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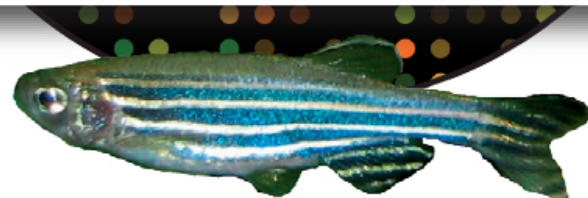


Frédéric Bastian, Marc Robinson-Rechavi

Bgee: **Integrating ontology and** **homology for the study of gene** **expression evolution**

ASIH 2009

| le savoir vivant |



Bgee: dataBase for Gene Expression Evolution



perform high throughput analyses of gene expression patterns.

Bgee: dataBase for Gene Expression Evolution



perform high throughput analyses of gene expression patterns.

Requirements:

- 1- integration of heterogeneous expression data
- 2- comparison criteria between anatomies, developmental stages, and genes

Integrating heterogeneous data

Integrating heterogeneous data poses several problems:

- comparing results of different types of techniques
- comparing results between experiments

Information we want to collect:

- where and when a gene is expressed
- with which confidence

Integrating heterogeneous data

Mapping expression data to ontologies:

- data annotations: need for manual curation
- data granularity: need for ontologies
- experimental factors: limitation to “normal” conditions

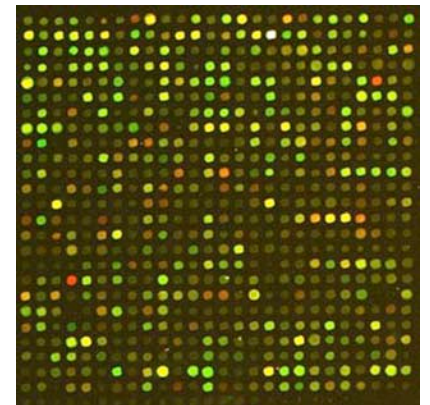
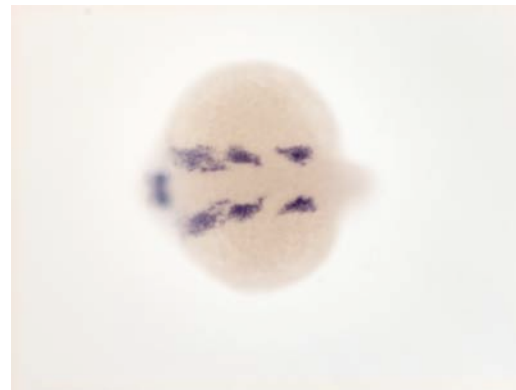
Integrating heterogeneous data

Expression confidence:

Bgee currently includes EST, Affymetrix, and *in situ* hybridization data

For each data: assign a level of confidence (low, high)

Require dedicated statistical tests



Integrating heterogeneous data

Expression confidence: experiments based on tag counting

High confidence: number of tags significantly $\neq 0$

⇒ Gene expressed with **95%** confidence: **7 tags** mapped to this gene (Audic and Claverie, Genome Res., 1997)

⇒ Low confidence: 1 to 6 tags

⇒ High confidence: ≥ 7 tags

Integrating heterogeneous data

Expression confidence: Affymetrix data



All probes mapping to the same transcript
= a probeset

Gene significantly expressed:
probeset signal \neq background signal

Integrating heterogeneous data

Expression confidence: Affymetrix data

Critical point: estimation of the background signal

- Use of the gcRMA algorithm to normalize the signal
- Use a subset of weakly expressed probesets for estimating the background

(Schuster *et al*, Genome Biology, 2007)

Wilcoxon test: probeset signal vs background signal

Low confidence: $1\% < \text{p-value} \leq 5\%$

High confidence: $\text{p-value} \leq 1\%$ & consistency of all probes

Bgee: dataBase for Gene Expression Evolution

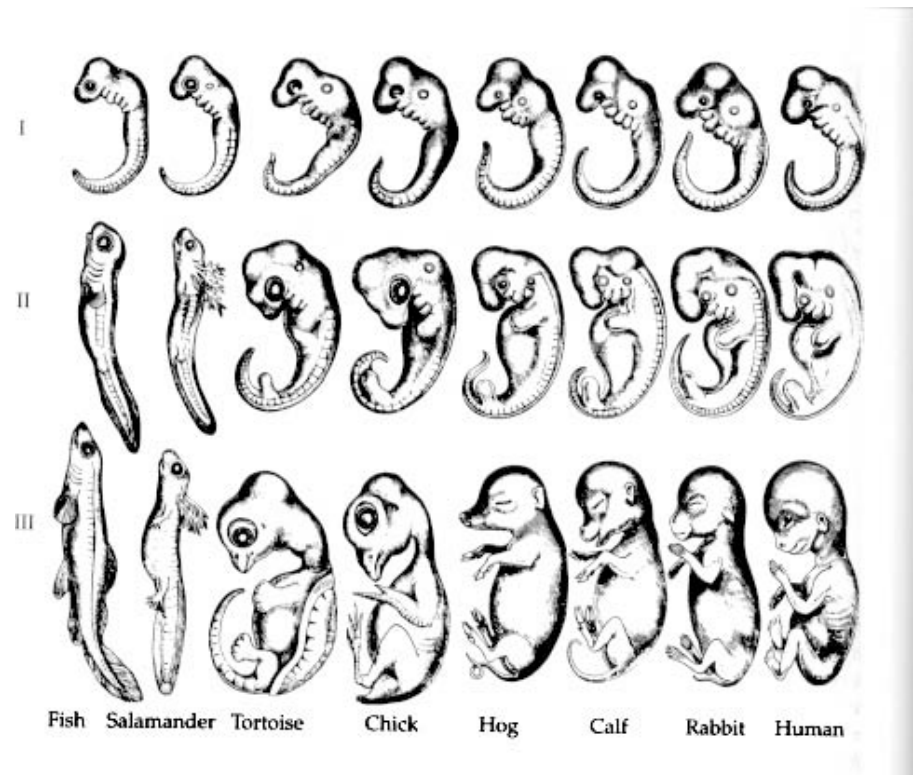


BGEE | Gene Expression Evolution

perform high throughput analyses of gene expression patterns.

Requirements:

- 1- integration of heterogeneous expression data
- 2- comparison criteria between **anatomies, developmental stages, and genes**



Bgee: dataBase for Gene Expression Evolution

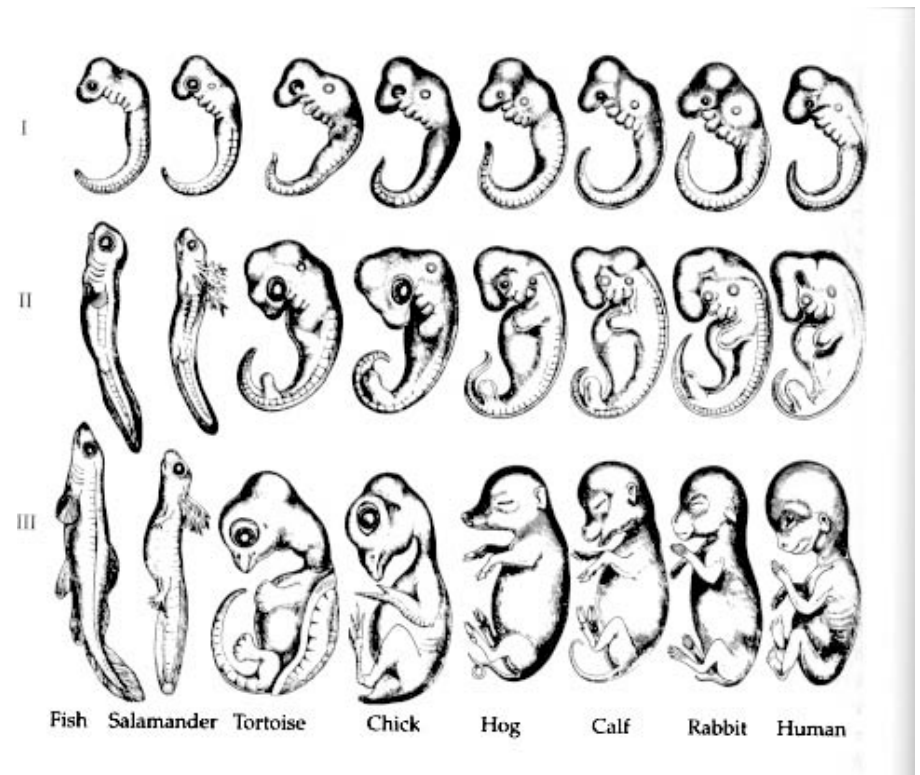


perform high throughput analyses of gene expression patterns.

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Orthologs from Ensembl

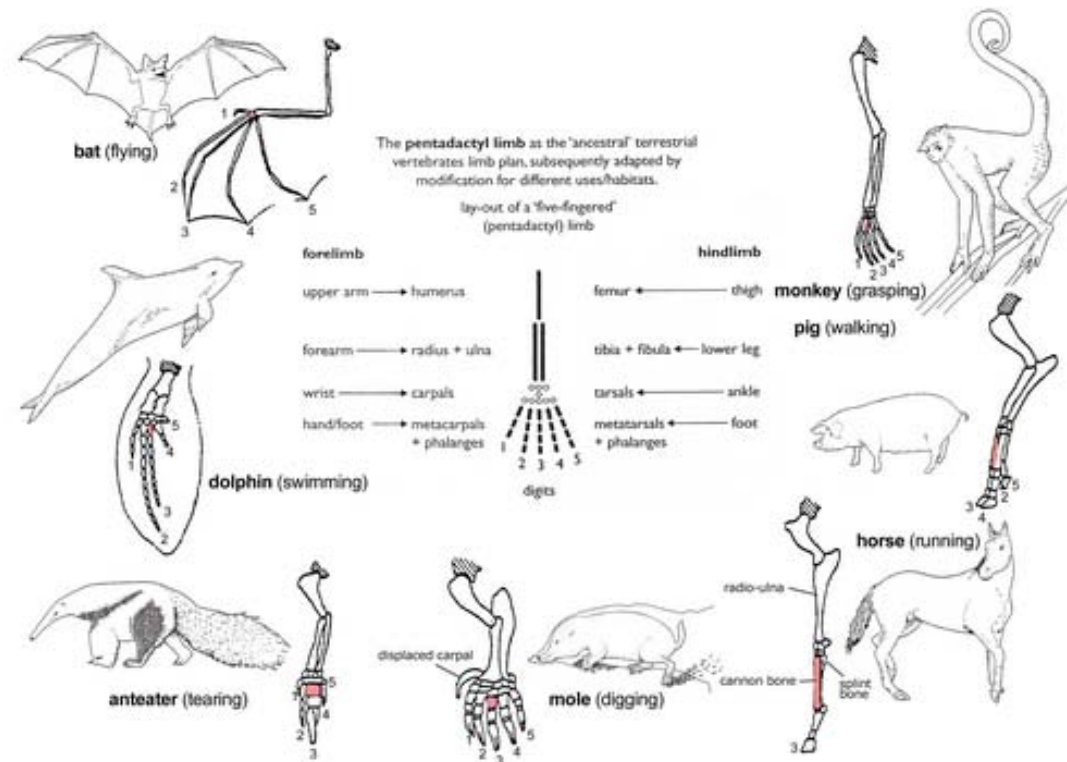


Homology relationships between anatomies

Evolutionary approach => appropriate comparison criterion:

homology

Homology: two anatomical structures within different organisms which originated from a structure of their common ancestral organism.



Homolonto

- Software to generate homology relationships
- Pairwise alignments of species-specific anatomical ontologies

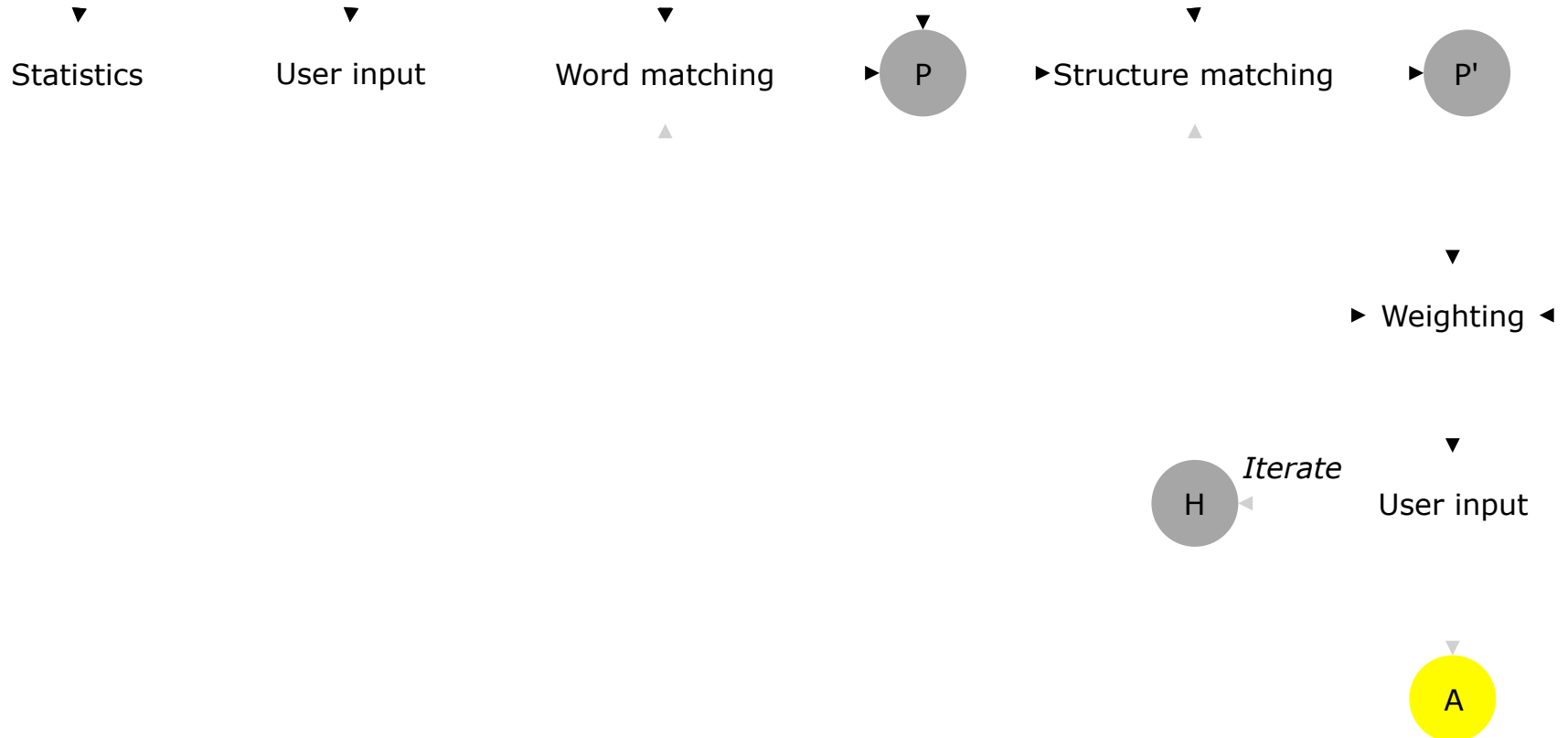
The screenshot displays the OntoAligner application window, which is used for generating homology relationships between species-specific anatomical ontologies. The interface is divided into several panels:

- File Find Alignment Homology**: The top menu bar.
- Detailed term xenopus_anatomy.obo**: A list of terms from the Xenopus ontology, including Class (Organ), Property (part_of), and Instance (I) terms with IDs like XAO:0000000, XAO:0000140, XAO:0000125, XAO:0000122, XAO:0000117, XAO:0000113, XAO:0000100, XAO:0000039, XAO:0001017, XAO:0001010, XAO:0000177, XAO:0000215, XAO:0000020, XAO:0000010, XAO:0000179, XAO:0000178, XAO:0000176, XAO:0000168, XAO:0000158, and XAO:1000000.
- Detailed term zebrafish_anatomy.obo**: A list of terms from the Zebrafish ontology, including Class (Organ), Property (part_of), and Instance (I) terms with IDs like ZFA:0100000, ZFA:0000023, ZFA:0000163, ZFA:0000434, ZFA:0000098, ZFA:0001159, ZFA:0001158, ZFA:0000036, ZFA:0000396, ZFA:0000142, ZFA:0000134, ZFA:0000025, ZFA:0000012, ZFA:0001261, ZFA:0000145, ZFA:0000075, ZFA:0000022, ZFA:0000008, ZFA:0001002, ZFA:0001328, ZFA:0000641, ZFA:0000282, and ZFA:0001355.
- Current organ**: A hierarchical diagram showing the 'brain' term under the 'nervous system' and 'central nervous system' categories. The ID is [XAO:0000010](#).
- Putative homolog**: A hierarchical diagram showing the 'brain' term under the 'nervous system' and 'central nervous system' categories. The ID is [ZFA:0000008](#).
- Current Org. stats.**: A box showing the number of homologs (0) and the number of propositions (1).
- Score**: A box showing the score (117.89).
- Annotations**: A section with input fields for Author, Links, and a large text area for Comments.
- Buttons**: A row of buttons labeled 'Iterate', 'Previous', and 'Next'.
- Radio buttons**: A set of radio buttons for selecting the validation method: ☒ Validate Homology, ☐ Validate Partial Homology, ☐ Delay, ☐ Delay and ignore, and ☐ Invalidate.

Homolonto

O_2

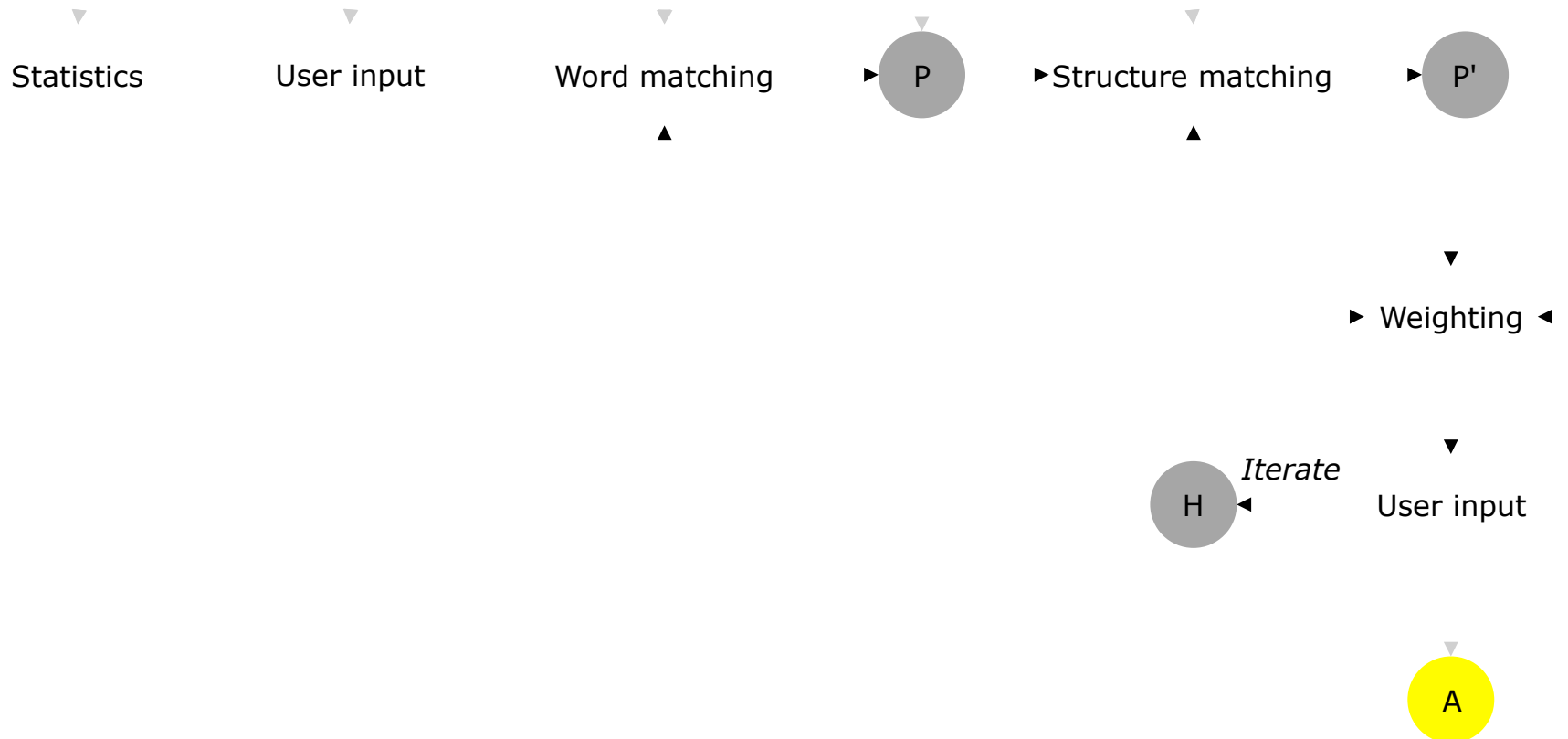
O_1



Homolonto

O_2

O_1



Homolonto

O_2

O_1

Statistics

User input

Word matching

P

Structure matching

P'

Weighting

H

Iterate

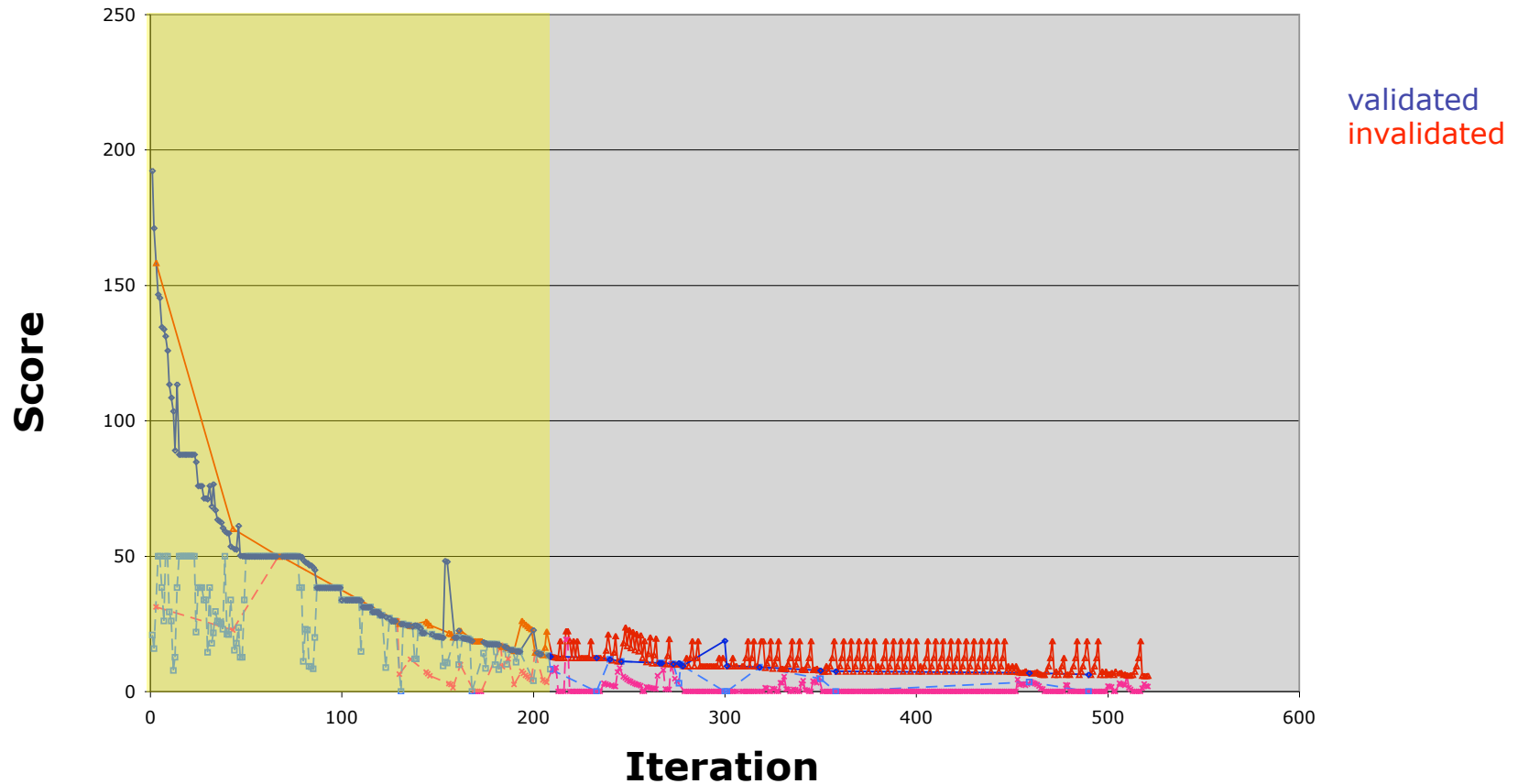
User input

A



Test case: Xenopus-zebrafish ontologies

213 first pairs: 80% validated - contains 91% of homologs validated



Generating a multi-species ontology

-Homolonto: generates pairwise relationships between ontologies

ZFA:0000008 brain

EHDAA:2629 brain

XAO:0000010 brain



Generating a multi-species ontology

-Homolonto: generates pairwise relationships between ontologies

ZFA:0000008 brain

EHDAA:2629 brain

XA0:0000010 brain

-Merging pairwise alignments: generates groups of homologs

HOG:0000157 brain

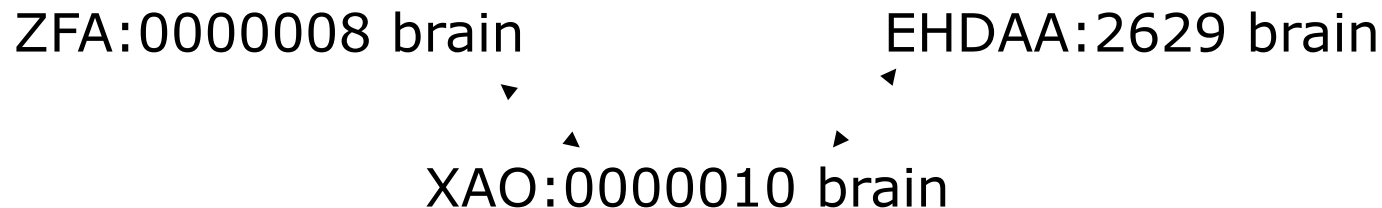
ZFA:0000008

XA0:0000010

EHDAA:2629

Generating a multi-species ontology

-Homolonto: generates pairwise relationships between ontologies



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HOG:0000157 brain

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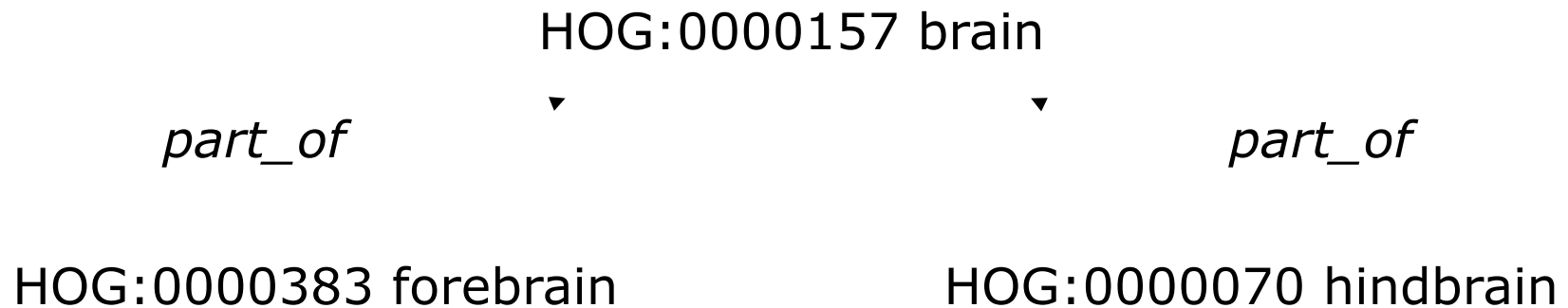
XAO:0000010

EHDAA:2629

=>List of Homologous Organs Groups (HOGs)

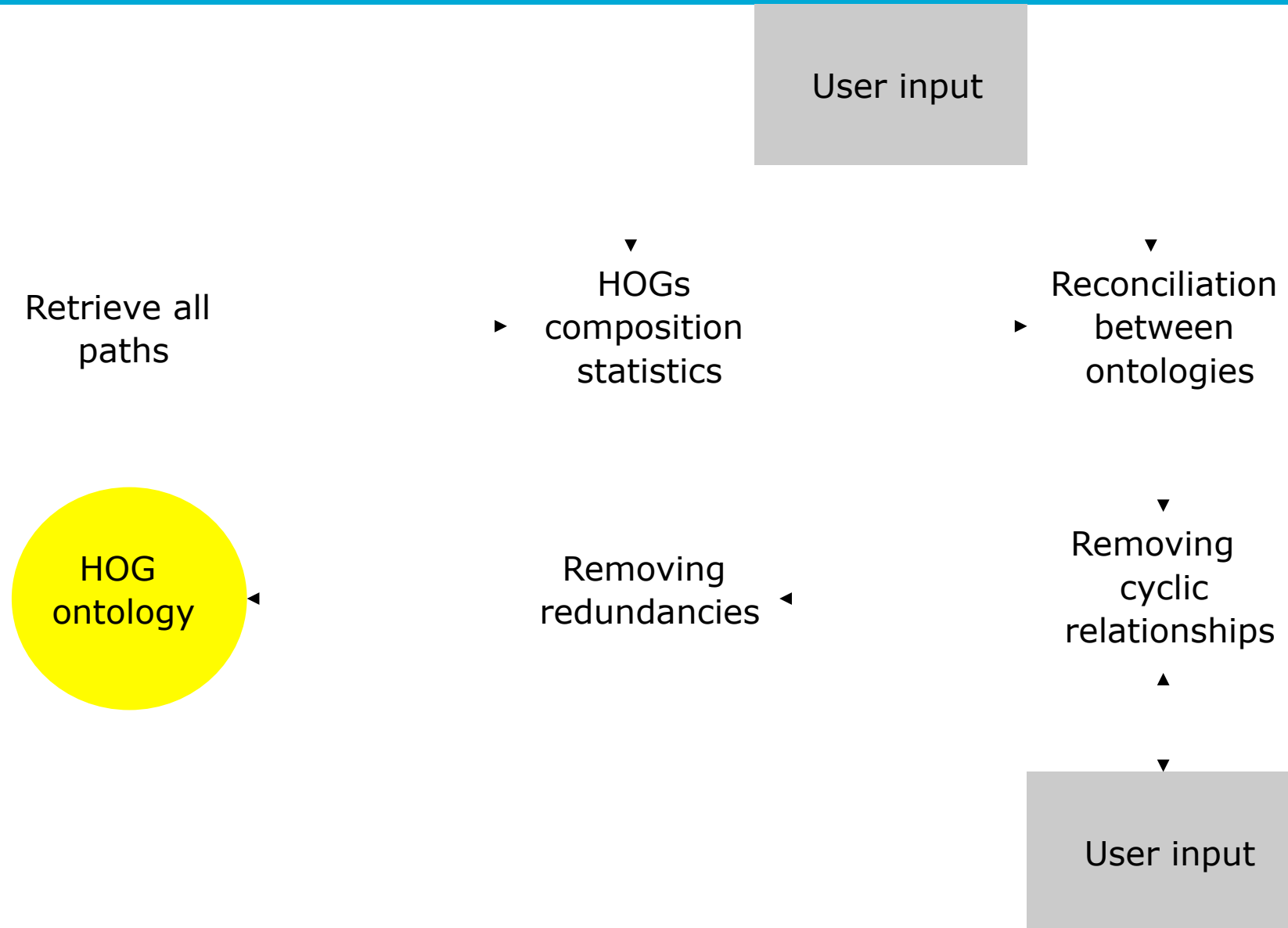
Generating a multi-species ontology

- HOGs need to be structured as an ontology to allow reasoning
- At a minimum, relationships amongst them have to be designed



=>Algorithm to infer relationships between HOGs

Inferring relationships between HOGs



HOGs in Bgee

Use of Homolonto, followed by a curation process:

- 4 species: human, mouse, zebrafish, Xenopus
- 6 ontologies: ZFA, EHDA, EV, EMAPA, MA, XAO

HOG ontology in OBO:

- 1241 HOGs, 311 with description, 400 with synonyms
- 1595 relations, 367 *part_of*, 12 *is_a*, 1216 *broader_than*

External Mapping file:

- involving 5314 anatomical structures
- all manually reviewed, with evidence codes and references

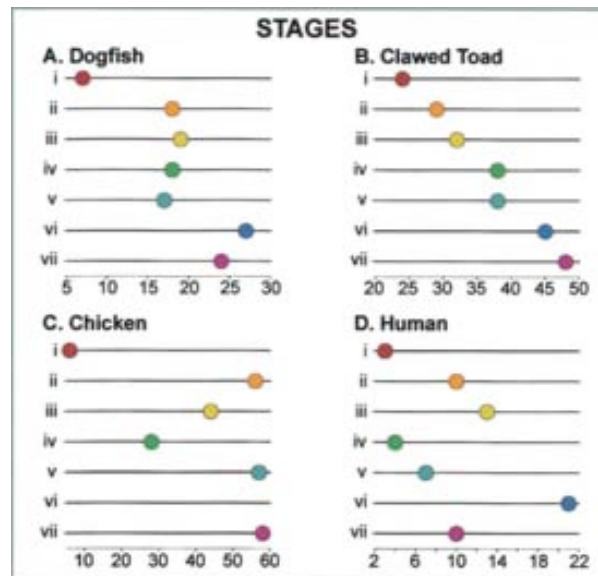
remarks and corrections are welcome!

Mapping of the developmental ontologies

To compare expression patterns, comparisons:

- between homologous organs
- at equivalent stage of development

Heterochrony: impossible to identify homologous stages



- (i) First somite
- (ii) Nasal placode
- (iii) Optic cup
- (iv) Heart loop
- (v) Thyroid depression
- (vi) Spleen anlage
- (vii) Forelimb buds

(Jeffery *et al.*, *Evol Dev.*, 2002)

Mapping of the developmental ontologies

Solution:

identify key events of development, common to all vertebrates

=> Ontology of "metastages"

All metastages

Embryo

Zygote

Cleavage

Blastula

Gastrula

Neurula

Organogenesis

Post-embryonic development

Adult

Bgee database

Database statistics

	Zebrafish	Mouse	Human	Xenopus
Ensembl Genes	24,233	31,804	37,435	19,017
Genes with expression data	15,820 65%	20,074 63%	19,354	3,721
Developmental stages	57	40	44	87
Developmental stages with expression data	57 100%	40 100%	19	18
Anatomical structures	2,173	6,408	2,724	645
Anatomical structures with expression data	1,109 51%	2,338 36%	200	52
EST libraries	101	686	2,396	66
Affymetrix chips	52	4,116	3,998	0
<i>In situ</i> figures/evidences	26,709	37,969	0	0

Example: Pax-6 and the eye

The screenshot shows the Bgee database homepage. The browser address bar displays 'http://bgee.unil.ch/bgee/bgee'. The page title is 'Bgee: a dataBase for Gene Expression Evolution'. Below the title is a navigation bar with links: Search, Anatomy & Development, About, and More. A search bar is located on the right side of the navigation bar. The main content area is titled 'Basic search' and contains a search form. The search form has a text input field with 'pax6' entered, a dropdown menu for 'Gene families', a checkbox for 'exact match', a 'Show' button with a value of '20', and a 'submit' button. Below the search form, there is a list of example search results: 'e.g. embryo, retinoic acid, ESR1 HUMAN, ENSFM00440000236847, All data'. The 'News' section is located below the search form and contains two entries. The first entry is dated '2009 25th Jun' and is titled 'New version of the database (Bgee Release 05)'. It lists several updates: the database is now based on Ensembl Release 54; 3314 Affymetrix chips from ArrayExpress have been added; Bgee now includes in situ hybridization data for the adult mouse from MGI; and the Homologous Organs Groups (HOGs) have been updated. The second entry is dated '2009 19th Feb' and is titled 'New version of the database (Bgee Release 03)'. It lists updates: the database is now based on Ensembl Release 52; Bgee now includes in situ hybridization data for the mouse from MGI; and the Homologous Organs Groups (HOGs) have been updated.

Bgee – Welcome on Bgee home page: a dataBase for Gene Expression Evolution

http://bgee.unil.ch/bgee/bgee

Bgee: a dataBase for Gene Expression Evolution

Search Anatomy & Development About More

Basic search

Search [?] Gene families pax6 exact match Show 20 submit

e.g. embryo, retinoic acid, ESR1 HUMAN, ENSFM00440000236847, All data

News

2009 25th Jun

New version of the database (Bgee Release 05)

- The database is now based on Ensembl Release 54.
- 3314 Affymetrix chips from ArrayExpress, for human and mouse, have been manually annotated and added into Bgee. Bgee now includes 8166 Affymetrix chips.
- Bgee now includes *in situ* hybridization data for the **adult** mouse from [MGI].
- The Homologous Organs Groups (HOGs) have been updated: Bgee currently integrates 1241 HOGs, which involve 5314 anatomical structures (1253 more than in the previous release).

The files available for download have been updated.

2009 19th Feb

New version of the database (Bgee Release 03)

- The database is now based on Ensembl Release 52.
- Bgee now includes *in situ* hybridization data for the mouse from [MGI].
- The Homologous Organs Groups (HOGs) have been updated: Bgee currently integrates 1003 HOGs, which involve 4061 anatomical structures.

The files available for download have been updated.

Example: Pax-6 and the eye

Bgee - Basic family search: pax6

http://bgee.unil.ch/bgee/bgee?page=search&action=quick_search&search_type=3&search=pax6&exact_match=on&... Google

Bgee Bgee: a dataBase for Gene Expression Evolution

Search ▾ | Anatomy & Development | About | More ▾

Basic Search

Basic search

Search [\[?\]](#) Gene families exact match ☒ Show

e.g. [embryo](#), [retinoic acid](#), [ESR1](#) [HUMAN](#), [ENSMF00440000236847](#), [All data](#)

Basic Search result

[4 results](#)

Family ID	Family description	Gene count	
ENSMF00250000004203	Ensembl Gene Family ENSMF00250000004203 RECNAME: FULL=ELONGATOR COMPLEX 4; ALTNAM: FULL=PAX6 NEIGHBOR GENE PROTEIN;	4	expression in 136 organs and 60 stages
ENSMF00440000236845	Ensembl Gene Family ENSMF00440000236845 RECNAME: FULL=PAIRED BOX PAX	7	expression in 385 organs and 60 stages
ENSGTV:1127870	Ensembl Gene Trees Vertebrates 1127870 Elongator complex protein 4 (hELP4)(PAX6 neighbor gene protein) [Source:UniProtKB/Swiss-Prot;Acc:Q96EB1]	4	expression in 136 organs and 60 stages
ENSGTV:1460141	Ensembl Gene Trees Vertebrates 1460141 Paired box protein Pax-6 (Oculorhombin)(Aniridia type II protein) [Source:UniProtKB/Swiss-Prot;Acc:P26367]	5	expression in 359 organs and 59 stages

Example: Pax-6 and the eye

Bgee – Details for the gene family: ENSGTV:1460141

http://bgee.unil.ch/bgee/bgee?page=gene_family&action=family_details&super_stage_id=OGEM%3A000001&gene_fa Google

Bgee Bgee: a dataBase for Gene Expression Evolution

Search ▾ Anatomy & Development About More ▾

Details for the gene family: ENSGTV:1460141

Expression data: [Anatomical ontology browsing](#) - Miscellaneous: [General information](#) - [Gene List](#)

General information Hide | Top

Gene family ID	ENSGTV:1460141
Prediction method	Ensembl Gene Trees Vertebrates [2]
Description	Paired box protein Pax-6 (Oculorhombin)(Aniridia type II protein) [Source:UniProtKB/Swiss-Prot;Acc:P26367]
Organisms with expression data	<p>This gene family is expressed in the following organisms:</p> <ul style="list-style-type: none">• <i>Danio rerio</i> (zebrafish) - 2 genes expressed in 58 organs and 27 stages• <i>Homo sapiens</i> (human) - 1 genes expressed in 74 organs and 7 stages• <i>Mus musculus</i> (mouse) - 1 genes expressed in 227 organs and 25 stages• <i>Xenopus tropicalis</i> (xenopus) - no expression data <p>Retrieve gene expression patterns for this family by anatomy browsing</p>
Expression data	<p>Retrieve expression patterns by anatomy browsing.</p> <p>Or retrieve all raw expression data for this gene family</p>

Expression data - Anatomical ontology browsing Hide | Top

Species comparison

Choose species (select several species to compare expression patterns)


Choose a stage

Stages [2] -embryo ▾

Data parameters

Danio rerio
Homo sapiens
Mus musculus
Xenopus tropicalis

Example: Pax-6 and the eye



Bgee: a dataBase for Gene Expression Evolution

Search ▾ | Anatomy & Development | About

Details for the gene family

Expression data: [Anatomical ontology browsing](#) - Miscellaneous: [General information](#) - [Gene List](#)

General information

Gene family ID	ENSGTV:1460141
Prediction method	Ensembl Gene Trees Vertebrates [?]
Description	Paired box protein Pax-6 (Oculorhombin)(Aniridia)
Organisms with expression data	<p>This gene family is expressed in the following organisms:</p> <ul style="list-style-type: none"> <i>Danio rerio</i> (zebrafish) - 2 genes expressed in <i>Homo sapiens</i> (human) - 1 genes expressed in <i>Mus musculus</i> (mouse) - 1 genes expressed in <i>Xenopus tropicalis</i> (xenopus) - no expression <p>Retrieve gene expression patterns for this family by anatomy browsing</p>
Expression data	<p>Retrieve expression patterns by anatomy browsing. Or retrieve all raw expression data for this gene family</p>

Expression data - Anatomical ontology browsing Hide | Top

Species comparison

Choose species (select several species to compare expression patterns)

Danio rerio
Homo sapiens
Mus musculus
Xenopus tropicalis

Choose a stage

Stages [\[?\]](#)

Data parameters

Data type [\[?\]](#) Data quality [\[?\]](#)

Enter a list of [\[?\]](#) OR enter keywords

Tip: To compare expression patterns gene by gene, check the checkboxes in the first row of the chart below, then click "show/hide gene details".

Legend

- 0: expression data exist for this homologous organs group or its substructures in this species, but no detection
- x: no expression data for this homologous organs group or its substructures at this metastage in this species.
- : this homologous organs group is not defined for this species

[Display all homologous organs groups](#)

	<i>Danio rerio</i>	<i>Xenopus tropicalis</i>	<i>Homo sapiens</i>	<i>Mus musculus</i>
Homologous organs common to all the selected species, with expression data	See genes details <input type="checkbox"/>	See genes details <input type="checkbox"/>	See genes details <input type="checkbox"/>	See genes details <input type="checkbox"/>
HOG:0000671 : organism	15 est (6 libraries) - 54 probesets (23 chips) - 35 in situ evidences (31 experiments) - Expression in substructures	0	0	37 probesets (37 chips) - 2 in situ evidences (2 experiments) - Expression in substructures

Gene List Hide | Top

Tip: Click on a gene identifier to retrieve expression pattern for this gene.

Example: Pax-6 and the eye

Bgee - Details for the gene family: ENSGTV:1460141

http://bgee.unil.ch/bgee/bgee?page=gene_family&action=family_details&gene_family_id=ENSGTV%3A1460141&supe Google

misc

Bgee - BgeeMart DAVID: Functional Annotation Res... Details for the gene family: ENSG...

Expression data - Anatomical ontology browsing Hide | Top

Species comparison

Choose species (select several species to compare expression patterns)

Danio rerio
Homo sapiens
Mus musculus
Xenopus tropicalis

Choose a stage

Stages [\[?\]](#) --organogenesis

Data parameters

Data type [\[?\]](#) All Data quality [\[?\]](#) >= high

Enter a list of [\[?\]](#) Ensembl gene ID OR enter keywords

submit

Tip: To compare expression patterns gene by gene, check the checkboxes in the first row of the chart below, then click "show/hide gene details".

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- 0: expression data exist for this homologous organs group or its substructures in this species, but no detection
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Display all homologous organs groups

Homologous organs common to all the selected species, with expression data	Danio rerio		Mus musculus
show/hide genes details	See genes details <input checked="" type="checkbox"/>		See genes details <input checked="" type="checkbox"/>
	pax6a	pax6b	Pax6
<input checked="" type="checkbox"/> HOG:0000671: organism	12 probesets (12 chips) - 34 in situ evidences (30 experiments) - Expression in substructures	20 probesets (10 chips) - 7 in situ evidences (5 experiments) - Expression in substructures	1 probesets (1 chips) - 2 in situ evidences (2 experiments) - Expression in substructures
<input checked="" type="checkbox"/> HOG:0000098: endocrine system	3 in situ evidences (3 experiments) - Expression in	3 in situ evidences (3 experiments) - Expression in	Expression in substructures

Example: Pax-6 and the eye

Bgee - Details for the gene family: ENSGTV:1460141

http://bgee.unil.ch/bgee/bgee?page=gene_family&action=family_details&gene_family_id=ENSGTV%3A1460141&sup= Google

Bgee - BgeeMart DAVID: Functional Annotation Res... Details for the gene family: ENSG...

<input checked="" type="checkbox"/> HOG:0000275: eye	5 in situ evidences (5 experiments) - Expression in substructures	1 in situ evidences (1 experiments) - Expression in substructures	11 in situ evidences (8 experiments) - Expression in substructures
HOG:0000164: cornea	x	x	5 in situ evidences (3 experiments)
<input checked="" type="checkbox"/> HOG:0000165: optic vesicle	10 in situ evidences (8 experiments)	3 in situ evidences (3 experiments)	1 in situ evidences (1 experiments) - Expression in substructures
HOG:0000521: optic neural ectoderm	x	x	2 in situ evidences (1 experiments)
HOG:0000166: lens placode	0	0	6 in situ evidences (5 experiments)
<input checked="" type="checkbox"/> HOG:0000167: optic cup	2 in situ evidences (2 experiments) - Expression in substructures	1 in situ evidences (1 experiments) - Expression in substructures	3 in situ evidences (3 experiments) - Expression in substructures
<input checked="" type="checkbox"/> HOG:0000229: retina	12 in situ evidences (9 experiments) - Expression in substructures	5 in situ evidences (4 experiments) - Expression in substructures	7 in situ evidences (7 experiments) - Expression in substructures
HOG:0000088: ciliary marginal zone	1 in situ evidences (1 experiments)	1 in situ evidences (1 experiments)	x
<input checked="" type="checkbox"/> HOG:0000535: neural retinal epithelium	Expression in substructures	0	6 in situ evidences (4 experiments)
HOG:0001166: retinal ganglion cell layer	3 in situ evidences (3 experiments)	0	x
HOG:0001167: retinal inner nuclear layer	3 in situ evidences (3 experiments)	0	x
HOG:0000536: pigmented retinal epithelium	0	0	1 in situ evidences (1 experiments)
HOG:0000490: optic cup inner layer	x	x	3 in situ evidences (2 experiments)
HOG:0000492: optic cup outer layer	x	x	1 in situ evidences (1 experiments)

Example: Pax-6 and the eye

The screenshot shows a web browser window with the URL <http://bgee.unil.ch/bgee/bgee?page=expression&action=bgeemart>. The page title is "Bgee - BgeeMart". The main heading is "Bgee: a dataBase for Gene Expression Evolution". Below this is a navigation bar with links: Search ▾, Anatomy & Development, About, and More ▾. A search bar is also present.

BgeeMart: Search gene expression

Examples:

- Basic queries: [genes expressed in zebrafish brain](#) - [genes expressed in adult zebrafish brain](#)
- Homologous genes expressed in adult zebrafish heart **and** adult human heart: [by anatomical structures query](#) - [by Homologous Organs Group query](#)

Tip 1: click the "Results" button to preview your results.

The search interface includes a sidebar with the following sections:

- Dataset**
 - Search by homology
 - Ensembl Gene Trees Vertebrate
- Attributes**
 - Gene ID
 - Gene name
 - Gene family ID
- Filters**
 - [None selected]
- Expression in species:**
 - [No species selected]

The main search area is titled "Please choose a search method to retrieve expressed genes". It contains two dropdown menus:

- Dataset: Homologous Organs Groups and metastages
- Gene family prediction method [?] Ensembl Gene Trees Vertebrate

Below the dropdowns, a note states: "N.B.: cross-species comparison is enable with all search type options (even "anatomical structures and developmental stages"). Your query will retrieve homologous genes expressed in every species you selected."

At the bottom of the page, it says "BgeeMart, inspired from [BioMart](#)".

Example: Pax-6 and the eye

The screenshot shows the BgeeMart web interface in a browser window. The address bar displays <http://bgee.unil.ch/bgee/bgee?page=expression&action=bgeemart>. The page title is "Bgee - BgeeMart".

At the top, there are navigation links: "misc", "Bgee - BgeeMart", "DAVID: Functional Annotation Res...", and "Details for the gene family: ENSG...". Below these, there are two bullet points:

- Basic queries: [genes expressed in zebrafish brain](#) - [genes expressed in adult zebrafish brain](#)
- Homologous genes expressed in adult zebrafish heart and adult human heart: [by anatomical structures query](#) - [by Homologous Organs Group query](#)

A blue tip box states: "Tip 1: click the 'Results' button to preview your results." Below this, there are three tabs: "New", "Count", and "Results". The "Results" tab is selected.

The main content area is titled "Please choose gene expression criteria". It contains three sections:

- EXPRESSION IN:** "Choose species (multiple selection enable)". A list of species is shown:
 - ☒ Danio rerio * (zebrafish)
 - ☐ Homo sapiens * (human)
 - ☐ Mus musculus * (mouse)
 - ☐ Xenopus tropicalis * (xenopus)
- METASTAGES:** "include children metastages" (checked). "Choose metastages (multiple selection enable)". A list of metastages is shown:
 - ☒ All metastages (OGEM:000000)
 - ☐ embryo (OGEM:000001)
 - ☐ zygote (OGEM:000004)
 - ☐ cleavage (OGEM:000005)
 - ☐ blastula (OGEM:000006)
 - ☐ gastrula (OGEM:000007)
 - ☐ neurula (OGEM:000008)
 - ☐ organogenesis (OGEM:000009)
 - ☐ post-embryonic development (OGEM:000002)
 - ☐ adult (OGEM:000003)
- HOMOLOGOUS ORGANS GROUPS:** "include substructures" (checked). "Inside a species, expression in: every term entered" (selected) and "any term entered" (radio button). "Choose Homologous Organs Groups (multiple selection enable)". A list of groups is shown:
 - extraembryonic vascular system (HOG:0001396) * Part of: extraembryonic structure
 - extraembryonic venous system (HOG:0000282) * Part of: extraembryonic vascular system
 - extraembryonic vitelline vein (HOG:0000014) * Part of: extraembryonic venous system
 - extrahepatic part of the hepatic duct (HOG:0000215) * Part of: bile duct, hepatic duct
 - extraocular muscle (HOG:0000549) * Part of: eye
 - extrinsic tongue muscle (HOG:0000825) * Part of: muscle, tongue skeletal muscle
 - eye (HOG:0000275) * Part of: central nervous system, peripheral nervous system, sensory organ
 - eye anterior chamber (HOG:0001431) * Part of: eye
 - eye mesenchyme (HOG:0001084) * Part of: eye
 - eyelid (HOG:0000016) * Part of: eye

At the bottom left, it says "BgeeMart, inspired from [BioMart](#)". The footer contains logos for SIB, UNIL | Université de Lausanne, and CRESCENDO.

Example: Pax-6 and the eye

Bgee - BgeeMart

http://bgee.unil.ch/bgee/bgee?page=expression&action=bgeemart

misc ▾

Bgee - BgeeMart

DAVID: Functional Annotation Res... Details for the gene family: ENSG...

Search ▾ Anatomy & Development About More ▾

BgeeMart: Search gene expression

Examples:

- Basic queries: [genes expressed in zebrafish brain](#) - [genes expressed in adult zebrafish brain](#)
- Homologous genes expressed in adult zebrafish heart **and** adult human heart: [by anatomical structures query](#) - [by Homologous Organs Group query](#)

Tip 1: click the "Results" button to preview your results.

New Count Results Help

Dataset - 633 genes
Search by homology
Ensembl Gene Trees Vertebrate

Attributes
Gene ID
Gene name
Gene family ID




Filters
Data quality >= high

Expression in species:
Danio rerio - 1658 genes
Mus musculus - 1585 genes
Metastases
include children metastases
-- organogenesis (OGEM:000009)
Homologous Organs Groups
include substructures
every term entered
eye (HOG:0000275)

View 10 rows as html order by gene family (can be slow) View Export

Gene name	Gene ID	Gene family ID
znf503	ENSDARG0000018492	ENSGTV:1017087
zfp503	ENSMUSG0000039081	ENSGTV:1017087
hadha	ENSDARG0000057128	ENSGTV:1017389
Hadha	ENSMUSG0000025745	ENSGTV:1017389
zgc:101052	ENSDARG0000043271	ENSGTV:1023158
Morc3	ENSMUSG0000039456	ENSGTV:1023158
snai2	ENSDARG0000040046	ENSGTV:1039260
Snai2	ENSMUSG0000022676	ENSGTV:1039260
zff9	ENSDARG0000045776	ENSGTV:1041478
Cnbp	ENSMUSG0000030057	ENSGTV:1041478

BgeeMart, inspired from [BioMart](#)

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<http://bgee.unil.ch/>

Example: Pax-6 and the eye

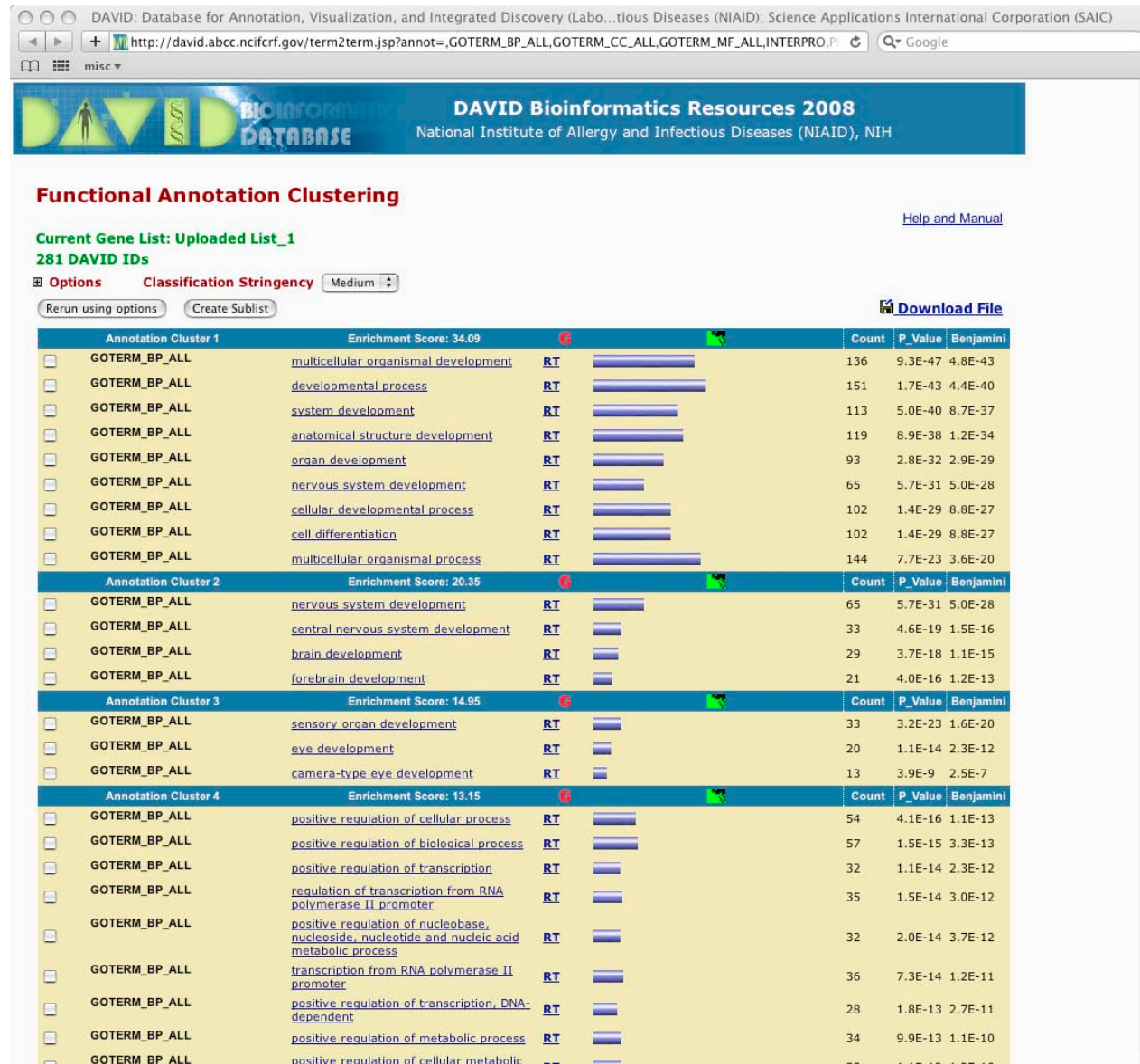
Bgee - BgeeMart results - expressed genes

http://bgee.unil.ch/bgee/bgee?page=expression&action=genes&result_per_page=0&species_details_id=7955&specie Google

BgeeMart results - expressed gen... DAVID: Functional Annotation Res... Details for the gene family: ENSG...

sox4b	ENSDARG00000043235	ENSGTV:1455358
sox4a	ENSDARG00000004588	ENSGTV:1455358
Sox4	ENSMUSG00000076431	ENSGTV:1455358
hsp90a.2	ENSDARG00000024746	ENSGTV:1456603
Hsp90aa1	ENSMUSG00000021270	ENSGTV:1456603
cmyb	ENSDARG00000053666	ENSGTV:1457556
Myb	ENSMUSG00000019982	ENSGTV:1457556
puf60b	ENSDARG00000001241	ENSGTV:1458135
Puf60	ENSMUSG00000002524	ENSGTV:1458135
gro1	ENSDARG00000069006	ENSGTV:1459192
Tle3	ENSMUSG00000032280	ENSGTV:1459192
pax6a	ENSDARG00000045045	ENSGTV:1460141
pax6b	ENSDARG00000045936	ENSGTV:1460141
Pax6	ENSMUSG00000027168	ENSGTV:1460141
smc4	ENSDARG00000038882	ENSGTV:1465825
Smc4	ENSMUSG00000034349	ENSGTV:1465825
sall1a	ENSDARG00000074319	ENSGTV:1470733
sall1a	ENSDARG00000074144	ENSGTV:1470733
Sall1	ENSMUSG00000031665	ENSGTV:1470733
apc	ENSDARG00000058868	ENSGTV:1472437
Apc	ENSMUSG00000005871	ENSGTV:1472437
usp9	ENSDARG00000013708	ENSGTV:1475177
Usp9x	ENSMUSG00000031010	ENSGTV:1475177

Example: Pax-6 and the eye



<http://bgee.unil.ch/>

Example: Pax-6 and the eye

DAVID: Database for Annotation, Visualization, and Integrated Discovery (Laboratory of Molecular Biology, National Institute of Health)

http://david.abcc.ncifcrf.gov/term2term.jsp?annot=GOTERM_BP_ALL,GOTERM_CC_ALL,GOTERM_MF_ALL,INTERPRO:IP

DAVID Bioinformatics Resources 2008
National Institute of Allergy and Infectious Diseases (NIAID), NIH

Functional Annotation Clustering

Current Gene List: Uploaded List_1
281 DAVID IDs

Options Classification Stringency Medium

Rerun using options Create Sublist Download File

Annotation Cluster	Enrichment Score	Count	P-Value	Benjamini
Annotation Cluster 1 Enrichment Score: 34.09				
GOTERM_BP_ALL	multicellular organismal development	136	9.3E-47	4.8E-43
GOTERM_BP_ALL	developmental process	151	1.7E-43	4.4E-40
GOTERM_BP_ALL	system development	113	5.0E-40	8.7E-37
GOTERM_BP_ALL	anatomical structure development	119	8.9E-38	1.2E-34
GOTERM_BP_ALL	organ development	93	2.8E-32	2.9E-29
GOTERM_BP_ALL	nervous system development	65	5.7E-31	5.0E-28
GOTERM_BP_ALL	cellular developmental process	102	1.4E-29	8.8E-27
GOTERM_BP_ALL	cell differentiation	102	1.4E-29	8.8E-27
GOTERM_BP_ALL	multicellular organismal process	144	7.7E-23	3.6E-20
Annotation Cluster 2 Enrichment Score: 20.35				
GOTERM_BP_ALL	nervous system development	65	5.7E-31	5.0E-28
GOTERM_BP_ALL	central nervous system development	33	4.6E-19	1.5E-16
GOTERM_BP_ALL	brain development	29	3.7E-18	1.1E-15
GOTERM_BP_ALL	forebrain development	21	4.0E-16	1.2E-13
Annotation Cluster 3 Enrichment Score: 14.95				
GOTERM_BP_ALL	sensory organ development	33	3.2E-23	1.6E-20
GOTERM_BP_ALL	eye development	20	1.1E-14	2.3E-12
GOTERM_BP_ALL	camera-type eye development	13	3.9E-9	2.5E-7
Annotation Cluster 4 Enrichment Score: 13.15				
GOTERM_BP_ALL	positive regulation of cellular process	54	4.1E-16	1.1E-13
GOTERM_BP_ALL	positive regulation of biological process	57	1.5E-15	3.3E-13
GOTERM_BP_ALL	positive regulation of transcription	32	1.1E-14	2.3E-12
GOTERM_BP_ALL	regulation of transcription from RNA polymerase II promoter	35	1.5E-14	3.0E-12
GOTERM_BP_ALL	positive regulation of nucleobase, nucleoside, nucleotide and nucleic acid metabolic process	32	2.0E-14	3.7E-12
GOTERM_BP_ALL	transcription from RNA polymerase II promoter	36	7.3E-14	1.2E-11
GOTERM_BP_ALL	positive regulation of transcription, DNA-dependent	28	1.8E-13	2.7E-11
GOTERM_BP_ALL	positive regulation of metabolic process	34	9.9E-13	1.1E-10
GOTERM_BP_ALL	positive regulation of cellular metabolic	33	4.1E-13	1.0E-10

Conclusion & Perspectives

To compare gene expression between species, Bgee includes:

- integrated expression data
- homology relationships between genes
- homology relationships between anatomical terms
- relationships between developmental terms

Bgee is available at: <http://bgee.unil.ch/>

Conclusion & Perspectives

To compare gene expression between species, Bgee includes:

- integrated expression data
- homology relationships between genes
- homology relationships between anatomical terms
- relationships between developmental terms

In progress:

- miRNAs
- analogy (homoplasy) and deep homology relationships
 - classification of relevant types of relationships
 - management of pairwise (non transitive) relationships
 - integration of Drosophila
- differential gene expression
- programmatic access
 - DAS ready, SOAP in progress, EMBOSS access in progress

Acknowledgements

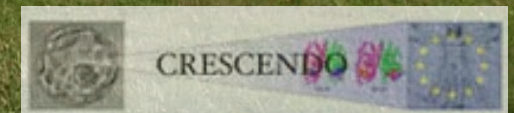
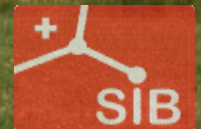
ex-members:

Gilles Parmentier
Frederic Ricci

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