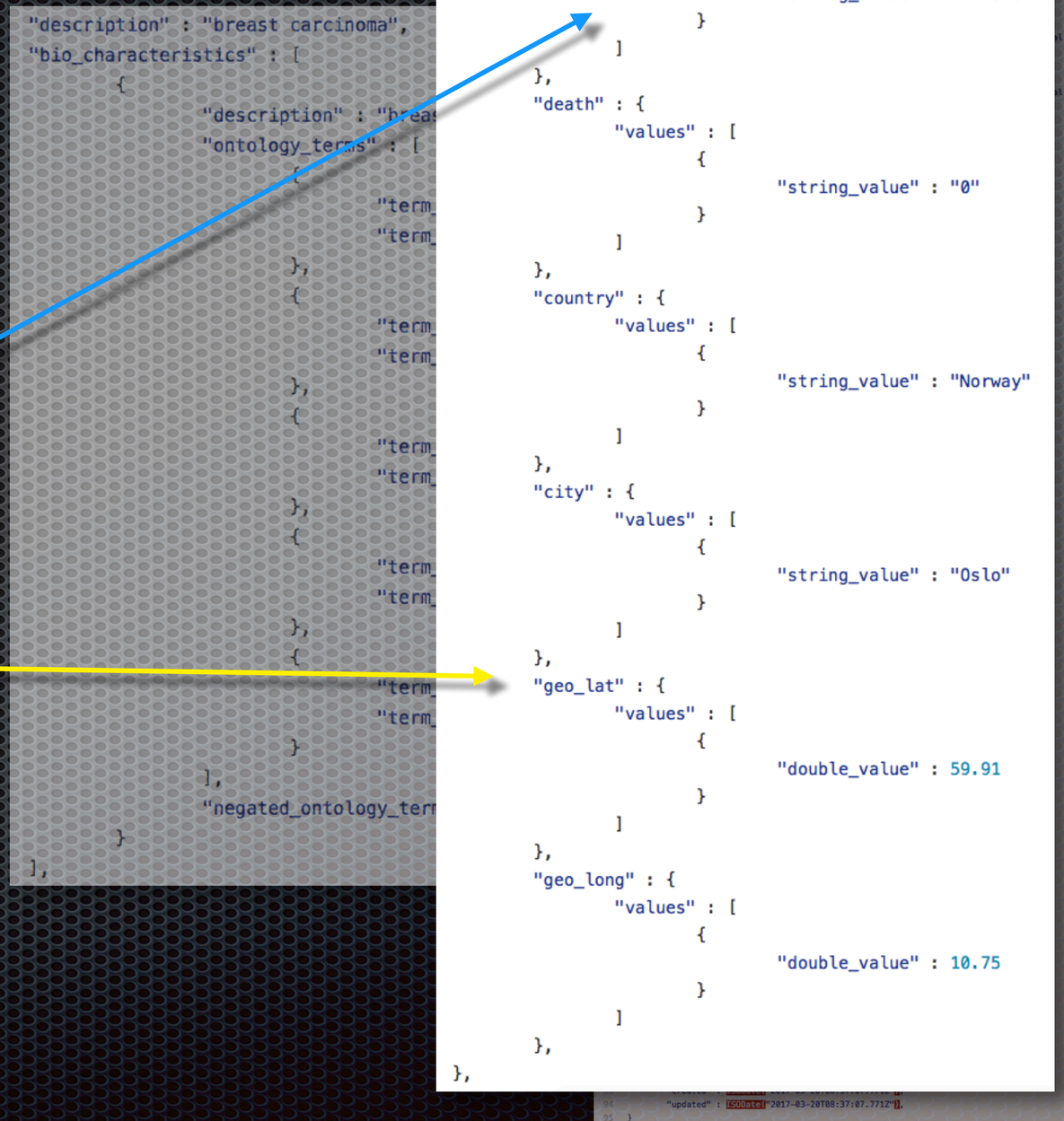

```
{
	"id" : "PGX_AM_BS_GSM510730",
	"individual_id" : "PGX_IND_GSM510730",
	"name" : "PGX_AM_BS_GSM510730",
	"description" : "breast carcinoma",
	"bio_characteristics" : [
		{
			"description" : "breast carcinoma",
			"ontology_terms" : [
				{
					"term_id" : "NCIT:C4017",
					"term_label" : "Ductal Breast Carcinoma"
				},
				{
					"term_id" : "SNMI:M-85003",
					"term_label" : "invasive carcinoma of no special type"
				},
				{
					"term_id" : "PGX:ICDOM:8500_3",
					"term_label" : "invasive carcinoma of no special type"
				},
				{
					"term_id" : "PGX:ICDOT:C50",
					"term_label" : "breast"
				},
				{
					"term_id" : "PGX:SEER:26000",
					"term_label" : "Breast"
				}
			],
			"negated_ontology_terms" : [ ],
		}
	],
	"individual_age_at_collection" : "P47Y",
	"attributes" : {
		"tnm" : {
			"values" : [
				{
					"string_value" : "T1N0M0"
				}
			]
		},
		"death" : {
			"values" : [
				{
					"string_value" : "0"
				}
			]
		},
		"country" : {
			"values" : [
				{
					"string_value" : "Norway"
				}
			]
		},
		"city" : {
			"values" : [
				{
					"string_value" : "Oslo"
				}
			]
		},
		"geo_lat" : {
			"values" : [
				{
					"double_value" : 59.91
				}
			]
		},
		"geo_long" : {
			"values" : [
				{
					"double_value" : 10.75
				}
			]
		},
	},
	"external_identifiers" : [
		{
			"database" : "Pubmed",
			"identifier" : "20592421"
		},
		{
			"database" : "GEO",
			"identifier" : "GSM510730"
		},
		{
			"database" : "GEO",
			"identifier" : "GSE20394"
		}
	],
	"created" : ISODate("2017-03-20T08:37:07.771Z"),
	"updated" : ISODate("2017-03-20T08:37:07.771Z"),
}
```

- drop of diseases | phenotypes wrapper used to type characteristics (discussion with code integration team at UCSC)
- **TODO**: introduce alternative characteristic_type label?
- introduction of “PGX” prefix for “ontologized” local versions of ICD-O 3 etc.



Biosample from arrayMap, 2017-03-20

- drop of diseases | phenotypes wrapper used to type characteristics (discussion with code integration team at UCSC)
- **TODO**: introduce alternative characteristic_type label?
- introduction of “PGX” prefix for “ontologized” local versions of ICD-O 3 etc.
- typed constructors now being used for “arbitrary” attributes
- **TODO**: Finish design of a geographic location object



Biosample from arrayMap, 2017-03-20

GeoLocation object proposal

- general consensus about some sort of **geographic attribution**, for a yet to be determined subset of GA4GH records/objects
- GeoJSON itself is not a good option for storing data, but rather for indicating objects on a maplocal **obfuscation** approaches will be needed for privacy protection
- destructive obfuscation can recode addresses to (random) points in higher level administrative boundaries
- the combination of *lat*, *long* with a location name seems a good compromise, with a "**precision level**" providing additional features (e.g. possibility to randomize point locations in a given boundary)

```
message GeoLocation {
  // a text representation, preferably using standard geographic identification
  // elements, of the corresponding latitude,longitude(,altitude)
  // This representation serves the purposes to
  //  - capture standard data entry parameters
  //  - provide a sanity check for latitude,longitude values
  // Example:
  //  - 34 Washington Blvd, Venice Beach, Los Angeles, CA, United States
  //  - Str Marasesti 5, 300077 Timisoara, Romania
  //  - Heidelberg, Deutschland
  string geo_label = 1;

  // an optional indication of the maximum precision to be derived from the
  // latitude,longitude values
  // Example:
  // Given a street address "Winterthurerstrasse 190, 8057 Zürich, Switzerland",
  // a privacy driven (destructive) obfuscation approach could recode this
  // to
  //  "latitude": 47.37, "longitude": 8.54
  //  while providing
  //  "geo_precision":"city", "geo_label": "Zürich, Switzerland"
  // ... indicating that the original location could correspond to any
  // latitude,longitude point value inside the administrative boundaries of
  // the city of Zürich, Switzerland
  string geo_precision = 2;

  // signed decimal degrees (North, relative to Equator)
  double latitude = 3;

  // signed decimal degrees (East, relative to IERS Reference Meridian)
  double longitude = 4;

  // optional, e.g. for environmental samples
  double altitude = 5;
}
```

- drop of diseases | phenotypes wrapper used to type characteristics (discussion with code integration team at UCSC)
- **TODO**: introduce alternative characteristic_type label?
- introduction of “PGX” prefix for “ontologized” local versions of ICD-O 3 etc.
- typed constructors now being used for “arbitrary” attributes
- **TODO**: Finish design of a geographic location object
- External identifiers as pointers to other places where this record is represented
- **TODO**: Add label for type of representation (i.e., contained_in)

Biosample from arrayMap, 2017-03-20

- sex described here, not at Biosample level
- referencing of ontologies instead of text descriptors

- diseases & phenotypes which are associated with the individual are recorded here
- diseases can also include those for which biosample records exist (independent of the specific annotation there)

Individual from arrayMap, 2017-03-20


```
{
        "id" : "PGX_IND_GSM847445",
        "name" : "PGX_IND_GSM847445_edited",
        "species" : {
                "term_id" : "NCBITaxon:9606",
                "term_label" : "Homo sapiens"
        },
        "sex" : {
                "term_id" : "PATO:0020002",
                "term_label" : "female genotypic sex"
        },
        "description" : "individual with Li-Fraumeni syndrome",
        "bio_characteristics" : [
                {
                        "description" : "Li-Fraumeni syndrome carrier",
                        "ontology_terms" : [
                                {
                                        "term_id" : "DOID:3012",
                                        "term_label" : "Li-Fraumeni syndrome",
                                },
                        ],
                },
                {
                        "description" : "adrenocortical carcinoma",
                        "ontology_terms" : [
                                {
                                        "term_label" : "Adrenal Cortex Carcinoma",
                                        "term_id" : "NCIT:C9325",
                                },
                        ],
                }
        ],
        "attributes" : null,
        "created" : ISODate("2017-03-20T08:37:07.771Z"),
        "updated" : ISODate("2017-03-20T08:37:07.771Z"),
}
```

Structural *Variants* from arrayMap

- name here could be e.g. an rsid
- calls are embedded in the variant set
- alternative option?
- “info” provides an intensity measurement
- could e.g. provide QC, copy number count …
- Housekeeping needed?


```
{
    "id" : "AM_V_3110636",
    "name" : null,
    "reference_name" : "11",
    "reference_bases" : ".",
    "start" : 75085926,
    "alternate_bases" : ".",
    "end" : 75744338,
    "variant_type" : "DEL",
    "svlen" : 658412,
    "info" : {},
    "calls" : [
        {
            "call_set_id" : "AM_CS_GSM902433",
            "info" : {
                "segvalue" : -0.3881
            },
            "genotype" : [ “.”, “.” ]
        },
        {
            "call_set_id" : "AM_CS_GSM902435",
            "info" : {
                "segvalue" : -0.4112
            },
            "genotype" : [ “.”, “.” ]
        }
    ],
    "updated" : ISODate("2017-02-10T17:15:02.380Z"),
    "created" : ISODate("2017-02-10T17:15:02.380Z"),
}
```

progenetix / arraymap2ga4gh

Unwatch 5 | Star 1 | Fork 2

Code | Issues 1 | Pull requests 0 | Projects 0 | Wiki | Pulse | Graphs

Schema examples

21 commits | 1 branch | 0 releases | 3 contributors

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

mbaudis edited individual entry ... Latest commit 34234a7 6 hours ago

data	changing the project structure	2 months ago
examples	edited individual entry	6 hours ago
README.md	links	21 days ago

README.md

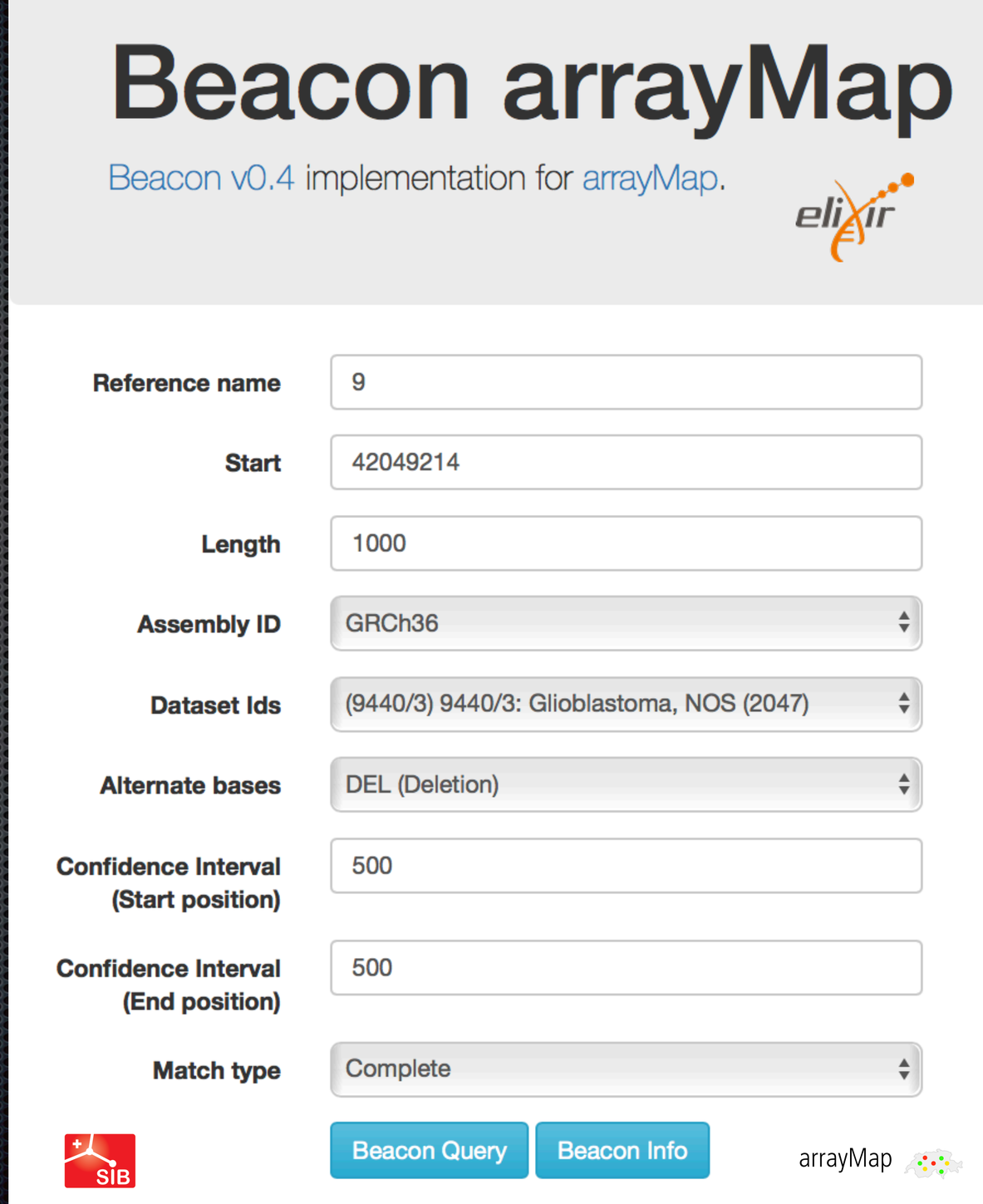
Implementation of the GA4GH schema based on genome profiles and metadata from arrayMap

This repository will contain data and information regarding the arrayMap based implementation of a GA4GH schema structure. While it is not expected that GA4GH compliant resources mirror the schema in their internal structure, this

Beacon+ Concept

- Implementation of cancer beacon prototype, backed by arrayMap data
- structural variations
- quantitative queries
- metadata
- current version uses GA4GH schema compatible, non-SQL database backend (MongoDB)

Heinz Stockinger, Séverine Duvaud & SIB Technology Group



GA4GH Metadata

"Everything but the sequence"

BAUDISGROUP @ UZH

MICHAEL BAUDIS
PAULA CARRIO CORDO
BO GAO
SAUMYA GUPTA

EMBL-EBI

MELANIE COURTOT
HELEN PARKINSON

SIB

HEINZ STOCKINGER
SÉVERINE DUVAUD
VASSILIOS IOANNIDIS
DANIEL TEIXEIRA

University of Zurich[UZH]

SIB

elixir

EMBL-EBI

Global Alliance for Genomics & Health

ELIXIR

JORDI RAMBLA DE ARGILA
MACHA NIKOLSKI
S. DE LA TORRE PERNAS
SUSANNA REPO
SERENA SCOLLEN

GA4GH DWG + CWG

JACQUI BECKMANN
ANTHONY BROOKES
MARK DIEKHANS
MELISSA HAENDEL
SARAH HUNT
STEPHEN KEENAN
SUZY LEWIS
DAVID LLOYD
MICHAEL MILLER
ELEANOR STANLEY
DAVID STEINBERG