hQuery

The MITRE Corporation

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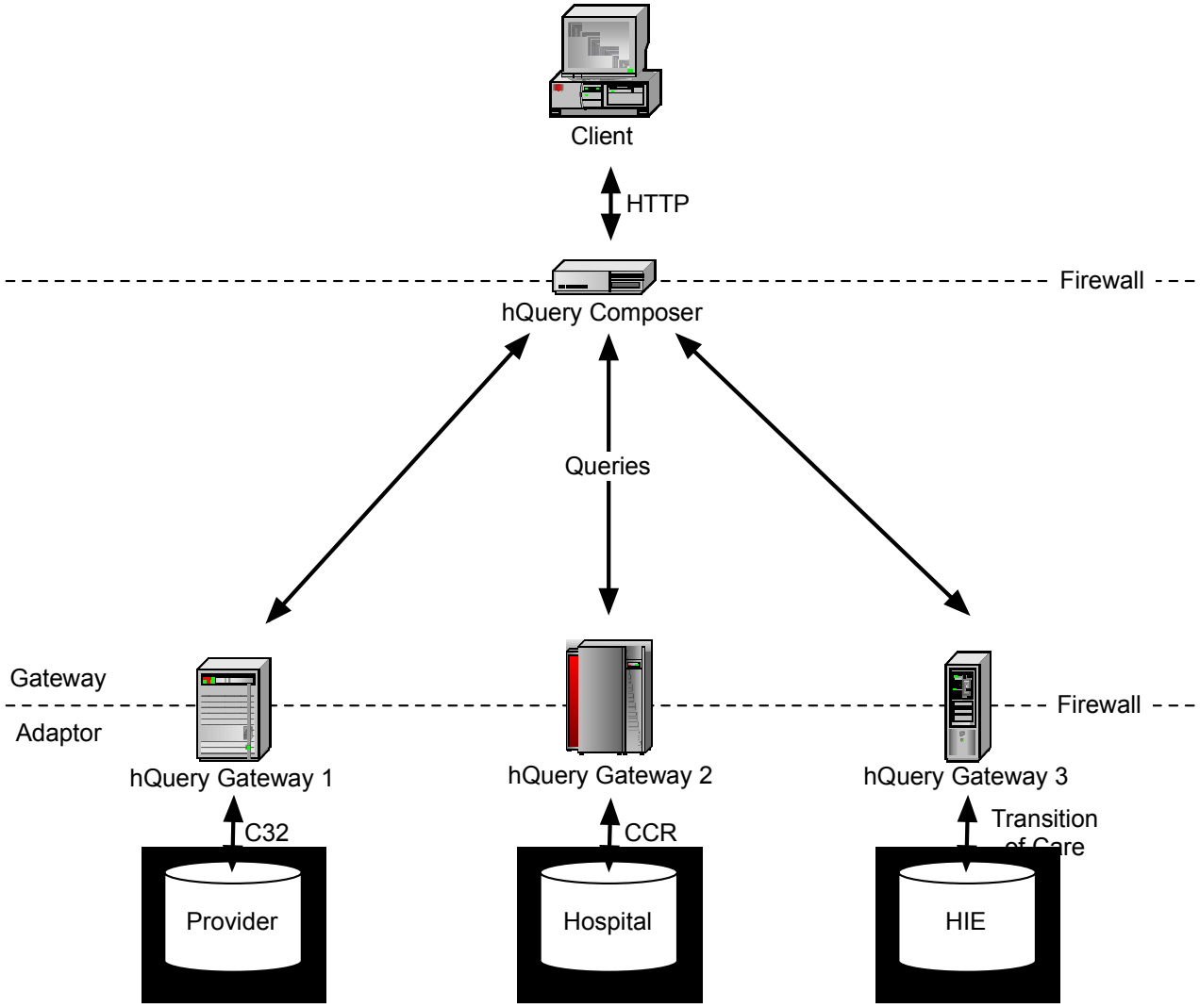
Background

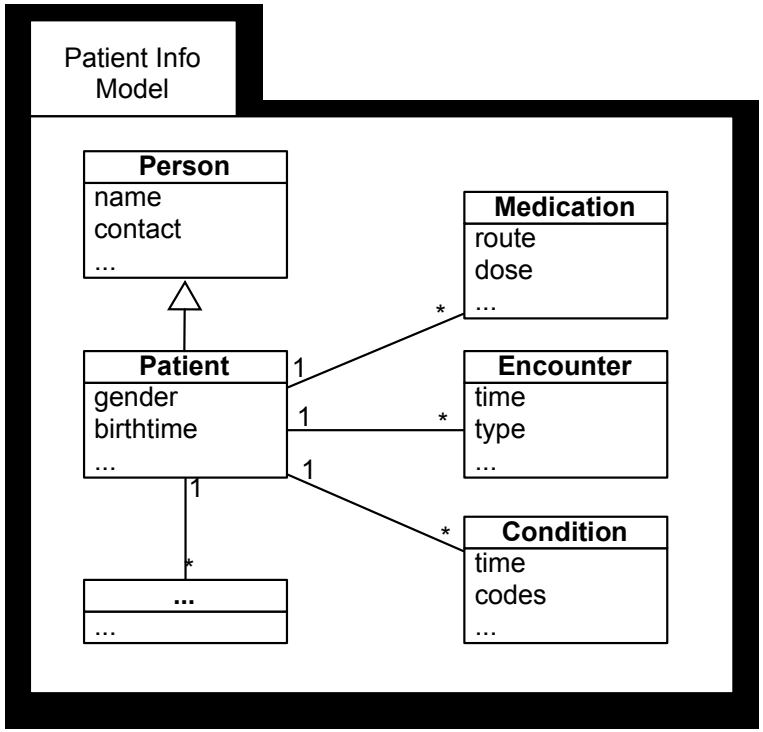
- Sponsored by Office of the National Coordinator for Health IT (ONC)
- Building on experience in healthcare data standards and population health reporting
  - Laika: http://laika.sourceforge.net/
  - hData: http://www.projecthdata.org/
  - popHealth: http://projectpophealth.org/
- Initial proof-of-concept to generalize popHealth architecture for ad-hoc distributed queries
  - Started May 20th 2011
  - Finishing end of September, 2011
- Agile PM, fifth sprint currently underway

High Level Architecture

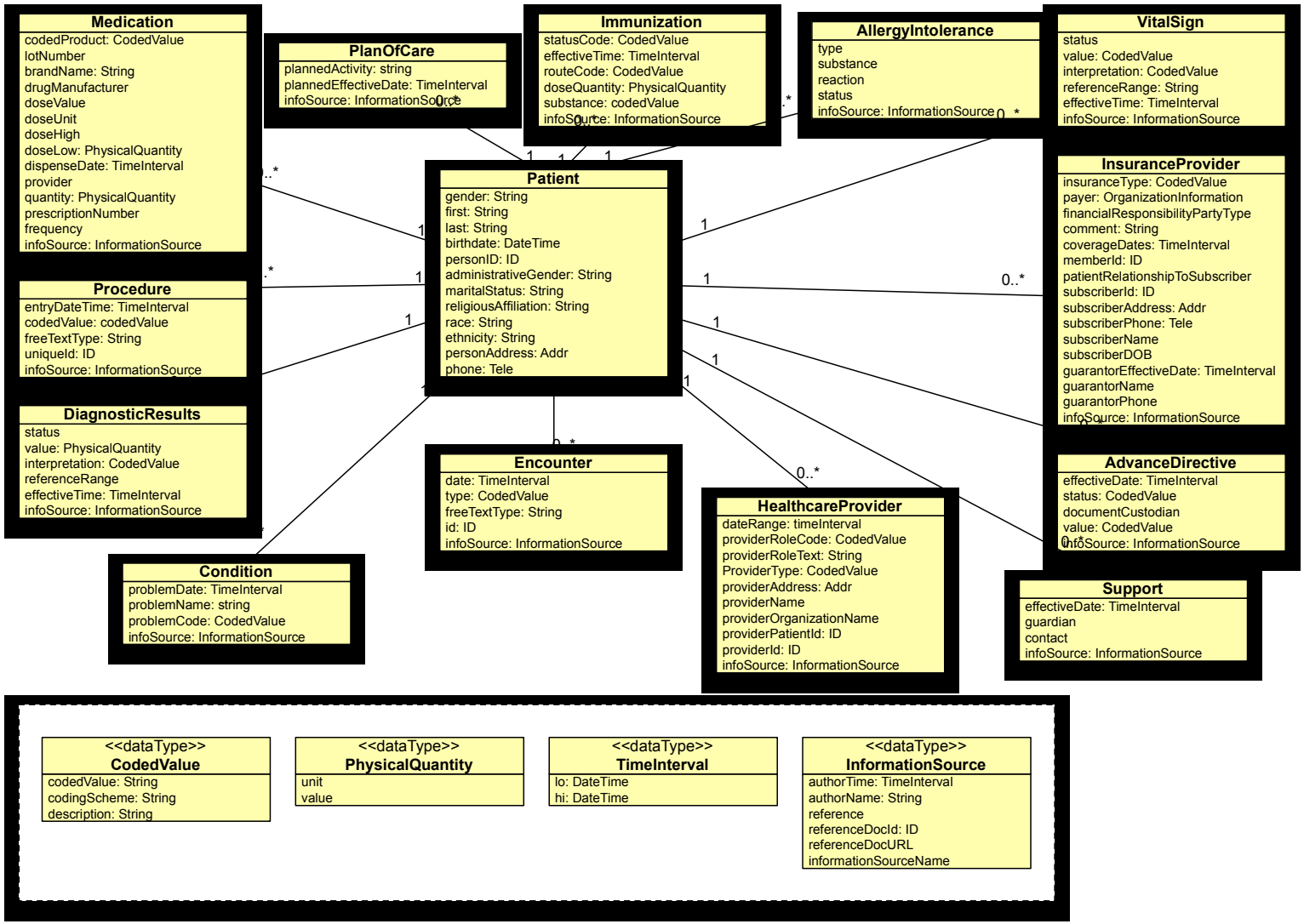


Patient Information Model

- Standard information model exposed to queries
- Independent of backing data source (C32, CCR, RDBMS, …)
- Enables generic queries regardless of backing data source
- Tuned for ease of querying



Information Model Based on Green CDA for C32

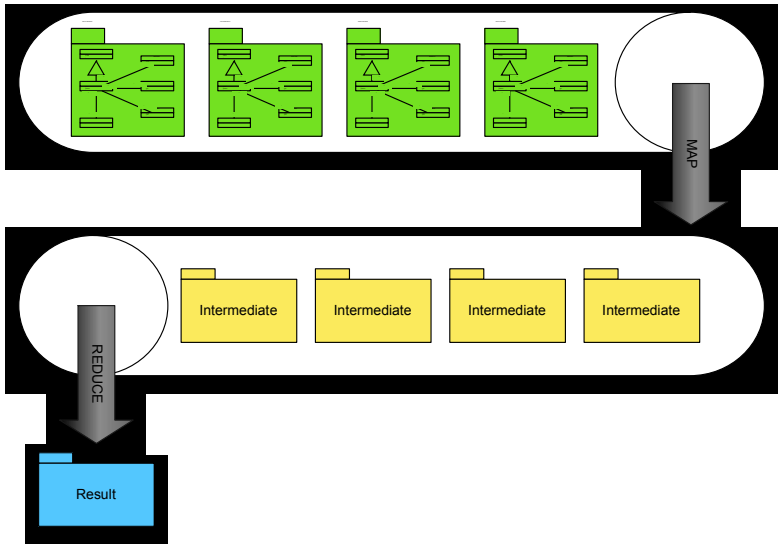


Information Model Properties

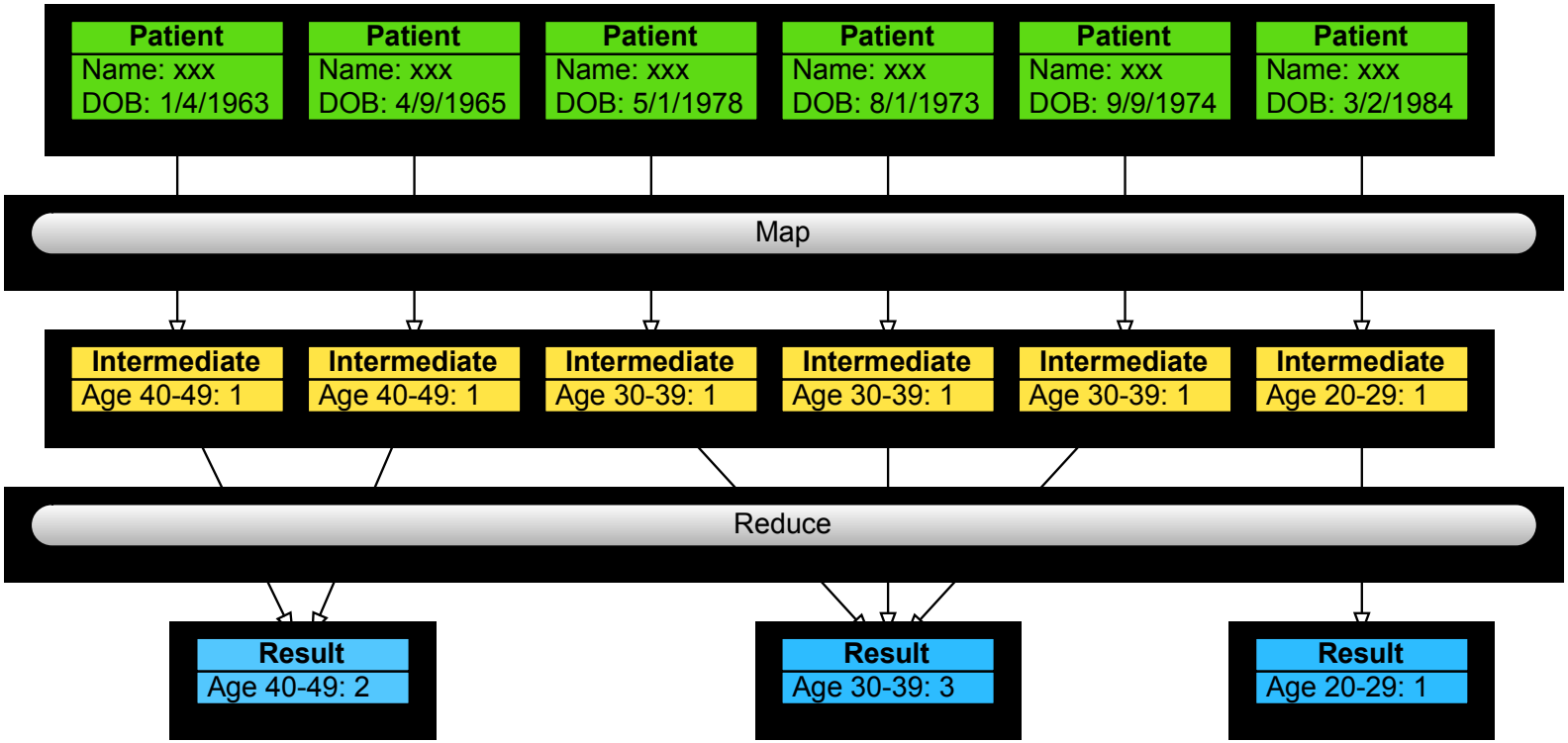
- Easy to understand and navigate
  - Balance of specificity and abstraction
- Extensible via coding, but
  - Code set and code dependent
  - Still a challenge for semantic interoperability
- Based on patient summary information model
- May not currently include required detail for all queries, e.g.:
  - Communications
  - Social and family history
  - Devices/medical equipment
  - Functional status
- Reliance on availability of coded data

Map-Reduce Query Engine

- Two-part queries
  - Map takes an instance of patient data model and produces an intermediate data structure
  - Reduce takes a set of intermediate data structures and produces a final result
- Powerful algorithm
  - Highly concurrent
  - Easily distributed
- Queries define their own output data structure
  - Ad-hoc queries fully supported



Map-Reduce Example: Stratifying Patients by Age



Query Format

- Query consists of JavaScript Map and Reduce functions wrapped in a MIME package
- Patient information model is presented to Map function as an object-oriented API that includes:
  - Raw data (e.g., patient date of birth)
  - Convenience functions to simplify queries (e.g., get patient age on specified date)
- Framework executes map function on each patient and summarizes results using reduce function
- Declarative pre-filtering for efficiency
- Required libraries included with query

Why JavaScript ?

- ECMA International Standard
- Ubiquitous
  - Implementations for all major hardware and software platforms
  - Already widely used in “big-data” technologies: MongoDB, CouchDB, Riak, …
- “Assembly language of the Web”
  - Fast and getting faster
  - Full programming language with many useful libraries
  - Easy to build concise but arbitrarily complex queries
  - Craft manually or compile from another language
- Readily sandboxed
  - Building on 15+ years of Web browser usage

Simple Example: Stratifying Patients by Age

```
function map(patient) {
  var when = new Date(2011, 6, 1);
  var decade = Math.floor(patient.age(when)/10)
    *10;
  emit(decade, 1);
}

function reduce(decade, counts) {
  var sum = 0;
  for(var i in counts)
    sum += counts[i];
  return sum;
}
```

Full Example: NQF 43 - Pneumonia Vaccination Status for Older Adults

```
function map(patient) {

  var outpatientEncounterCodes = {
    "CPT": ["99201", …],
    "ICD-9-CM": ["V70.0", …]
  };

  var pneumococcalMedicationCodes = {
    "RxNorm": ["854931", …]
  };

  var pneumococcalProcedureCodes = {
    "CVX": ["33", …],
    "CPT": ["90669", …]
  };

  var start = new Date(2010, 1, 1);
  var end = new Date(2010, 12, 31);
```

Full Example continued

```
function population(patient) {
  return (patient.age(start)>=64);
}

function denominator(patient) {
  var encounters = patient.encounters().match(
    outpatientEncounterCodes, start, end);
  return (encounters>0);
}

function numerator(patient) {
  var medication = patient.medications().match(
    pneumococcalMedicationCodes, null, end);
  var procedure = patient.procedures().match(
    pneumococcalProcedureCodes, null, end);
  return medication || procedure;
}

function exclusion(patient) {
  return false;
}
```

Full Example continued

```
  if (population(patient)) {
    emit("population", 1);
    if (denominator(patient)) {
      if (numerator(patient)) {
        emit("denominator", 1);
        emit("numerator", 1);
      } else if (exclusion(patient)) {
        emit("exclusion", 1);
      } else {
        emit("denominator", 1);
      }
    }
  }
}
```

JavaScript vs eMeasure: NQF 43 Population

```
function population(patient) {
  return (patient.age(start)>=64);
}
```

```
<entry typeCode="DRIV">
 <observation classCode="OBS" moodCode="EVN.CRT"
  isCriterionInd="true">
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      <sourceOf typeCode="SBS">
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      </sourceOf>
     </observation>
    </sourceOf>
   </act>
  </sourceOf>
 </observation>
</entry>
```

JavaScript vs eMeasure: NQF 43 Numerator

```
function numerator(patient) {
  var medication = patient.medications().match(
    pneumococcalMedicationCodes,
    null, end);
  var procedure = patient.procedures().match(
    pneumococcalProcedureCodes,
    null, end);
  return medication || procedure;
}
```

```
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      <sourceOf typeCode="COMP">
       <substanceAdministration classCode="SBADM" moodCode="EVN" isCriterionInd="true">
        <title>Medication administered: Pneumococcal Vaccine all ages</title>
        <participant typeCode="CSM">
         <roleParticipant classCode="MANU">
          <playingMaterial classCode="MMAT" determinerCode="KIND">
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       </procedure>
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      <title>Measurement period</title>
     </observation>
    </sourceOf>
   </act>
  </sourceOf>
 </observation>
</entry>
```
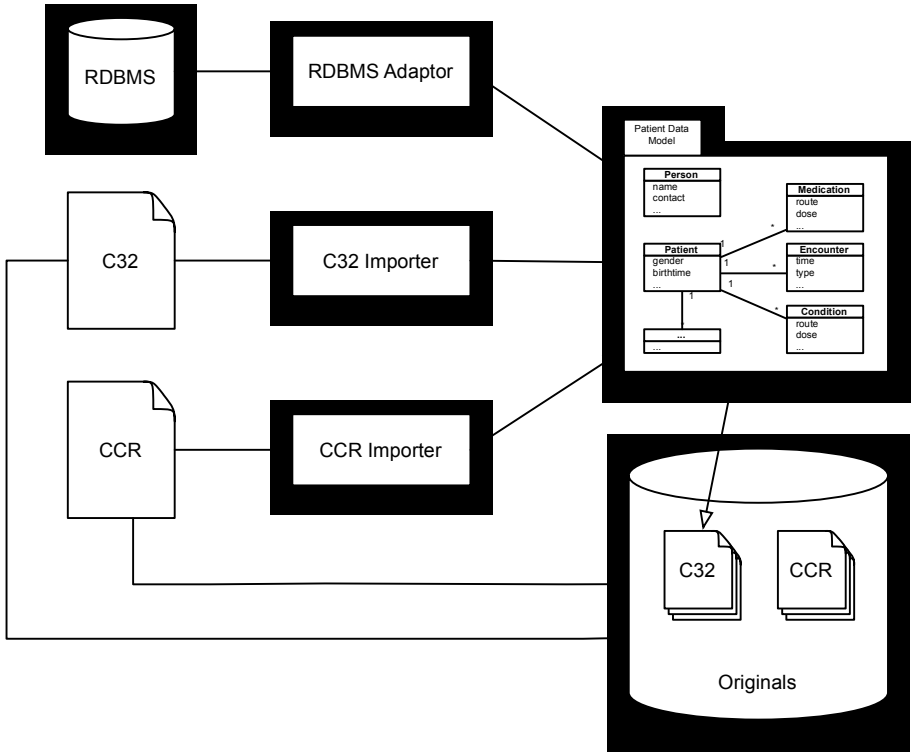
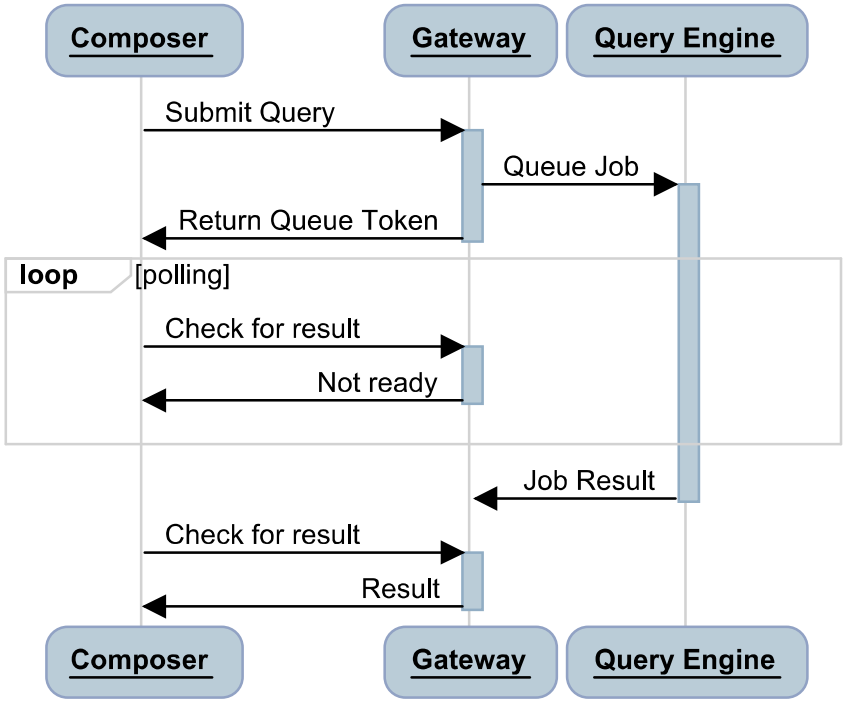

Gateway Data Import and Transformation

- **Data is transformed into patient information model**
  - **Statically on import**
  - **Dynamically during query execution**
- **Static Import**
  - **Transform C32 or CCR XML into JSON model**
  - **Original data preserved for provenance and linked to patient information model instance**
- **Dynamic Import**
  - **Requires adaptor to native data format**



Asynchronous Query Submission

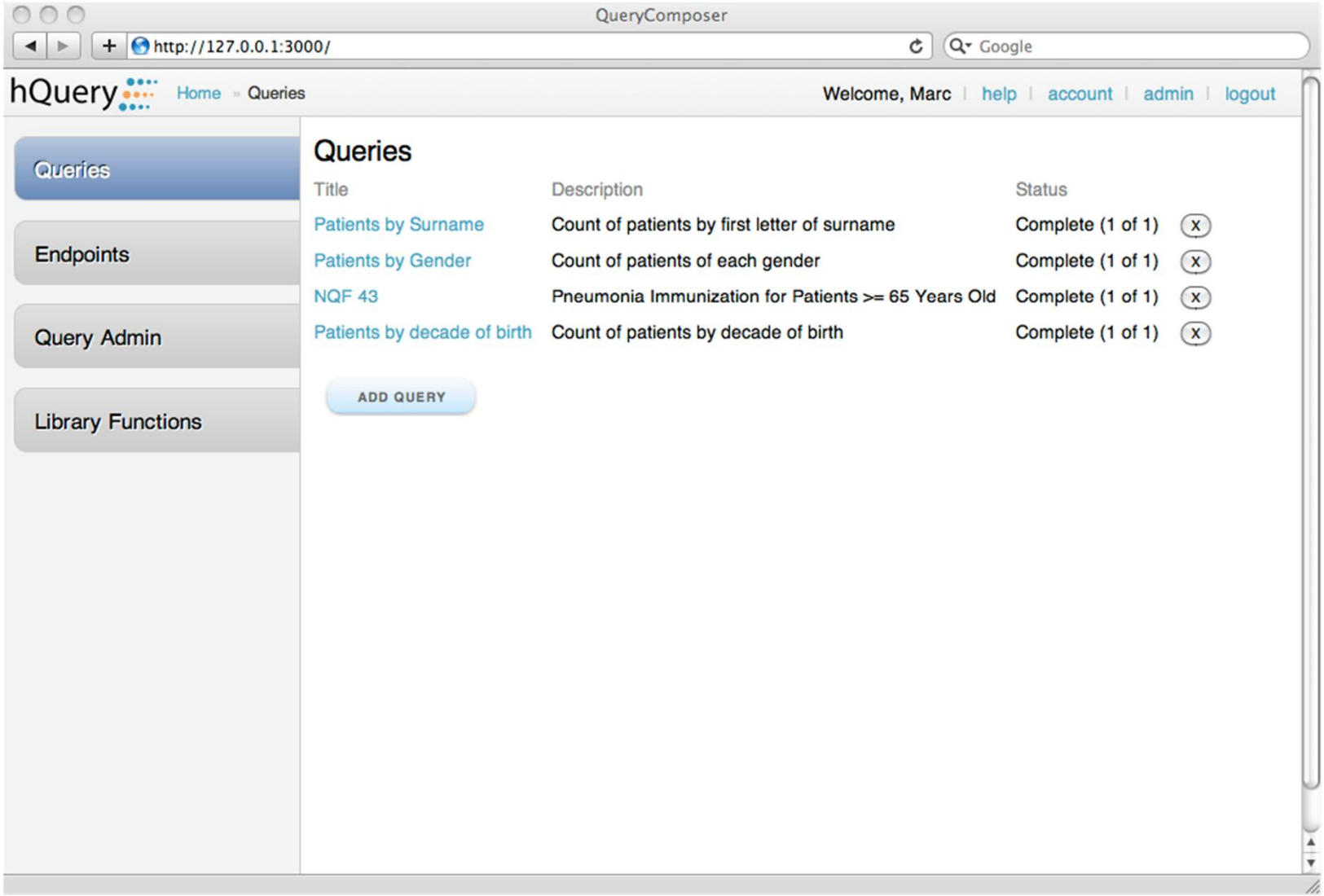
- Queries can take a long time to execute
  - Large data sets
  - Server loading
- Asynchronous query submission and result retrieval required
  - Polling vs notification
- RESTful Web service for submitting queries and obtaining results



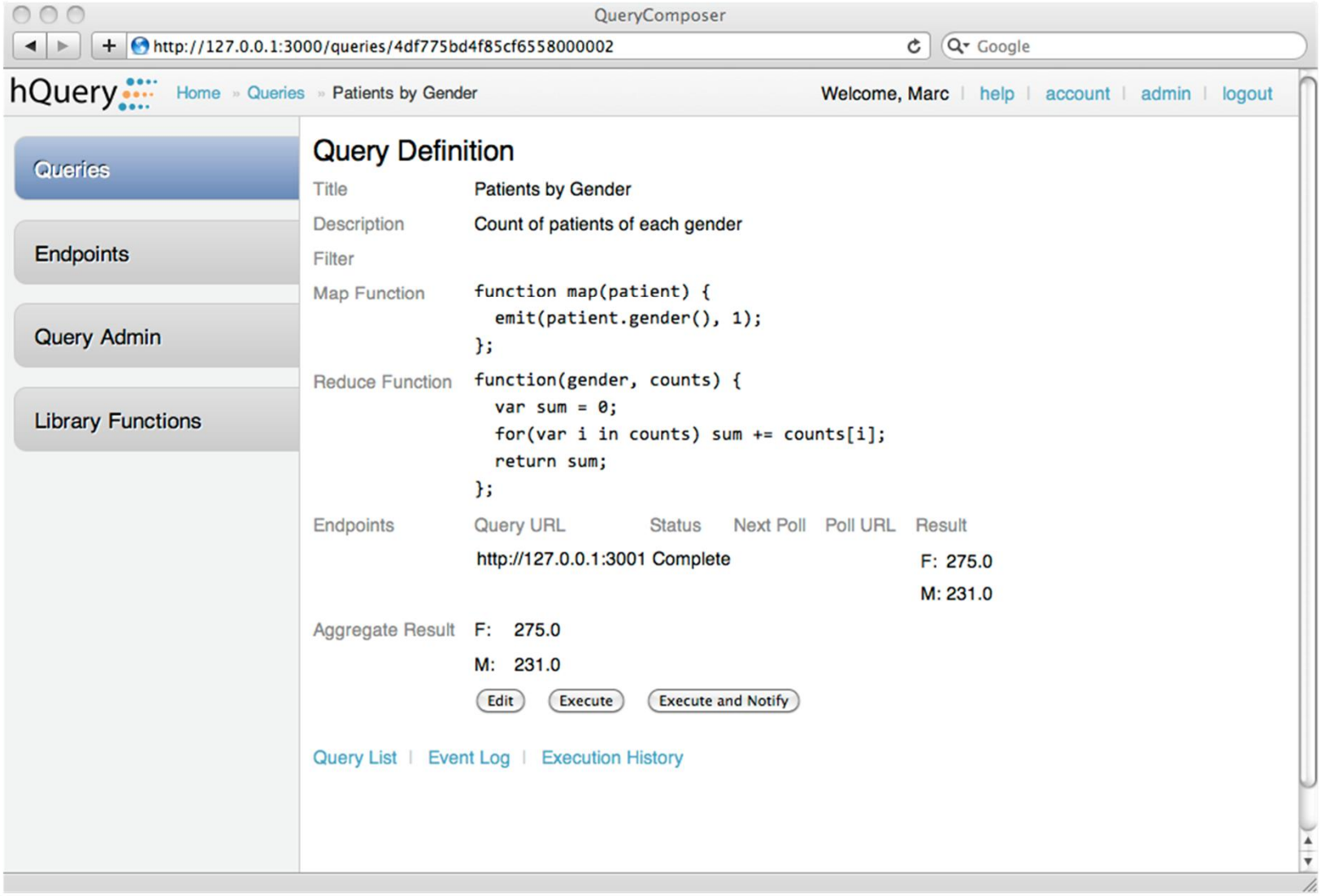
hQuery Composer Web Application

- Configure hQuery gateways
- Build and execute queries
  - Basic query syntax checking
- Monitor in-progress queries, maintain audit history
- Combine query results from multiple endpoints
- Query test harness
  - Simulated in-browser gateway with sample patient data
  - Query debugging

Developer UI: Dashboard



Developer UI: Query Execution



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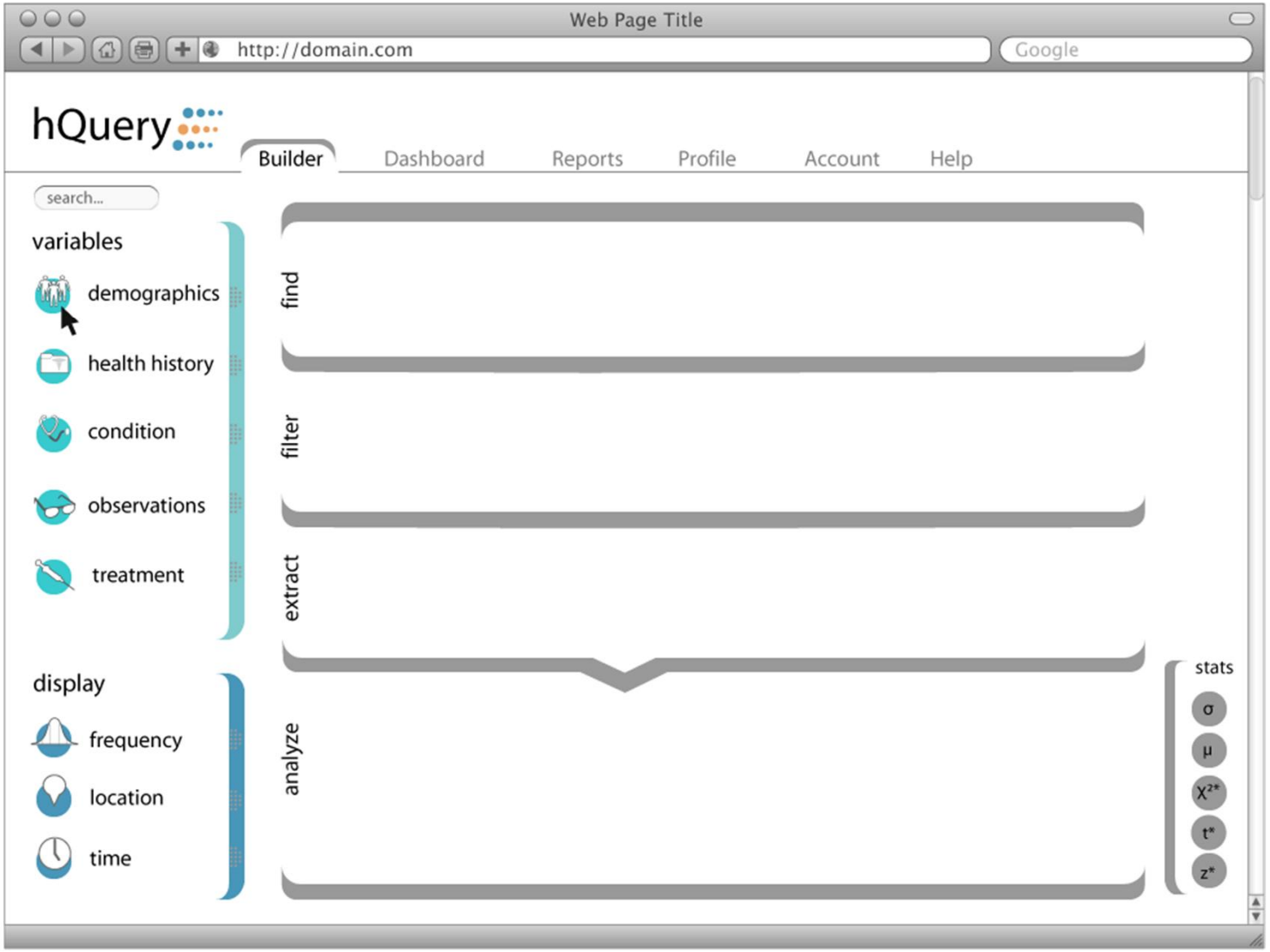
Graphical UI: Query Builder



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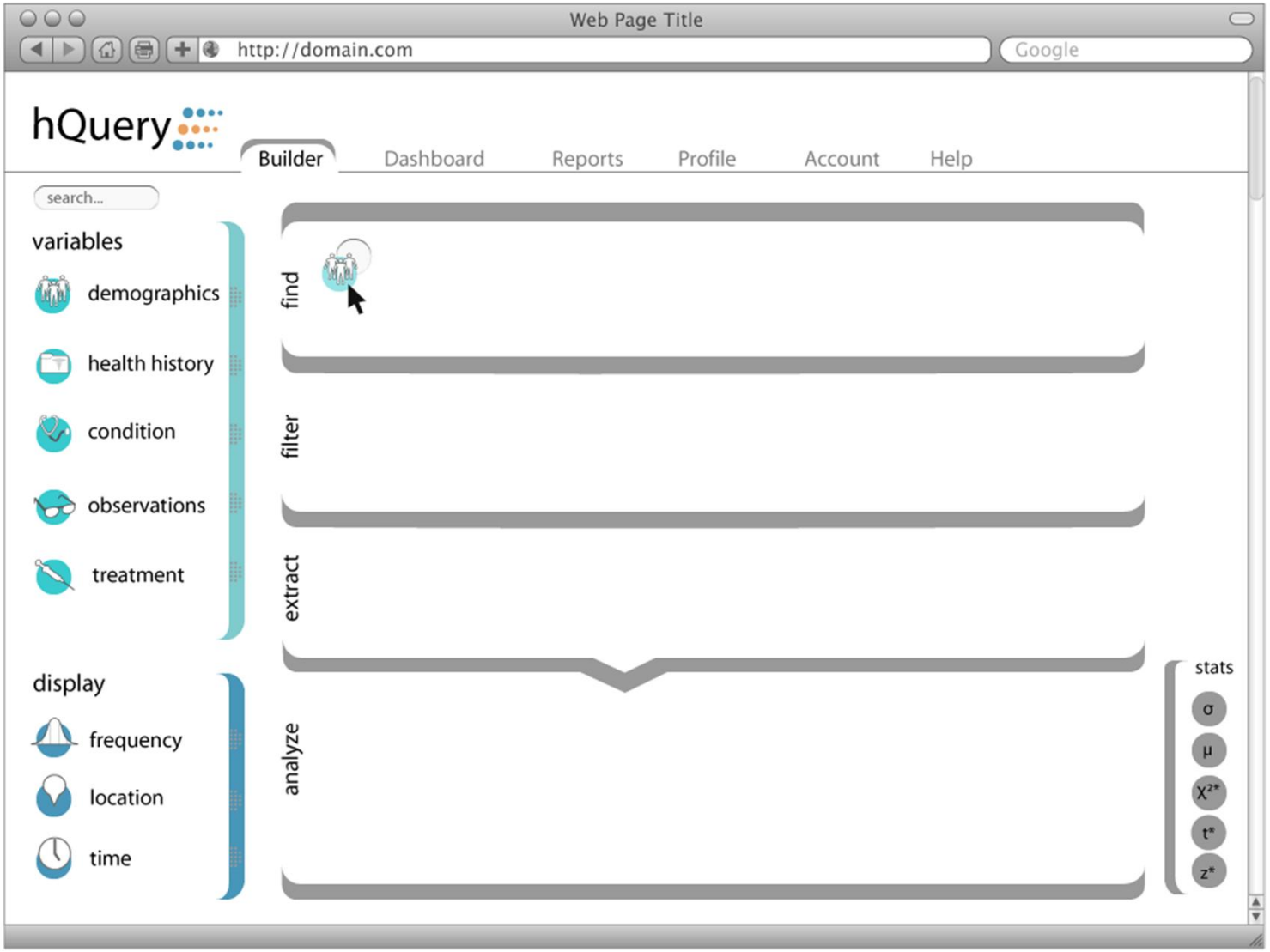
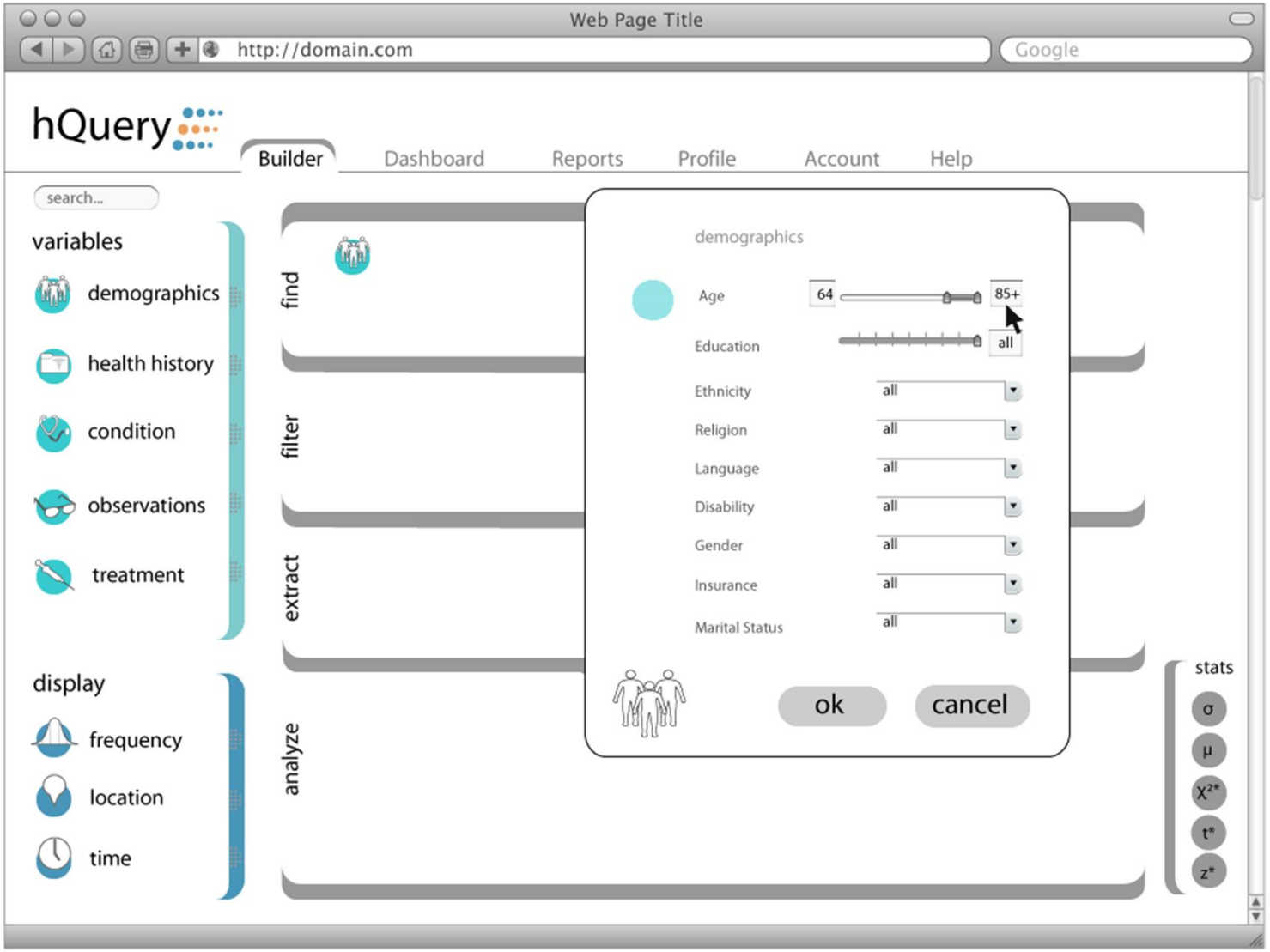
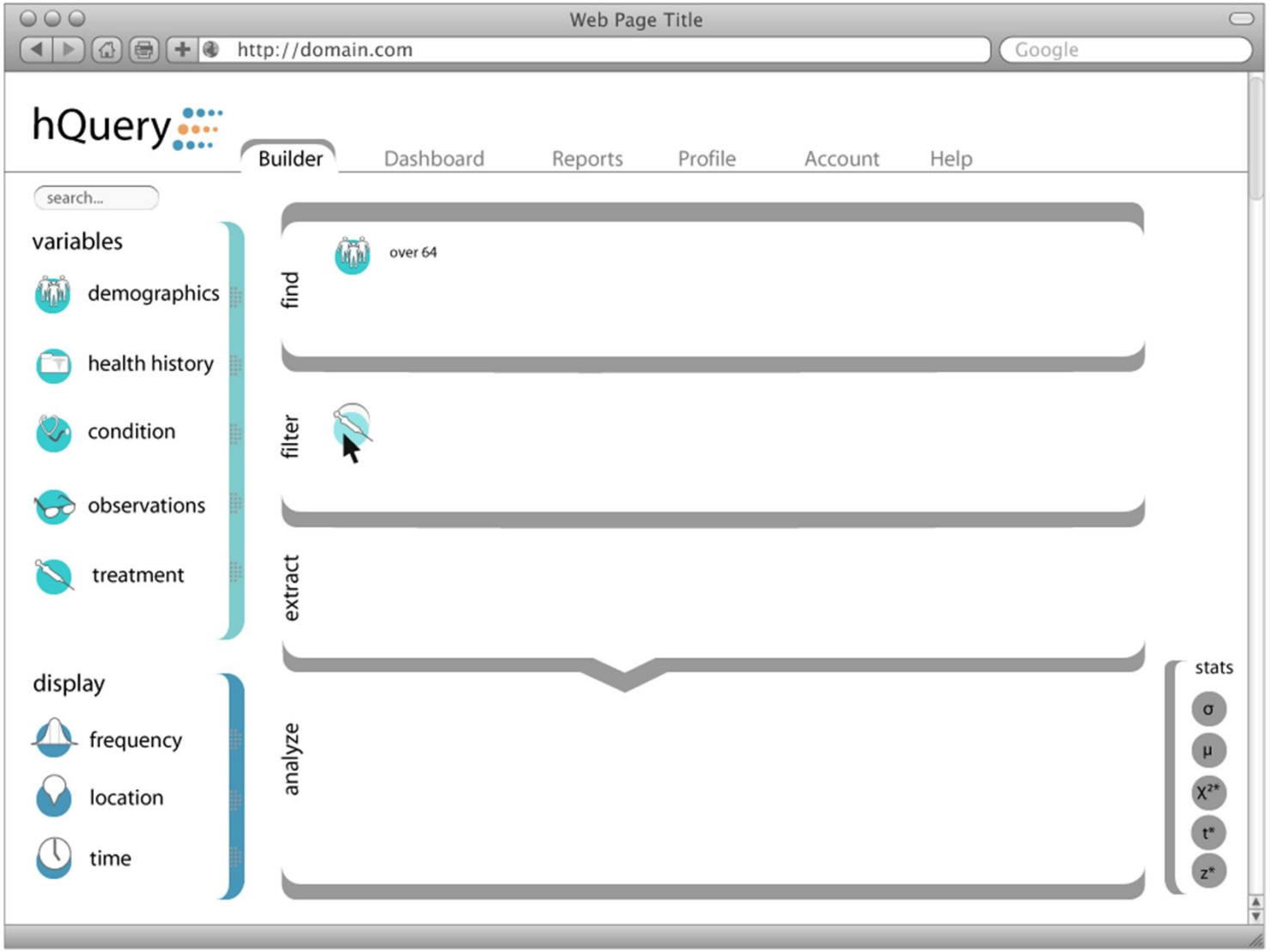
Graphical UI: Define Population



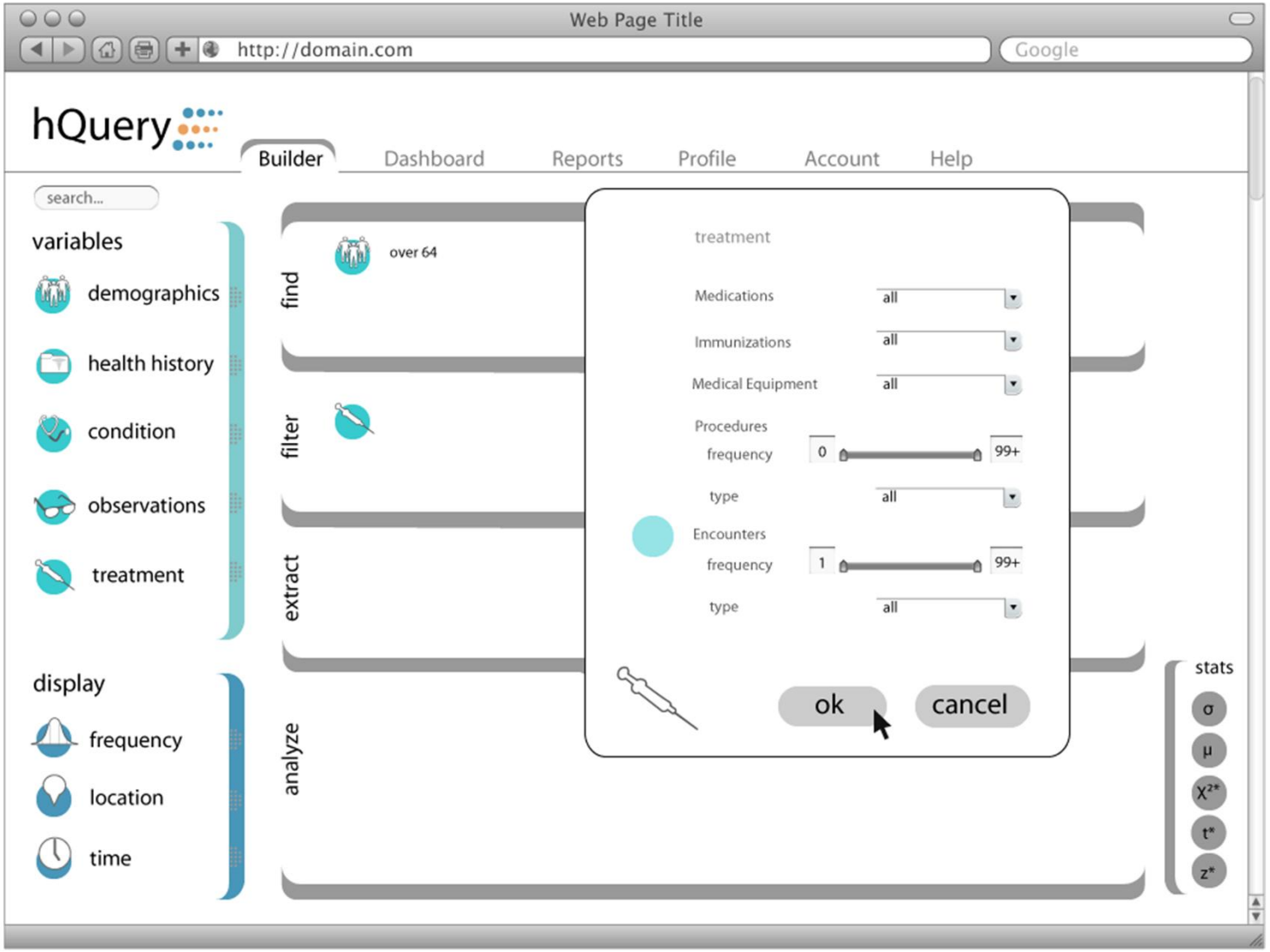
Graphical UI: Define Population



Graphical UI: Filter



Graphical UI: Filter



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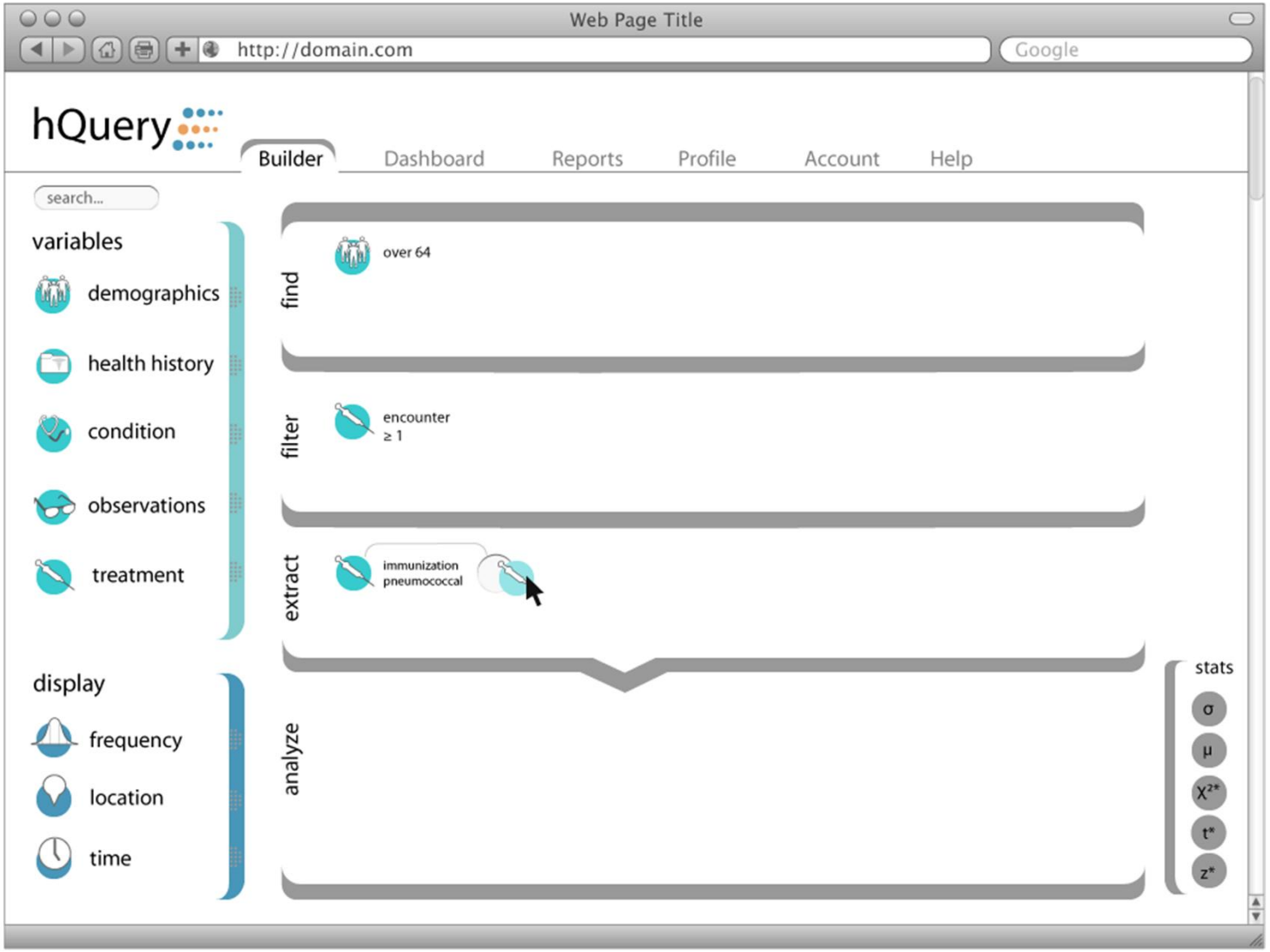
Graphical UI: Data Extraction



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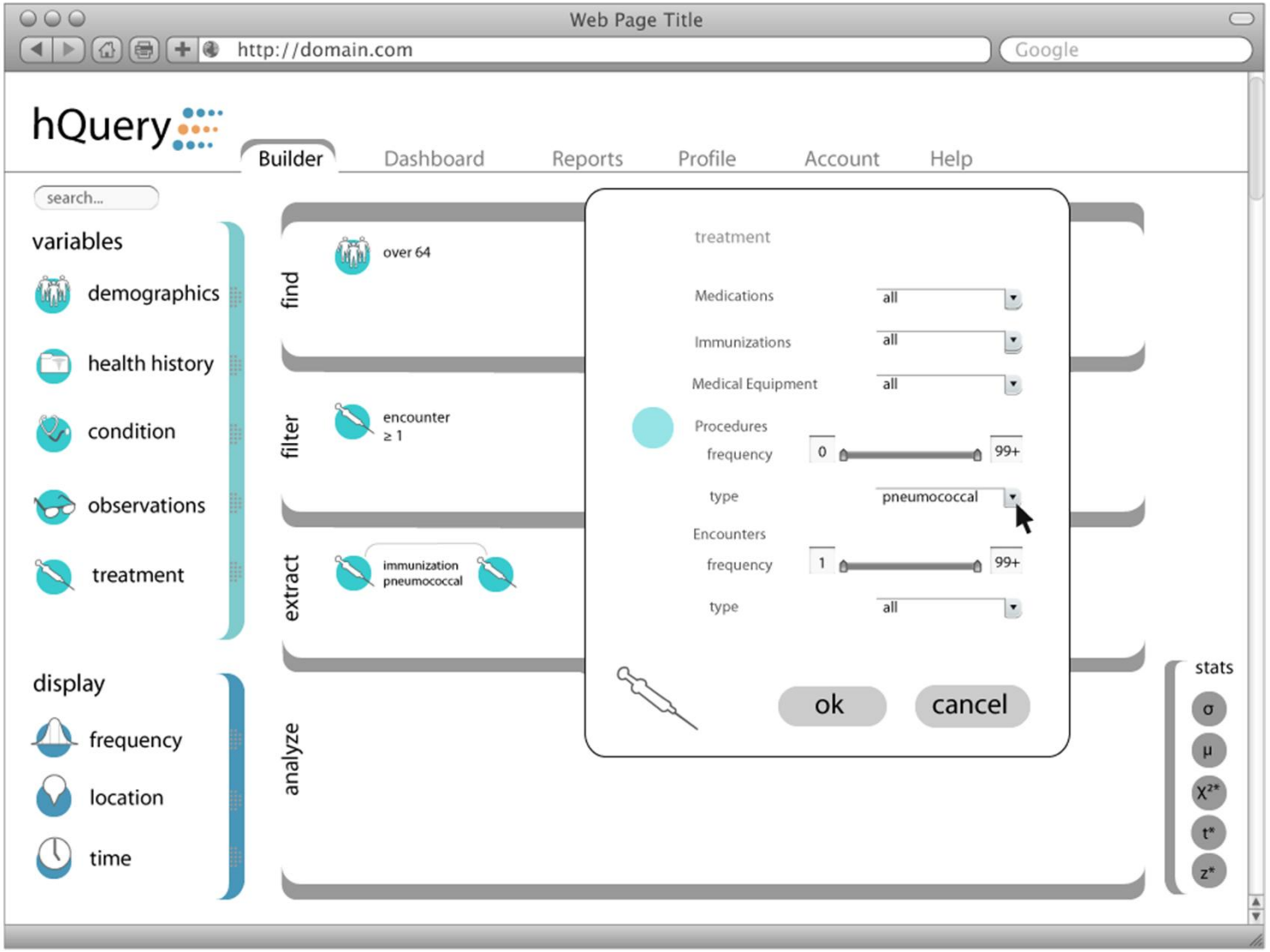
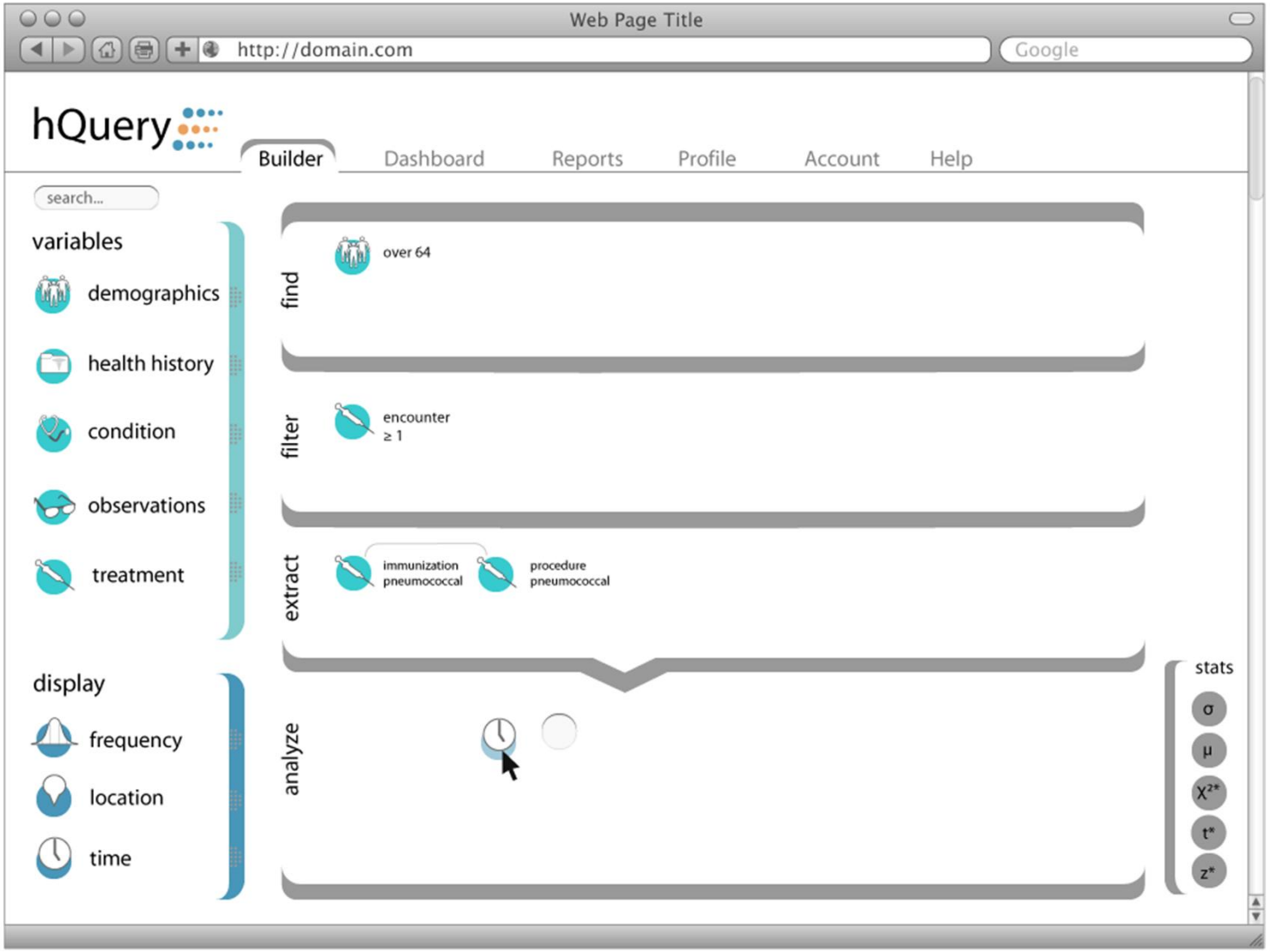
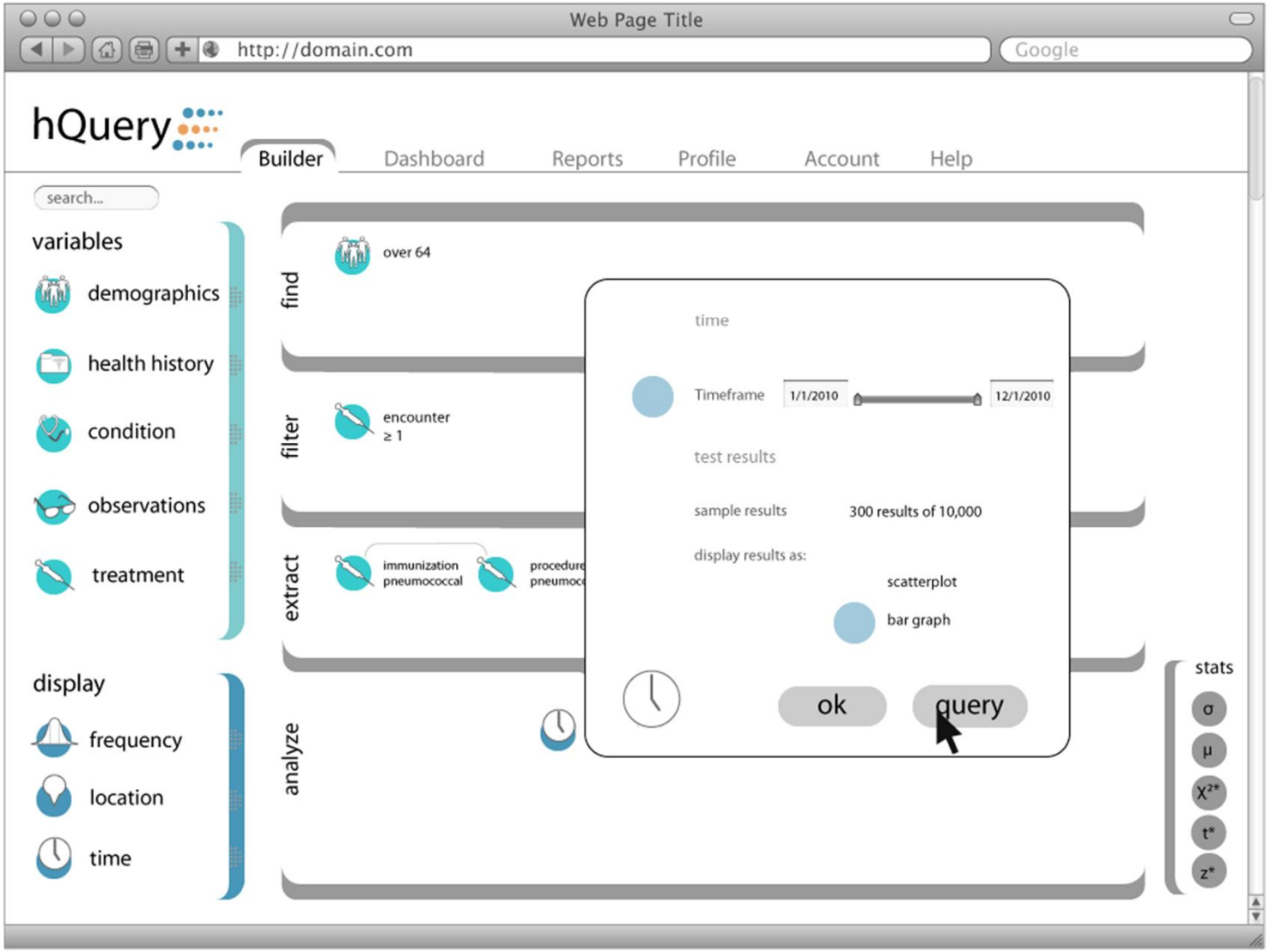


Graphical UI: Data Analysis



Graphical UI: Data Analysis



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Graphical UI: Query Dashboard

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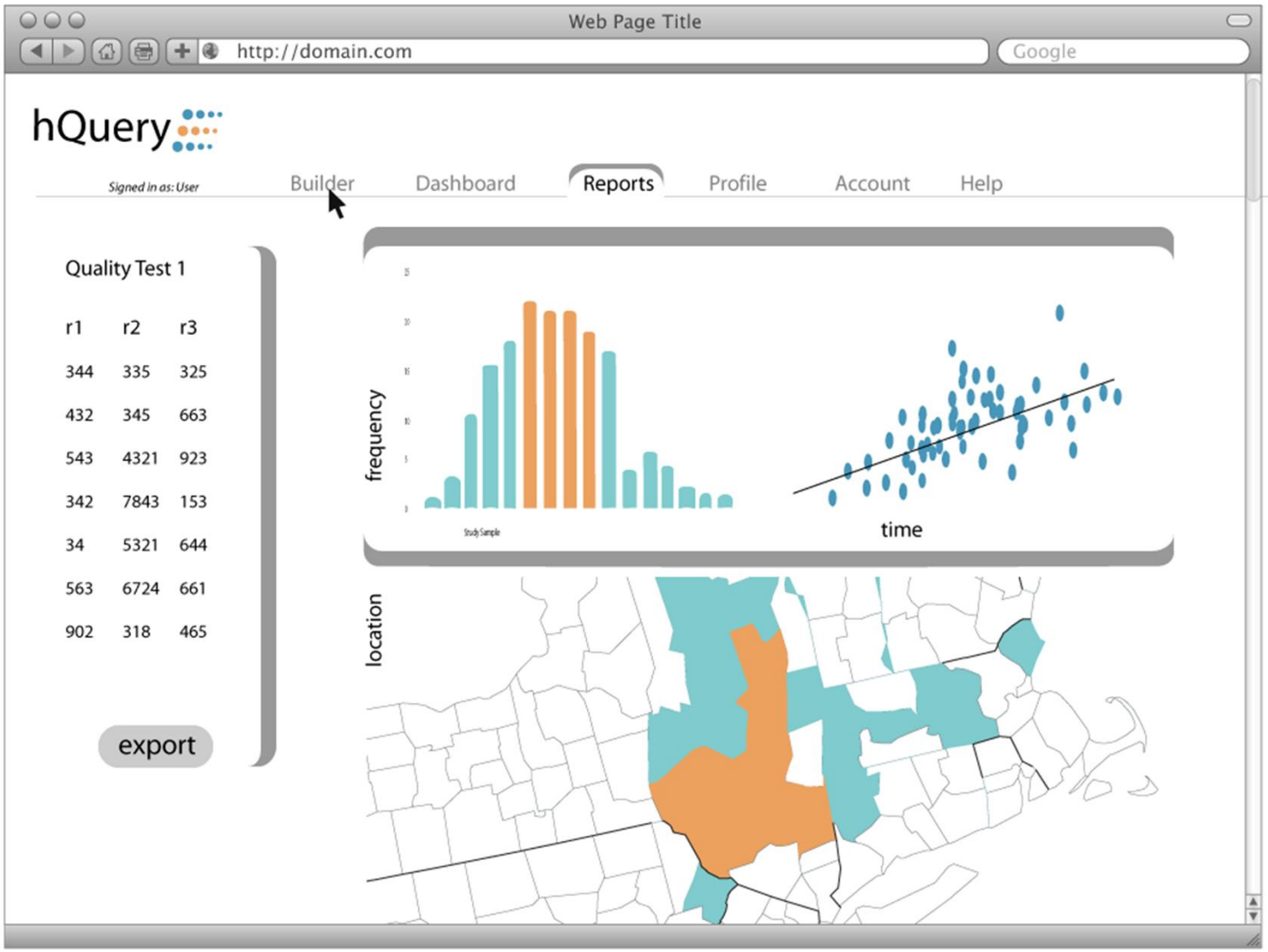
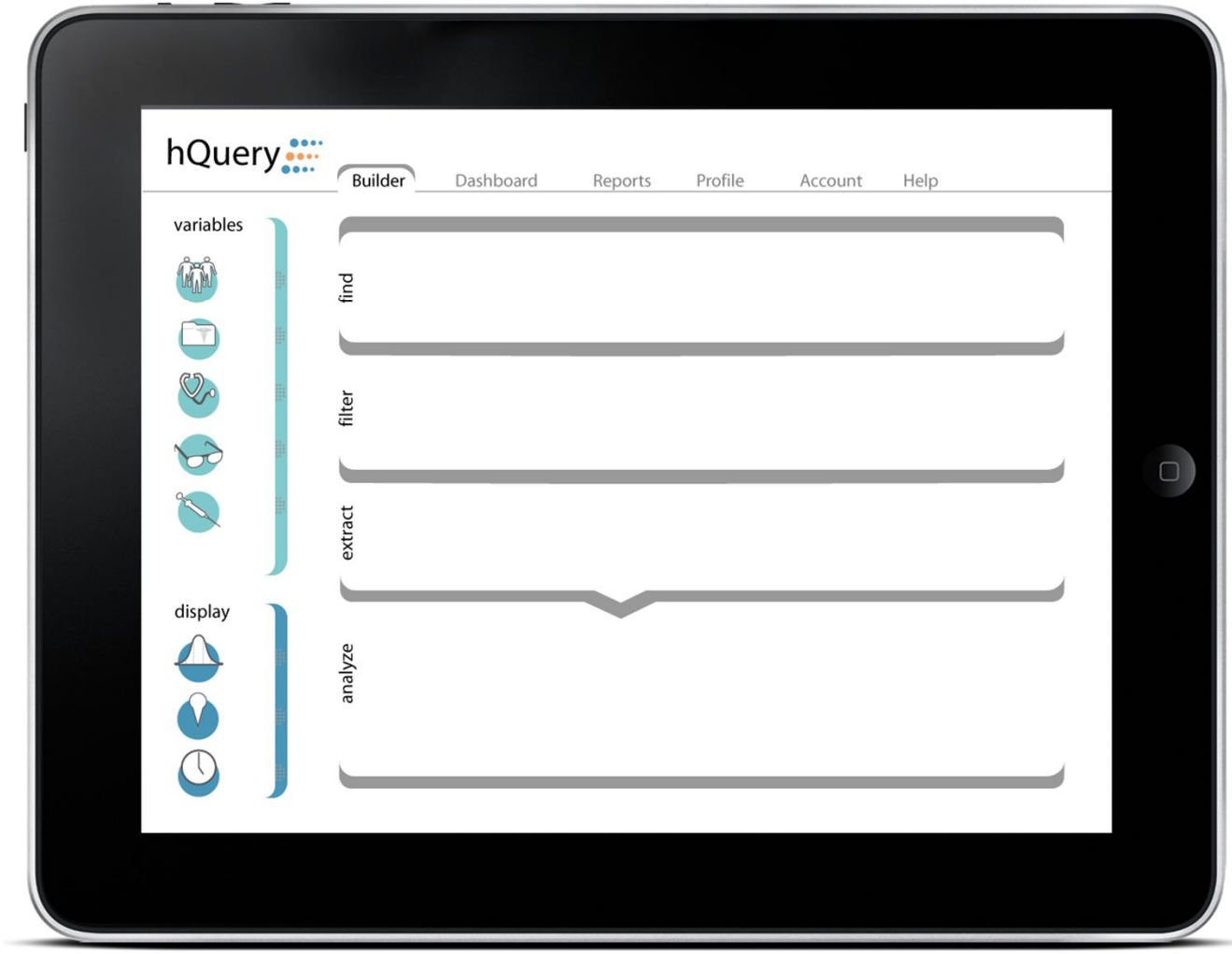
Graphical UI: Data Visualization



Graphical UI: Tablet Ready



Future Work

- Anonymization
  - Removal of PHI and PII from patient data model prior to exposing data to queries
    - Privacy-preserving patient identifiers for cross-gateway reconciliation
  - Policy and identity based, different clients may see different parts of data model depending on who they are and what they want to use the data for
- Vocabulary Management
  - Query can look for “diabetes” without including corresponding code sets in query
  - Queries can be code-set agnostic
- Patient data aggregation and reconciliation
  - Support for incremental updates
  - Support for record merging

Take-Home Messages

- Keep it simple
  - Complexity is the enemy of adoption and interoperability
- Base Query Health on standard internet technologies
  - HTTP, SMTP, MIME, JavaScript
- Queries should be self-contained
  - Decentralized extensibility
  - Avoids the need for additional standard vocabularies: both functional and clinical
- Promote serendipitous reuse
  - Make it easy to ask unanticipated questions
  - Support free-form queries and results

- More information:
  - Open source project: http://github.com/hquery (available now)
  - Project Web site: http://projecthquery.org/ (coming soon)