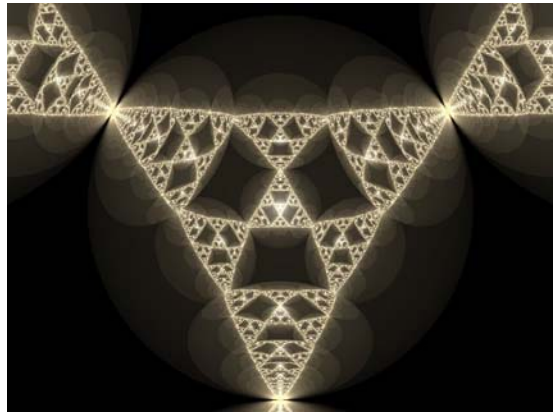


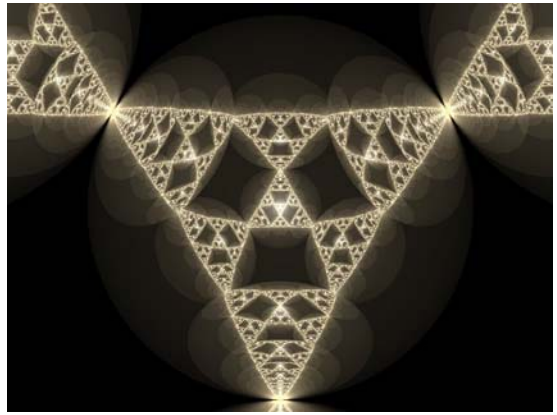
Using Web-based Tools for Teaching Embryology

Teratology Society, Monterey CA, July 1, 2008

Thomas B. Knudsen, PhD
National Center for Computational Toxicology
US EPA, Research Triangle Park NC
Knudsen.Thomas@epa.gov

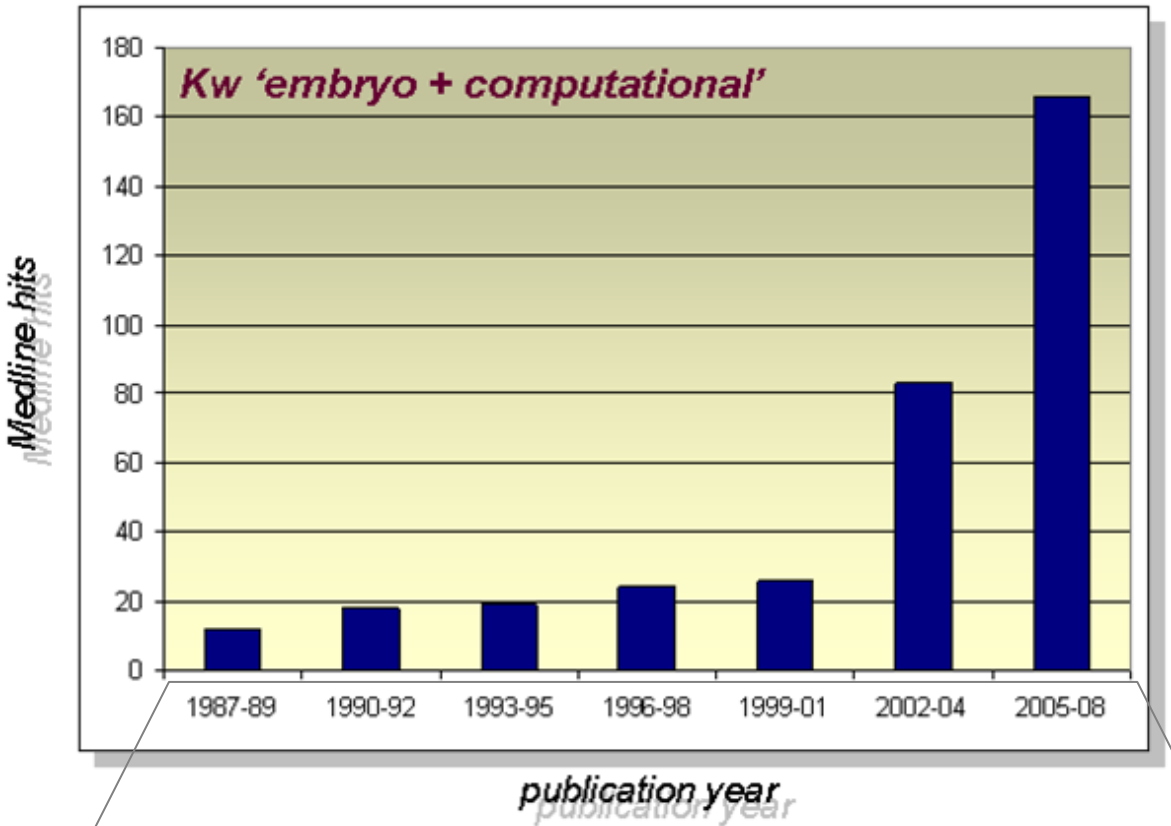
DISCLAIMER: views reflect those of the presenter and not EPA policy; any reference to commercial products or tradenames does not constitute endorsement

INTRODUCTION



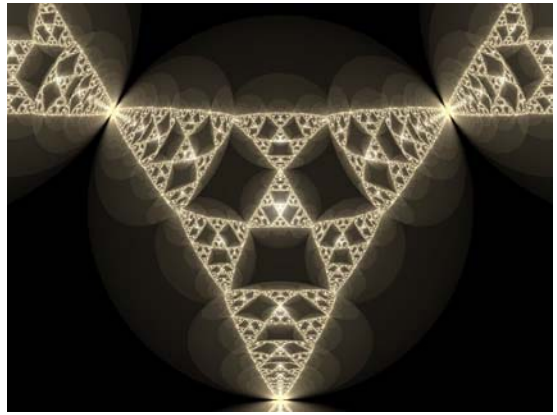
- computers, imaging, and the worldwide web have assumed an important role augmenting learning
- since mid-1990's web resources have become available to accelerate research and advance knowledge
- technologies to help computers access scientific information fuel drive to make it '*freely available to all*'
- efforts needed to prevent a '*free for all*' when elevating these data into computable knowledge

Computational (*in silico*) biology:
impact of the human genome project



descriptive biology ← **cell biology biochemistry** | **molecular biology** | **genomics bioinformatics** | **systems biology** → *virtual biology*

www: EDUCATIONAL USES FOR TERATOLOGISTS



- promote collaboration and scholarship through open exchange of useful educational and research materials
- computer-based methods for 3D rendering and visualizing difficult relationships in embryology
- community knowledge environment to extract and integrate information, and build ontologies
- map developmental endpoints to pathways and derive network topology of genes (GRN) and cells (CRN)

Virtual Libraries

About SDB
Membership
Meetings
Job Openings
Education
Interactive Fly
Publications
Virtual Library

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Site Map
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Webmaster

Virtual Library-Developmental Biology

This Virtual Library maintained by **Society for Developmental Biology**.

Developmental Biology
Published by Elsevier Science under Auspices of Society for Developmental Biology

Subject Index
- Gametogenesis and Fertilization
- Early Development
- Organogenesis and Morphogenesis
- Pattern Formation
- Gene Regulation and Genetics
- Cell Lineage and Fate Maps
- Evolution and Development
- Diseases, Defects and Development

Organisms Index
- Vertebrates
- Invertebrates
- Plants
- Unicellular/Lower Eukaryotes and Prokaryotes

Journals and Publishers Index
- Journals
- Publishers

Research Resources Index

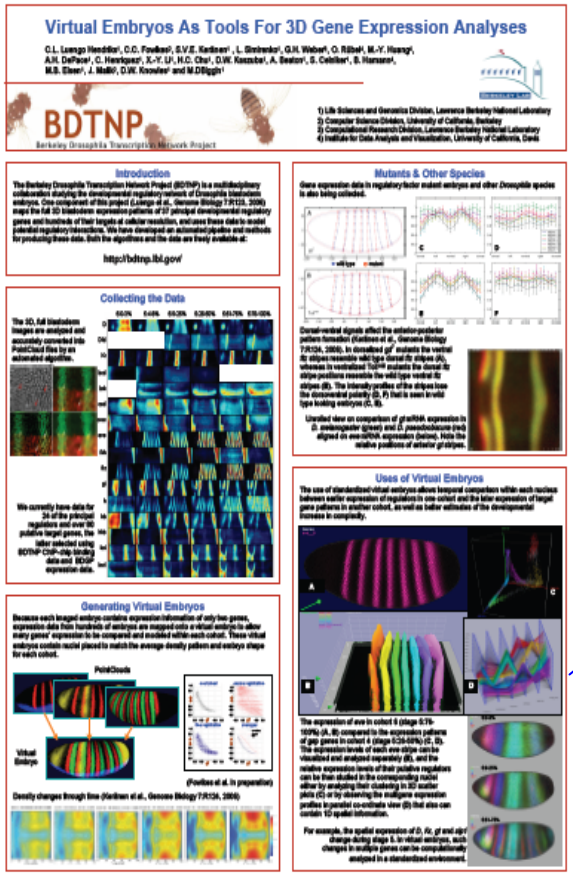
Educational Resources Index

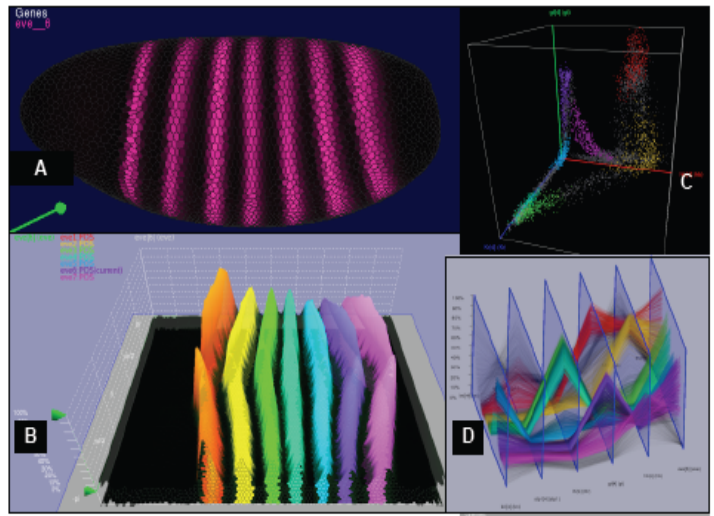
Departments and Institutes Index

Search Engines and Other Resources

Societies and Organizations Index

- Stephen Alexander's laboratory at the University of Missouri uses *Dictyiostelim discoideum* as a model system for studies on: 1. molecular and cellular mechanisms of resistance to anticancer drugs; 2. regulation of protein secretion during development.
- Zena Werb's lab at UC San Francisco studies the role of extracellular proteolysis in controlling vascular development and angiogenesis during embryonic development and placental formation, bone development and tumorgenesis.
- Tumor Suppressor Genes in Drosophila and Their Human Homologs; Genetics of Development in Drosophila The objective of research in Peter J. Bryant's laboratory (UC Irvine) is to understand how cell proliferation is controlled during development, and how genetic mutations lead to growth abnormalities and cancer. They approach this problem using a genetic approach in Drosophila, by identifying and characterizing tumor suppressor genes, in which mutations cause excessive cell proliferation in the developing organs of mutant larvae. Efforts from this lab and others have led to the identification of over 60 of these genes, and over 20 of them have been cloned. Almost all of them have human homologs whose potential roles in cancer are now being investigated.
- Atlas of Developmental Abnormalities in Common Laboratory Mammals This website is designed for rapid access to the image(s) of developmental abnormalities in common laboratory mammals.





Source: Berkeley Drosophila Transcription Network Project (BDTNP)
http://www-vis.lbl.gov/Publications/2007/LBNL-63062.pdf

Virtual Library needed for teratology

– relaunching of Society's website coming soon!

Fair Use Doctrine in education:

http://www.dartmouth.edu/~webteach/articles/copyright.html

1. **purpose:** not-for-profit use ‘fair’ if purpose of web content is instructional

2. **nature:** works created for research purposes likely ‘fair’ due to expectations for educational use

3. **substantiality:** ‘fair’ use if reasonable relative to the whole, or if not the basis of user’s work

4. **marketing:** ‘fair’ if use has little or no effect on creator's ability to market his/her work

BEST PRACTICE: assume work copyrighted when web page created; get author’s consent and acknowledge; disclose that materials fall under fair use exemption and are restricted from further use

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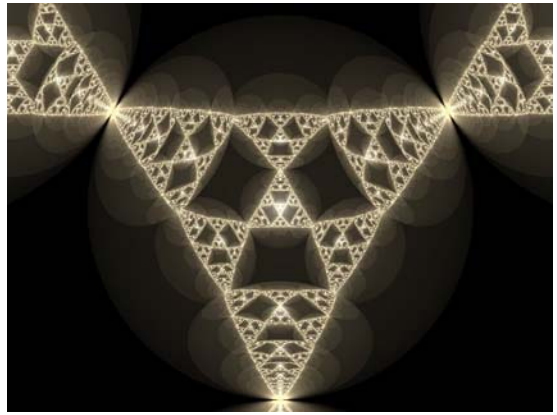

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Digital atlases:

Carnegie Human Embryology Collection

- The Virtual Human Embryo

  http://nmhm.washingtondc.museum/collections/hdac/index.ht

  image databases for 23 stages of human embryonic development; each includes a complete serially sectioned embryo from the Carnegie collection

- Multi-Dimensional Human Embryo

  http://embryo.soad.umich.edu/

  web-accessible 3D image reference resource based on magnetic resonance microscopy of the Carnegie Collection

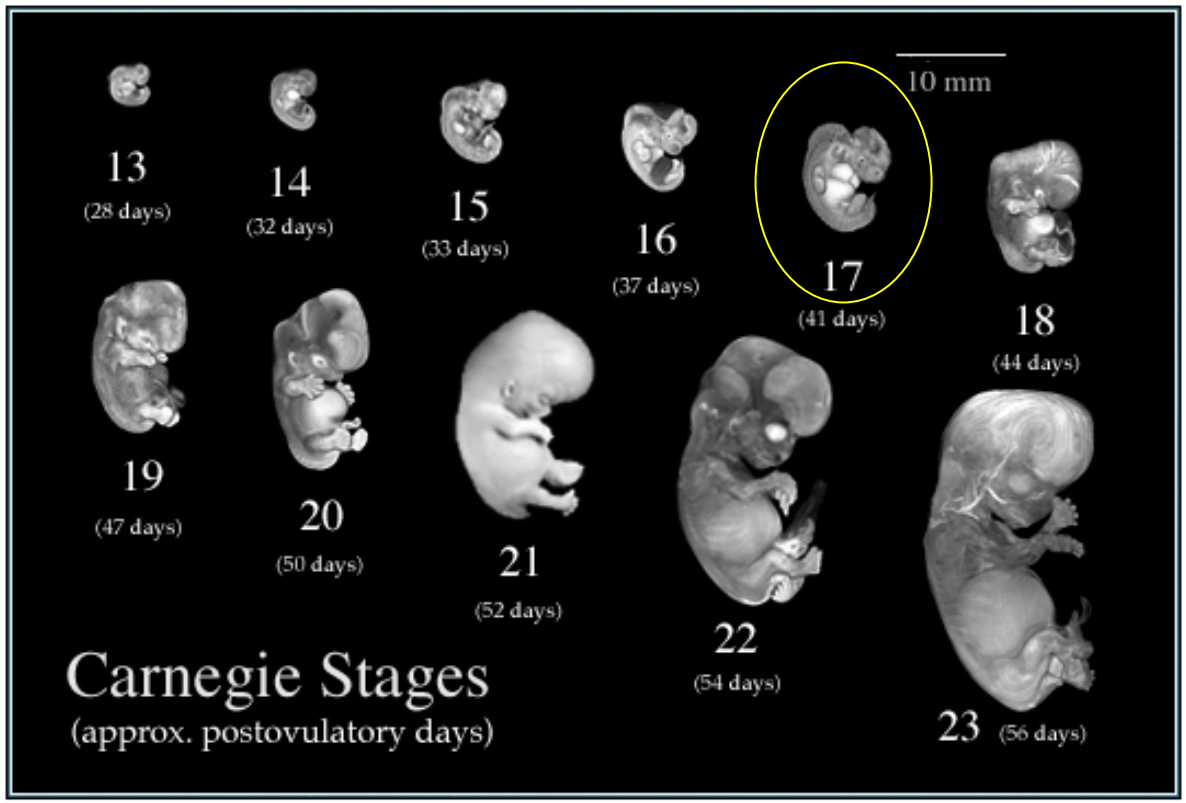
Multi-Dimensional Human Embryo

Sample images listed by: Carnegie Stages

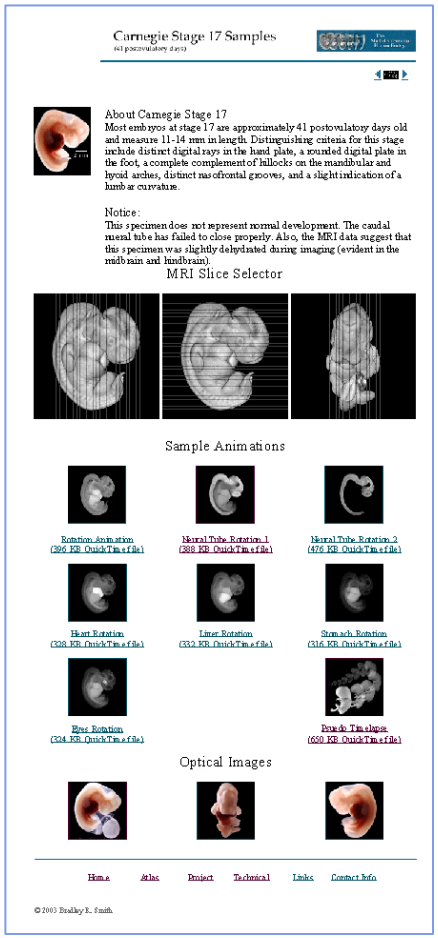
The Multi-Dimensional Human Embryo

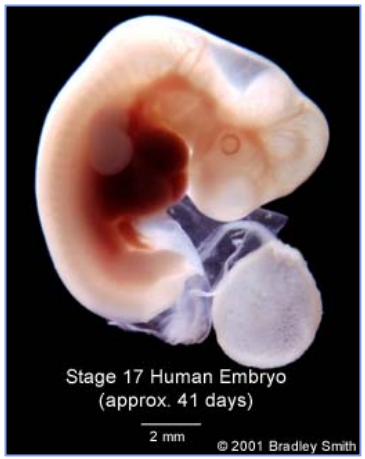
Home Atlas Project Technical Links Contact Info

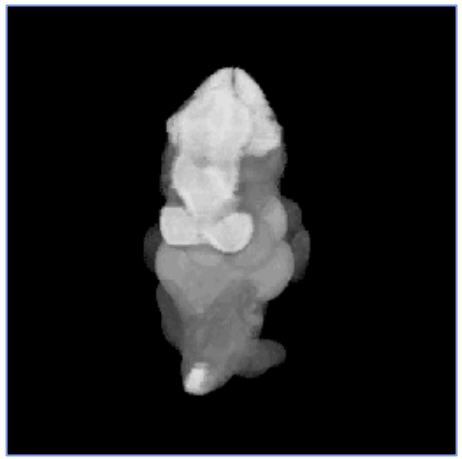
View Sample Images by Selecting an Embryo Below

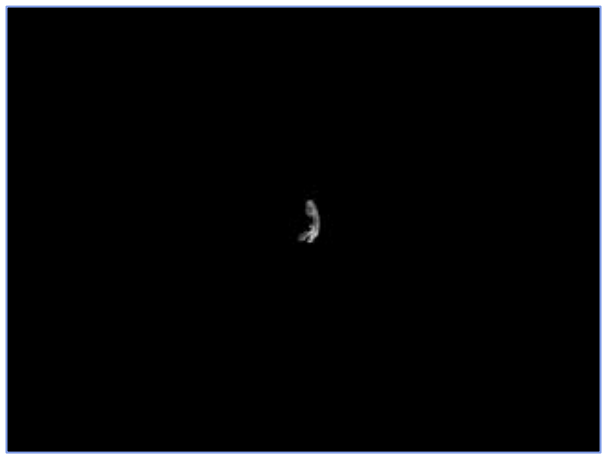


Carnegie Stage 17 Samples



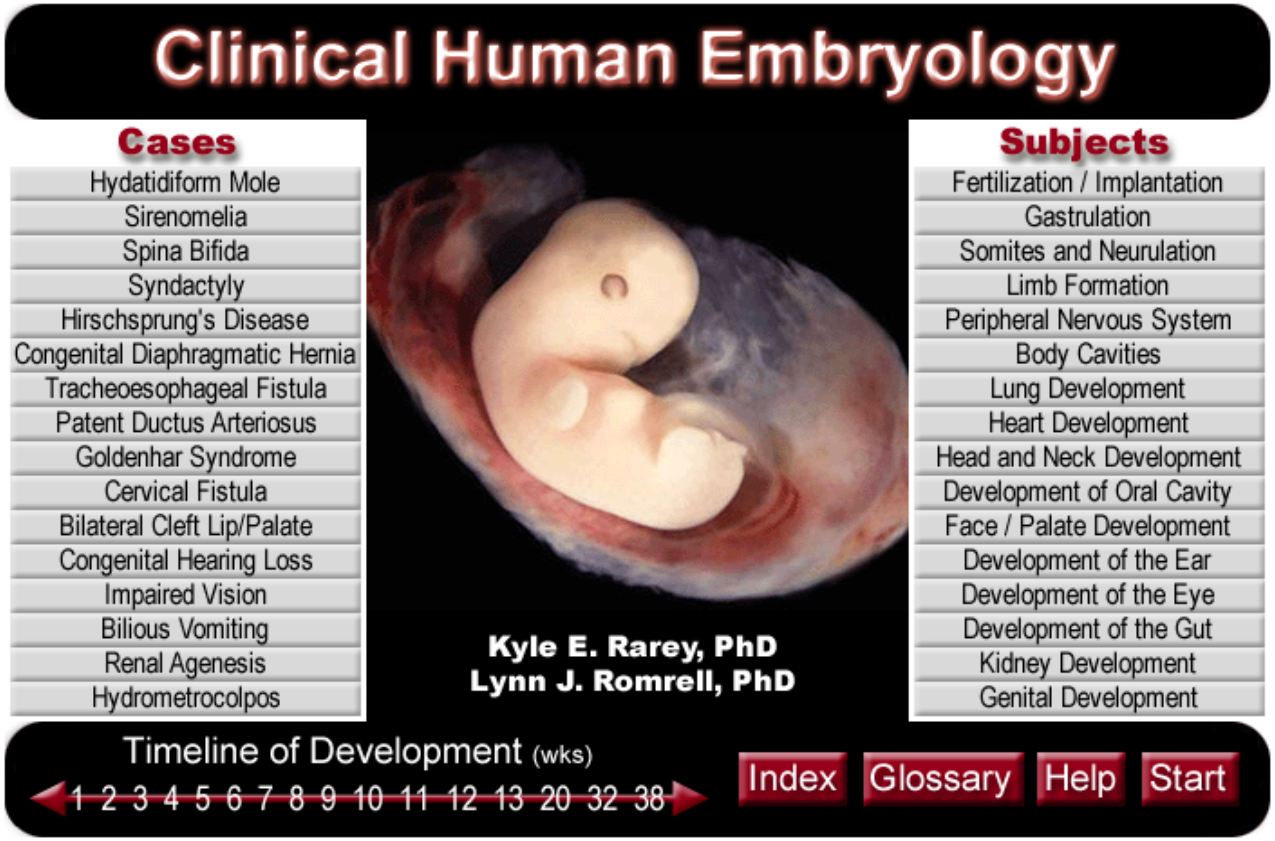






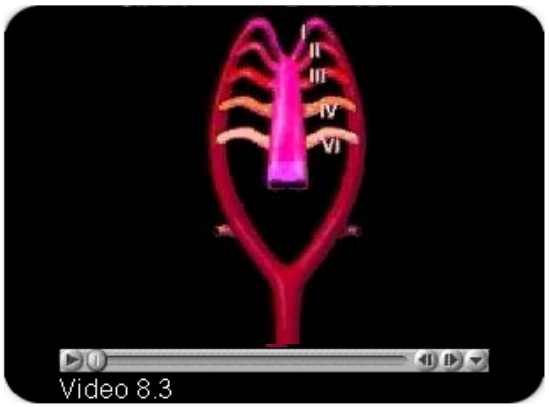
http://embryo.soad.umich.edu/

Online textbooks



Source: http://www.imc.gsm.com/siteinfo/browse_heinfo.htm

Chapter 8: Heart Development, discussion of aortic arches



Arterial Outflow Tract

The arterial outflow tract of the primitive heart is composed of the aortic sac and aortic arch arteries. Blood from the truncus arteriosus passes into the aortic sac and then into bilateral pair of six aortic arches that are located within the pharyngeal arches. Blood then enters paired dorsal aortas that unite to become one medial dorsal aorta below the heart. Branches from the dorsal aorta are vitelline arteries, umbilical arteries, and intersegmental arteries.

The truncus ateriosus eventually becomes part of the ascending aorta and the proximal portions of the pulmonary arteries. The aortic sac forms part of the aortic arch and part of the brachiocephalic artery. The adult derivatives of the six, paired aortic arches are listed in the following table (video 8.3 - developing arterial outflow seen from an anterior view).

Aortic Arch Artery	Adult Derivative
1st	Maxillary artery
2nd	Stapedial artery, hyoid artery
3rd	Common carotid arteries, roots of internal carotid arteries
4th	Part of the arch of the aorta, right subclavian artery
6th	Ductus arteriosus (left side), roots of pulmonary arteries

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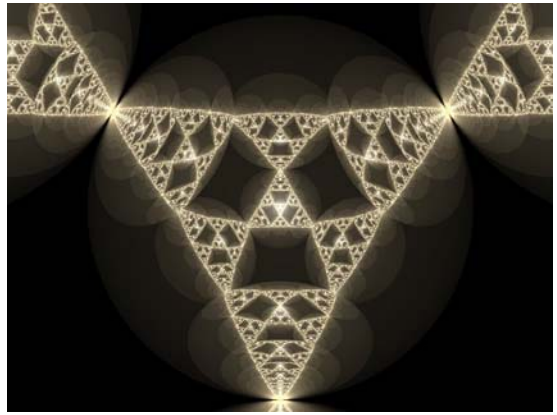

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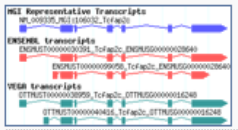
Mouse Genome Informatics

http://www.informatics.jax.org/

Explore MGI

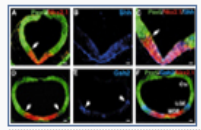
All Search Tools

Genes



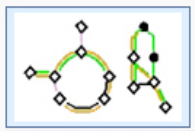
Phenotypes

Expression

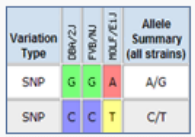


Function

Pathways

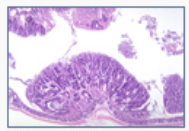


Strains / SNPs



Orthology

Tumors



FAQs

How do I...

.. search for genes? FAQ

.. find mutations for phenotypes or diseases? FAQ

.. find expression data? FAQ

.. view a structural genomic map? FAQ

More FAQs

News

17 June, 2008

- MGI genome coordinates are now updated to NCBI Mouse Build 37 and dbSNP Build 128.
- The MGI website and navigation tools have been redesigned. Take a quick tour.
- MouseCyc, a new database of curated biochemical pathways, is now available at MGI.

More MGI news MGI Statistics

Mouse Community News

MGI Roadshow: If you would like to host a MGI workshop at your institution, contact User Support to discuss the details.

Visit MGI posters at these upcoming conferences:

- XX International Congress of Genetics
- International Conference on Bioinformatics & Computational Biology
- International Conference on Intelligent Systems for Molecular Biology

Read about the International Mouse Knockout Consortium [KOMP (USA); EUCOMM (Europe); NorCOMM (Canada); TIGM (USA)] in Cell 2007; 128: 9-13, PMID: 17218247 and Cell 2007; 129: 235, PMID: 17448981.

MGI

Tour the new MGI website

About Help FAQ

Home Genes Phenotypes Ex

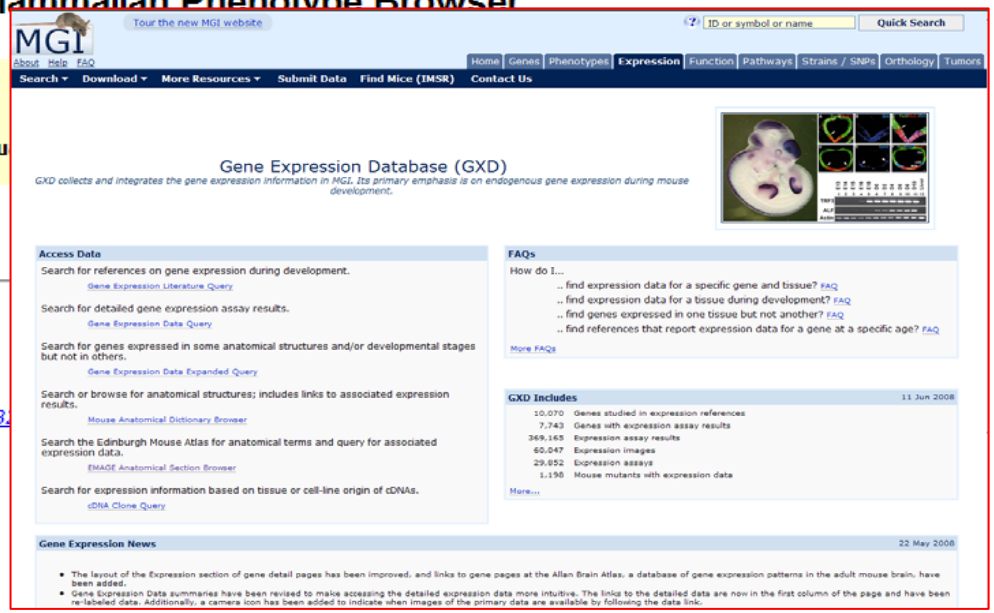
Search ▾ Download ▾ More Resources ▾ Submit Data Find Mice (IMSR) Contact Us

Mammalian Phenotype Browser

MP term: **abnormal eye development**
Synonym: **eye development abnormalities**
MP id: **MP:0001286**
Definition: **malformation or arrest of differentiation of the visu**
Number of paths to term: **1**

I denotes an 'is-a' relationship
P denotes a 'part-of' relationship

Phenotype Ontology
- I vision/eye phenotype
  - I abnormal eye morphology
    - I abnormal anterior eye segment morphology +
    - I abnormal eye development [MP:0001286] *(278 genotypes, 38*
      - I abnormal corneal stroma development
      - I abnormal eye muscle development
      - I abnormal lens development +
      - I abnormal optic cup morphology
      - I abnormal optic eminence morphology
      - I abnormal optic stalk morphology
      - I abnormal optic vesicle formation +
      - I abnormal periocular mesenchyme morphology
      - I abnormal retinal progenitor morphology
      - I aniridia
      - I coloboma
      - I cyclopia
      - I ectopia lentis
      - I lenticonus
      - I persistence of hyaloid capillary system
    - I abnormal eye distance/ position +
    - I abnormal eye muscle morphology +
    - I abnormal eye pigmentation +
    - I abnormal eye size +
    - I abnormal eyelid morphology +
    - I abnormal lacrimal gland morphology +
    - I abnormal orbit morphology +
    - I abnormal posterior eye segment morphology +
    - I abnormal sclera morphology +
    - I abnormal uvea morphology +
    - I intraocular calcification +

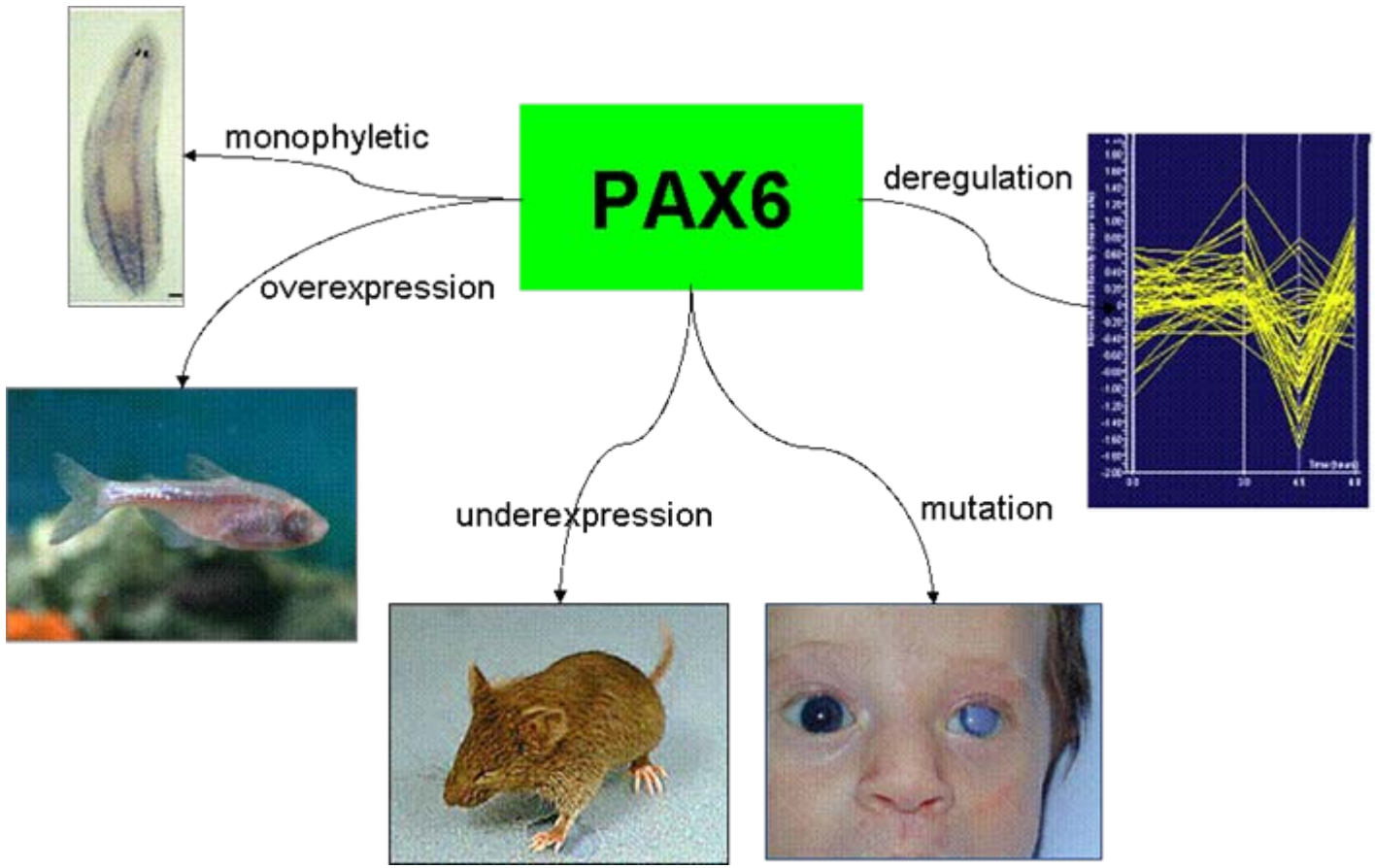


4 genotypes with 4 annotations displayed

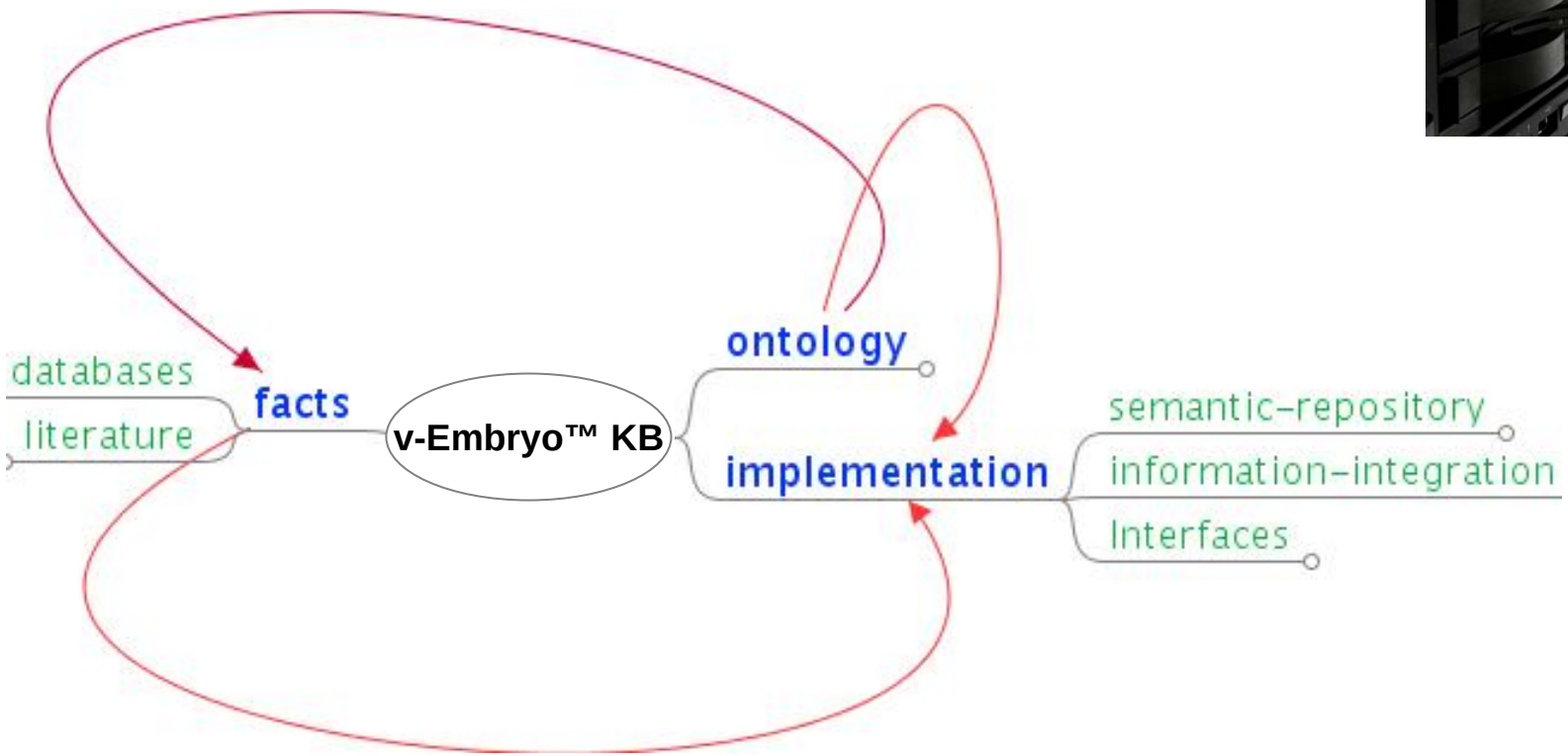
Searched Term: aniridia

Allelic Composition (Genetic Background)	Annotated Term	
Mab21l1^{tm1Nao}/Mab21l1^{tm1Nao} (involves: C57BL/6)	aniridia	J:82312
Pax6$^{Sey\text{-}Dey}$/Pax6^{+} (C3H/HeJ-Pax6$^{Sey\text{-}Dey}$)	aniridia	J:10820
Pax6^{tm1Gfs}/Pax6^{tm1Gfs} (involves: 129S7/SvEvBrd)	aniridia	J:76576
Tcfap2a^{tm1Will}/Tcfap2a^{tm1Will} (involves: Black Swiss)	aniridia	J:52402

Pax6 roles in eye development from analysis of the scientific literature



v-Embryo™ Knowledgebase:
normal and abnormal embryogenesis



Source: Imran Shah, NCCT – EPA

http://www.epa.gov/ncct/index.html

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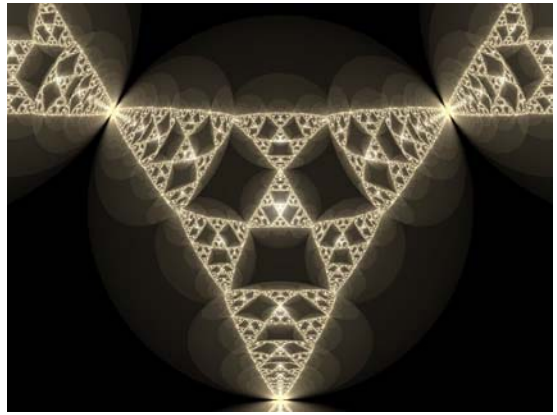

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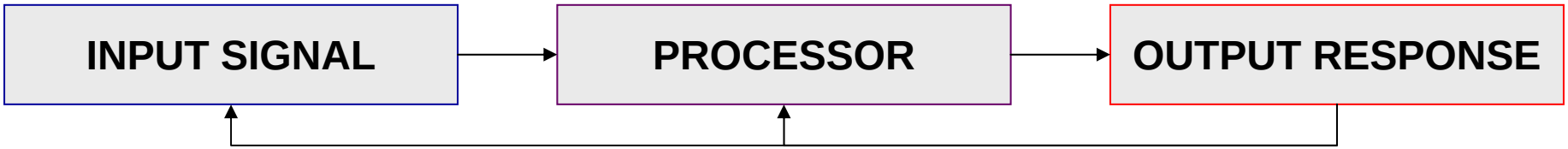
Developmental signaling pathways:
integrating these data at a systems level



Developmental Signals

Wnt, TGFβ, Shh, RTK, Notch-Delta, NF-kB, PCD, nuclear hormone receptors, RPTPs, receptor GC, cytokines, NO, GPCRs, integrins, CADs, gap junction, ligand-gated cation channels, UPR, p53

Morphoregulatory Responses

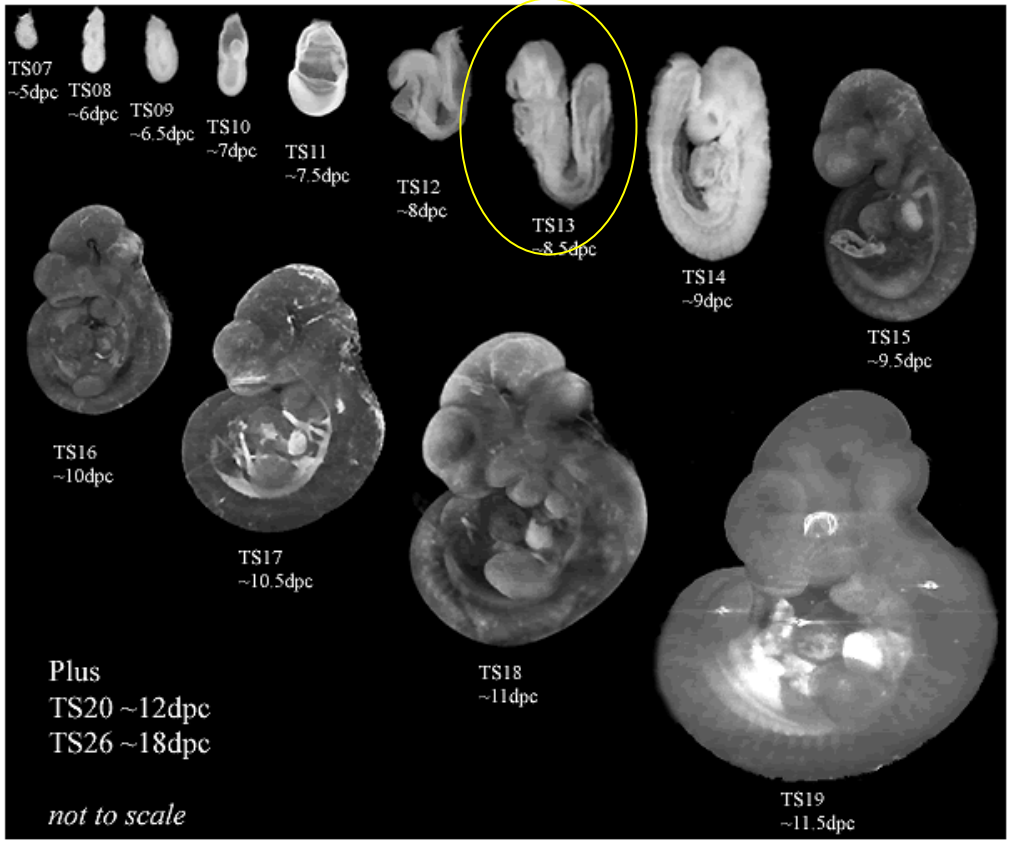
patterning
proliferation
apoptosis
differentiation
adhesion
motility
shape
ECM remodeling

Edinburgh Mouse Atlas Project

emap

3D digital atlas | theiler stage selector

HOME | 3D DIGITAL ATLAS | EMAGE DATABASE | RESOURCES | CONTACT | SITE SEARCH



emap models available:

Select the embryo you want

Theiler Staging Guide:

Individual Stages

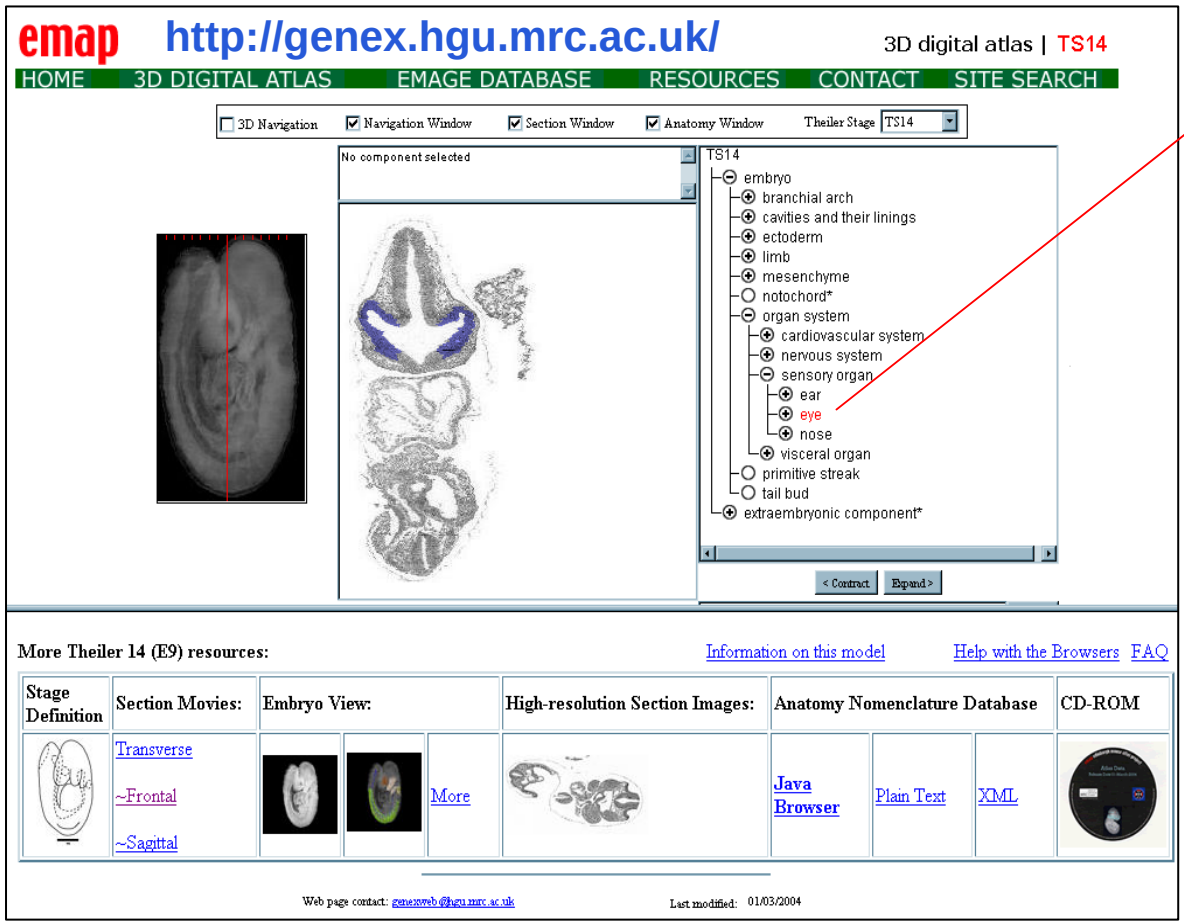
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

All Stages

- Criteria Summary table
- Pictorial stage index
- Text anatomy index
- Anatomy Database

FAQs

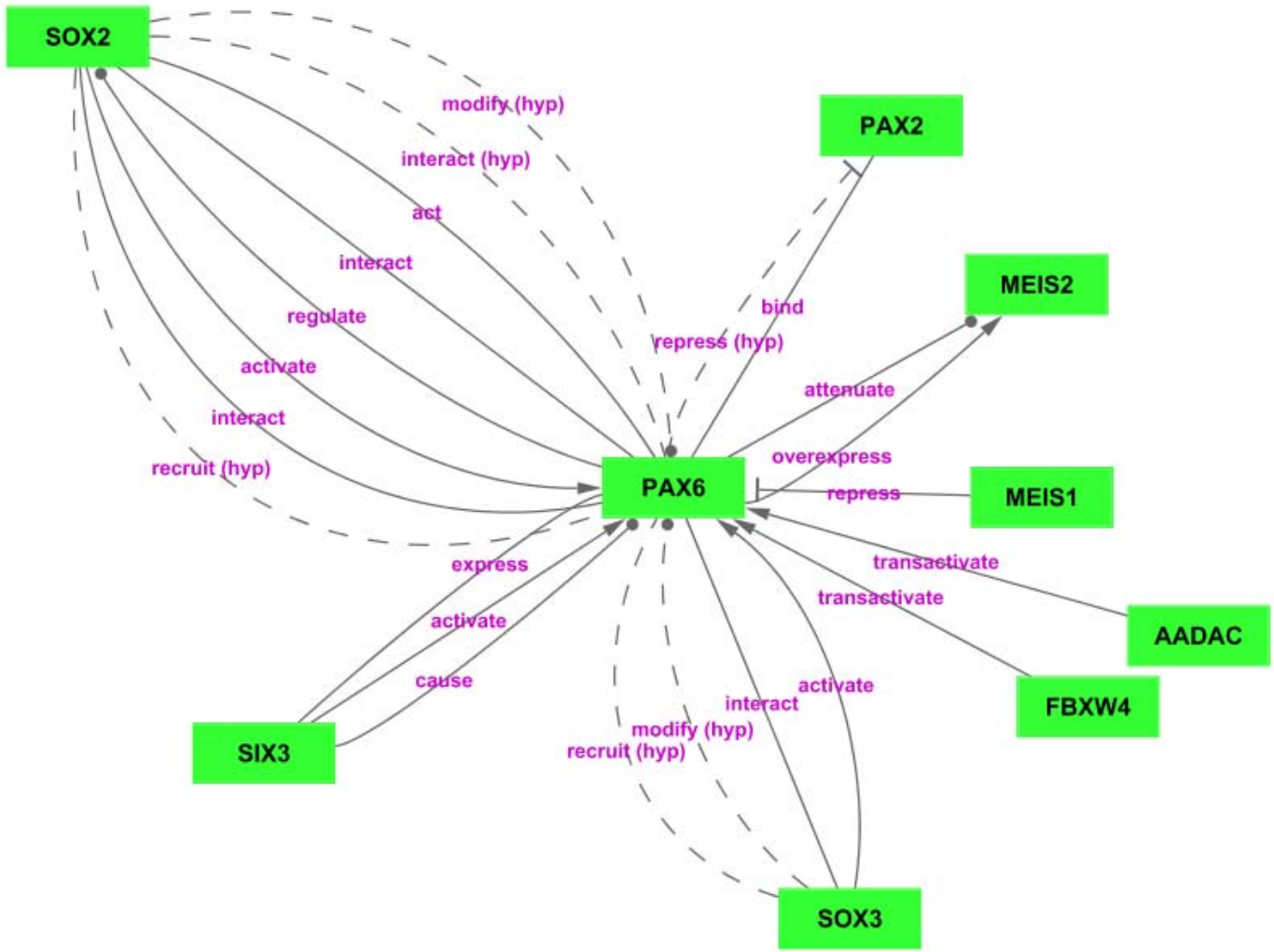
Capturing data from EMAGE, GXD and the scientific literature



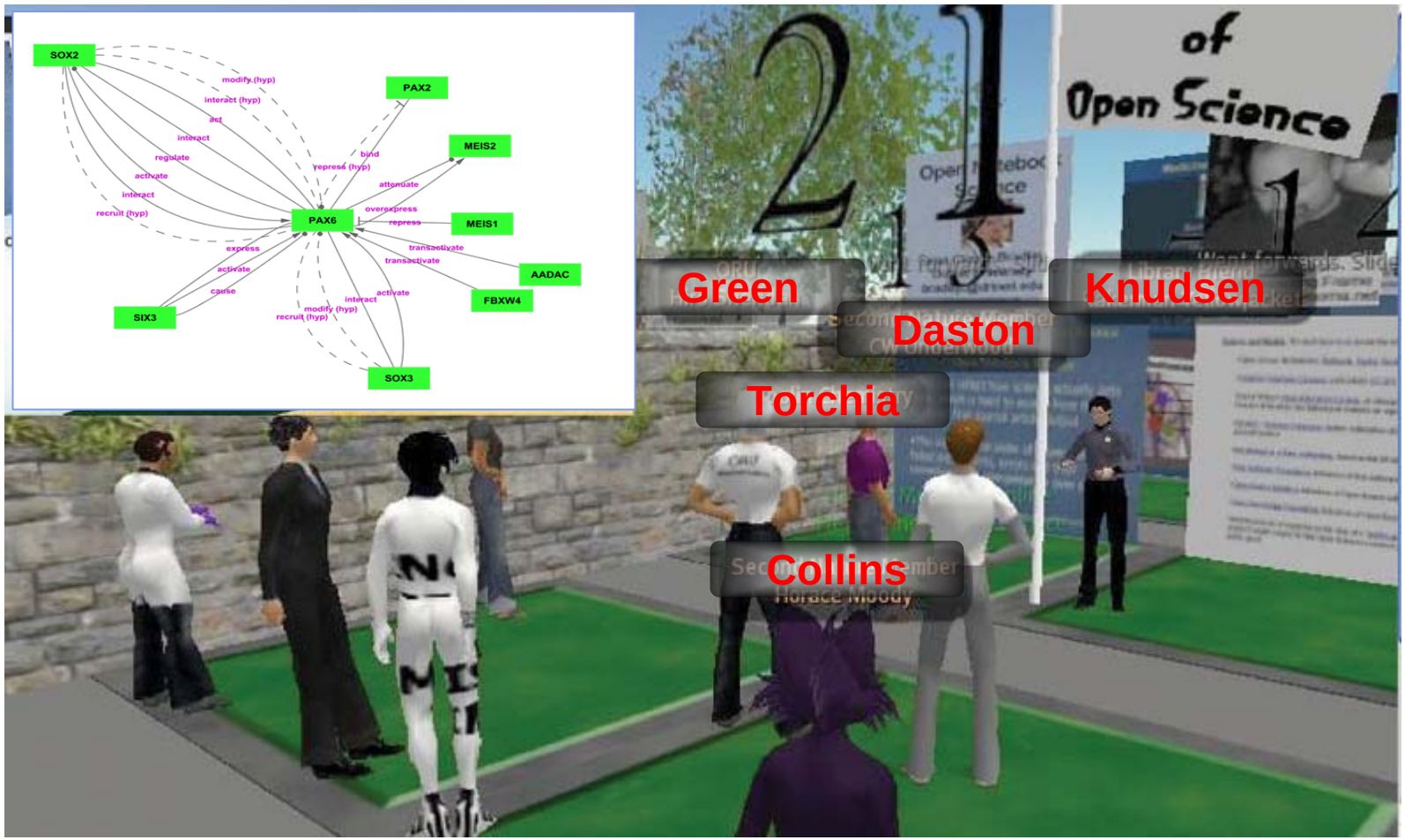
63 genes (TS12-18)
captures 2164 PMIDs

Sl.No.	Gene 1	Gene 2	Search1	Search2	PMID	Web link	Title	Authors	Read	Relevant	New Informatio
1	cyc	shh	fetal or embryo	mouse or mic	12763802	http://www.ncb	A temperature-sensitiv	Tian J., Yam	Y	Y	N
2	cyc	shh	fetal or embryo	mouse or mic	10852897	http://www.ncb	Direct action of the noc	Müller F., Alb	Y	Y	Y
3	cyc	shh	fetal or embryo	mouse or mic	10694427	http://www.ncb	Two distinct cell popul	Odenthal J., N	Y	N	N
4	cyc	shh	fetal or embryo	mouse or mic	8946241	http://www.ncb	Expression of axial and	Strähle U., Bl	Y	N	N
5	cyc	shh	fetal or embryo	mouse or mic	8674416	http://www.ncb	Complex expression of	Hauptmann G	Y	N	N
6	shh	pax2	fetal or embryo	mouse or mic	11731484	http://www.ncb	hnf1, the MODY5 and	Sun Z., Hopk	Y	N	N
7	shh	pax2	fetal or embryo	mouse or mic	10601036	http://www.ncb	Vax1, a novel homeobo	Hallonet M., H	Y	Y	Y
8	shh	pax2	fetal or embryo	mouse or mic	9655820	http://www.ncb	Sonic hedgehog is not	Schauerte H.,	Y	N	N
9	shh	six1	fetal or embryo	mouse or mic	15105370	http://www.ncb	Otx2 requires the ext	Puelles E., Ali	Y	N	N
10	Pax2	pax6	fetal or embryo	mouse or mic	17470285	http://www.ncb	Rybp, a polycomb com	Pirity M., Wal	Y	YN (develop	Y
11	Pax2	pax6	fetal or embryo	mouse or mic	17166916	http://www.ncb	Lmx1b is essential for	Guo C., Qiu H	Y	N	N
12	Pax2	pax6	fetal or embryo	mouse or mic	16934393	http://www.ncb	A role for GnRH in ear	Wu S., Page	Y	Y	Y
13	Pax2	pax6	fetal or embryo	mouse or mic	14711874	http://www.ncb	Prep1.1 has essential	Dellaviran G.,	Y	D?	Y
14	Pax2	pax6	fetal or embryo	mouse or mic	12970747	http://www.ncb	Paired-Box genes are	Muratovska A	Y	N	N
15	Pax2	pax6	fetal or embryo	mouse or mic	12756174	http://www.ncb	Retinal pigmented epit	Bäumer N., M	Y	Y	Y
16	Pax2	six6	fetal or embryo	mouse or mic	11804790	http://www.ncb	Oad1, a vertebrate ho	Neave T., Di	Y	YN (Day 13	N
17	Pax2	six6	fetal or embryo	mouse or mic	11458394	http://www.ncb	Six3 promotes the forn	Lagutin O., Zh	Y	Y	N
18	Pax2	pax6	fetal or embryo	mouse or mic	11003833	http://www.ncb	Spatial specification of	Schwarz M.,	Y	Y	N
19	Pax2	pax6	fetal or embryo	mouse or mic	10601036	http://www.ncb	Vax1, a novel homeobo	Hallonet M., H	Y	Y	Y
20	Pax2	pax6	fetal or embryo	mouse or mic	10051661	http://www.ncb	Ectopic bone morphog	Golden J., Br	Y	N	N
21	Pax2	pax6	fetal or embryo	mouse or mic	9831649	http://www.ncb	Zebrafish contains two	Nornes S., Cl	Y	Y	Y
22	Pax2	pax6	fetal or embryo	mouse or mic	9655820	http://www.ncb	Sonic hedgehog is not	Schauerte H.,	Y	N	N
23	Pax2	pax6	fetal or embryo	mouse or mic	9297966	http://www.ncb	Pax genes and organog	Dahl E., Kose	Y	Y	N
24	Pax2	pax6	fetal or embryo	mouse or mic	9126546	http://www.ncb	Roles of Pax-genes in	Stoykova A.,	Y	N	N
25	pax6	Ax1	fetal or embryo	mouse or mic	12142024	http://www.ncb	The homeobox gene m	Kawahara A.,	Y	Y	Y (Did not und
26	pax6	sox2	fetal or embryo	mouse or mic	17825048	http://www.ncb	PAX6 and SOX2-depe	Inoue M., Kan	Y		
27	pax6	sox2	fetal or embryo	mouse or mic	17470285	http://www.ncb	Rybp, a polycomb com	Pirity M., Wal	Y	YN	Y
28	pax6	sox2	fetal or embryo	mouse or mic	17066077	http://www.ncb	Six3 activation of Pax6	Liu W., Lagut	Y	Y	Y
29	pax6	sox2	fetal or embryo	mouse or mic	15926496	http://www.ncb	Understanding lens d	Uchikawa M.,	Y		
30	pax6	sox2	fetal or embryo	mouse or mic	15855760	http://www.ncb	The involvement of reg	Reza H., Yas	Y	Y	Y
31	pax6	sox2	fetal or embryo	mouse or mic	15652703	http://www.ncb	Requirement of mesod	Molotkova N.,	Y	N	N
32	pax6	sox2	fetal or embryo	mouse or mic	15558474	http://www.ncb	Interplay of Pax6 and S	Kondoh H., Li	Y	YN*	YN*
33	pax6	sox2	fetal or embryo	mouse or mic	12710953	http://www.ncb	Pax6 autoregulation ma	Aota S., Nake	Y	Y	Y
34	pax6	sox2	fetal or embryo	mouse or mic	12642482	http://www.ncb	Cell-autonomous involv	Yamada R., M	Y	N*	Y*
35	pax6	sox2	fetal or embryo	mouse or mic	11069887	http://www.ncb	Pax6 actively in the lens	Ashery-Padan	Y	N*	N
36	pax6	sox2	fetal or embryo	mouse or mic	9851982	http://www.ncb	BMP4 is essential for l	Furuta Y., Hog	Y	Y*	Y*
37	pax6	sox2	fetal or embryo	mouse or mic	9409835	http://www.ncb	Involvement of Sox1, 2	Kamachi Y., Ui	Y	Y	N
38	pax6	six3	fetal or embryo	mouse or mic	17470285	http://www.ncb	Rybp, a polycomb com	Pirity M., Wal	Y	YN (develop	Y
39	pax6	six3	fetal or embryo	mouse or mic	17066077	http://www.ncb	Six3 activation of Pax6	Liu W., Lagut	Y	Y	Y
40	pax6	six3	fetal or embryo	mouse or mic	16765103	http://www.ncb	Identification of genes	Lord-Grignon	Y	Y*	Y*
41	pax6	six3	fetal or embryo	mouse or mic	15569927	http://www.ncb	Tyrosine phosphorylati	Goloh N., Ito	Y		
42	pax6	six3	fetal or embryo	mouse or mic	15366004	http://www.ncb	Rax/hx2 expression in m	Mic F., Molotk	Y		
43	pax6	six3	fetal or embryo	mouse or mic	12642482	http://www.ncb	Cell-autonomous involv	Yamada R., M	Y	N	N
44	pax6	six3	fetal or embryo	mouse or mic	11956759	http://www.ncb	Aniridia, an X-linked inse	Cunningham	Y	N	N
45	pax6	six3	fetal or embryo	mouse or mic	11458394	http://www.ncb	Six3 promotes the forn	Lagutin O., Zh	Y	Y	N
46	pax6	six3	fetal or embryo	mouse or mic	10502109	http://www.ncb	Mouse Dach, a homolo	Davis R., She	Y	Y*	YN*
47	pax6	six3	fetal or embryo	mouse or mic	10090721	http://www.ncb	Six3 overexpression in	Loosli F., Win	Y	Y	Y
48	pax6	six3	fetal or embryo	mouse or mic	9651515	http://www.ncb	Six3, a medaka homolo	Loosli F., Kös	Y	Y	Y
49	sox2	foxe3	fetal or embryo	mouse or mic	12642482	http://www.ncb	Cell-autonomous involv	Yamada R., M	Y	N	N
50	vax1	chx10	fetal or embryo	mouse or mic	17470285	http://www.ncb	Rybp, a polycomb com	Pirity M., Wal	Y	YN (develop	Y
51	chx10	lhx2	fetal or embryo	mouse or mic	15385160	http://www.ncb	Requirement for Mab2	Yamada R., M	Y	N	N
52	chx10	mif	fetal or embryo	mouse or mic	16420617	http://www.ncb	Loss of retinal-progenit	Coles B., Hor	Y	N	N
53	chx10	mif	fetal or embryo	mouse or mic	15459106	http://www.ncb	Transdifferentiation of	Rowan S., Chi	Y	N	N
54	chx10	mif	fetal or embryo	mouse or mic	11023863	http://www.ncb	Extraocular mesenchy	Fuhrmann S.,	Y	Y	Y
55	chx10	mif	fetal or embryo	mouse or mic	10903182	http://www.ncb	Signaling and transcrip	Nguyen M., A	Y	Y	Y
56	Pax6	Meis	fetal or embryo	mouse or mic	12183364	http://www.ncb	Meis homeoproteins d	Zhang X., Frie	Y	Y	Y

EXAMPLE: Pax6 network in eye development

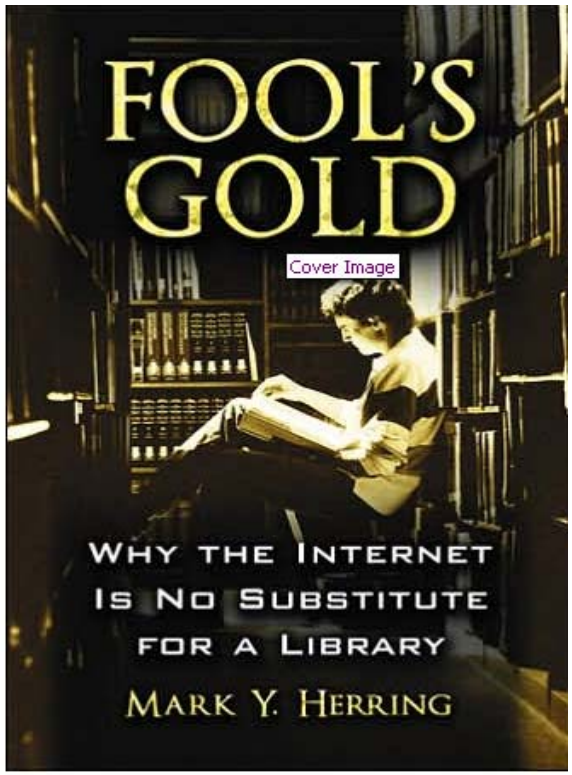


VIRTUAL WORLD: open discussion forum led by Avatars in the virtual-reality world of ‘Second Life’



Source: Figure 1, Murray-Rust (2008) Chemistry for everyone. Nature 451: 648-651

Internet extends but does not replace a traditional learning environment



Dacus Library, Winthrop University
Macfarland & Company (2007)
ISBN-13: 9780786430826

- Herring explores whether the internet will obviate need for traditional print-based academic libraries … *NOT!*
- pitfalls & prevarications of popular search engines and digitization of traditional print material
- argues for library's staying power in face of technological advancement