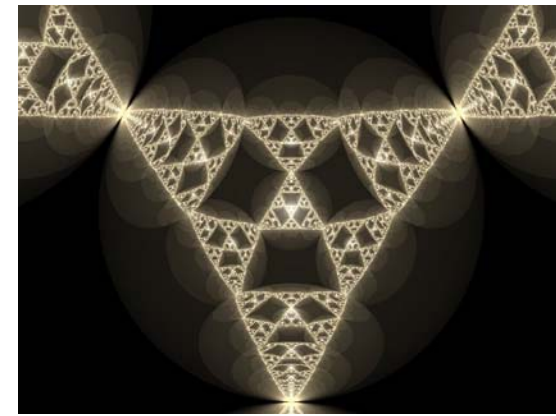


Using Web-based Tools for Teaching Embryology



Teratology Society, Monterey CA, July 1, 2008

Thomas B. Knudsen, PhD

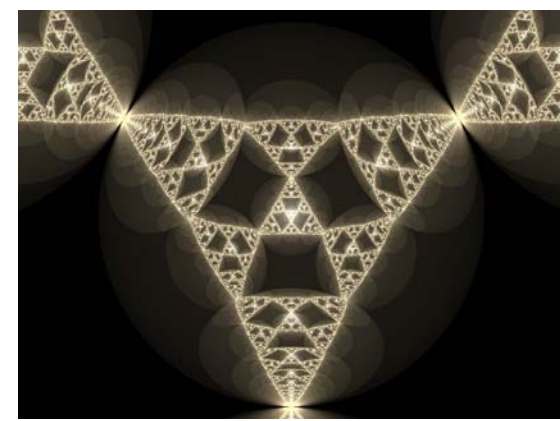
National Center for Computational Toxicology

US EPA, Research Triangle Park NC

Knudsen.Thomas@epa.gov

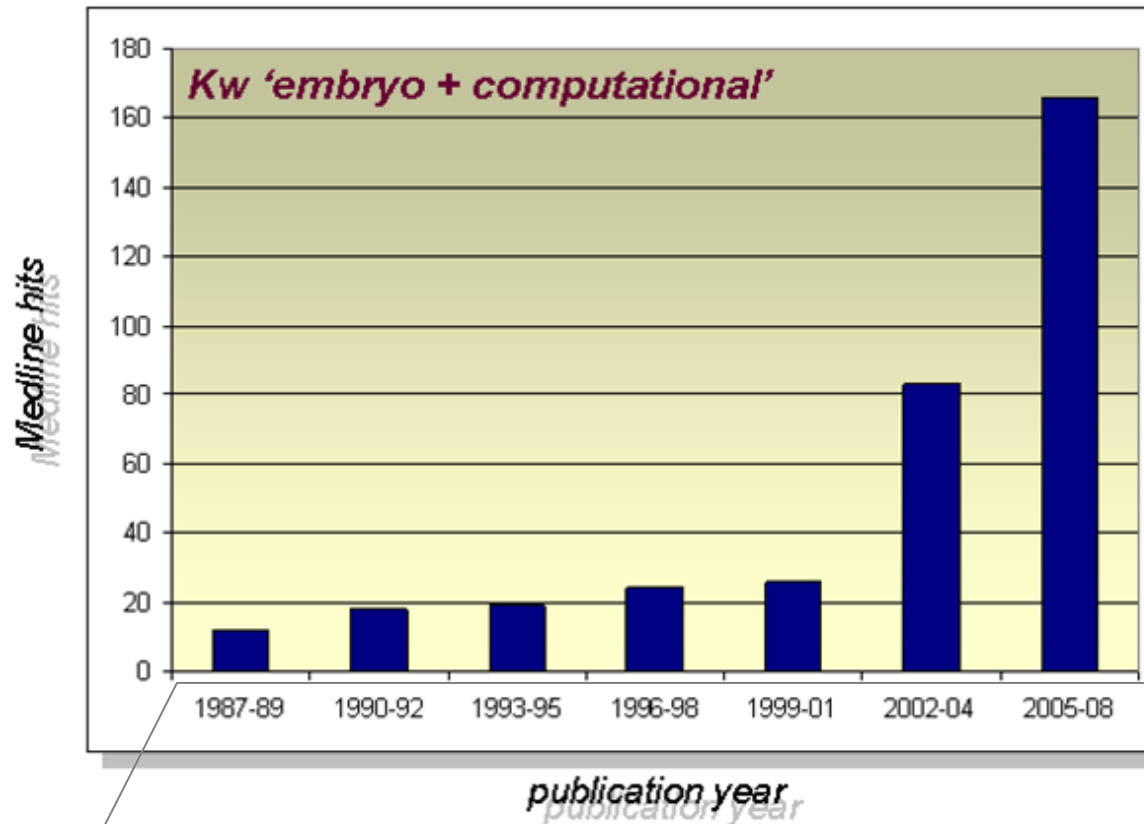
DISCLAIMER: views reflect those of the presenter and not EPA policy; any reference to commercial products or tradenames does not constitute endorsement

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

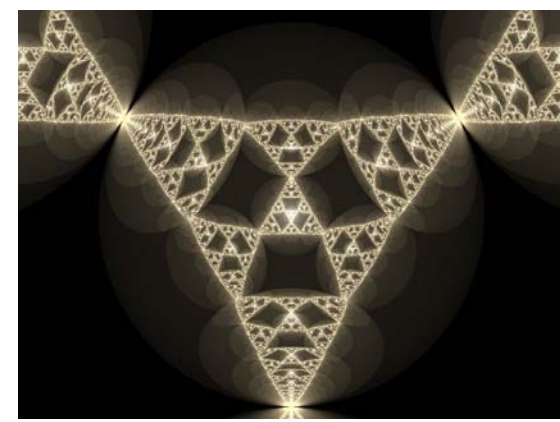
molecular
biology

genomics
bioinformatics

systems
biology

*virtual
biology*

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- ❖ 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

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Job Openings

Education

Interactive Fly

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Virtual Library

[Home](#)

[Site Map](#)

[Search](#)

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Virtual Library-Developmental Biology



This Virtual Library maintained by 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](#)

[Search Engines and Other](#)

[Resources](#)

[Departments and Institutes](#)

[Index](#)

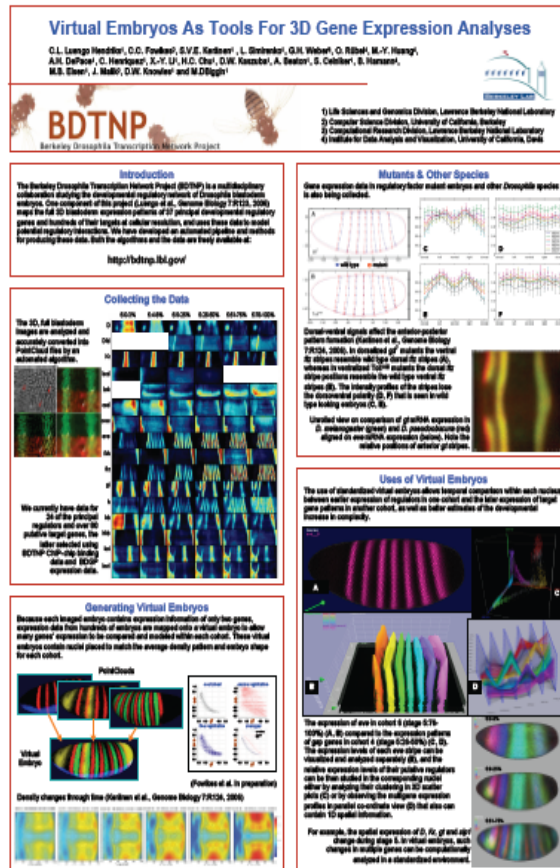
[Societies and Organizations](#)

[Index](#)



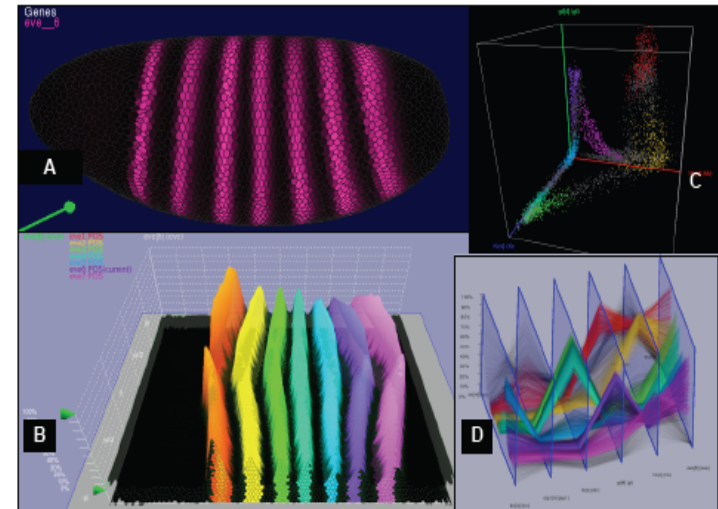
[Developmental Biology](#)
Published by Elsevier Science
under Auspices of Society for
Developmental Biology

- [Stephen Alexander's](#) laboratory at the University of Missouri uses *Dictyostelium 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 tumorigenesis.
- [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.



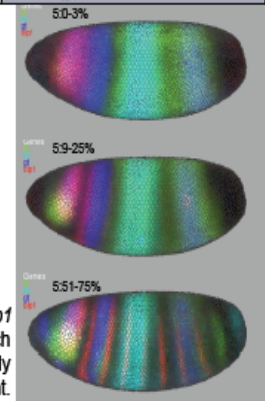
Uses of Virtual Embryos

The use of standardized virtual embryos allows temporal comparison within each nucleus between earlier expression of regulators in one cohort and the later expression of target gene patterns in another cohort, as well as better estimates of the developmental increase in complexity.




The expression of *eve* in cohort 6 (stage 5:76-100%) (A, B) compared to the expression patterns of gap genes in cohort 4 (stage 5:26-50%) (C, D). The expression levels of each *eve* stripe can be visualized and analyzed separately (B), and the relative expression levels of their putative regulators can be then studied in the corresponding nuclei either by analyzing their clustering in 3D scatter plots (C) or by observing the multigene expression profiles in parallel co-ordinate view (D) that also can contain 1D spatial information.

For example, the spatial expression of *D*, *Kr*, *gt* and *slp1* change during stage 5. In virtual embryos, such changes in multiple genes can be computationally analyzed in a standardized environment.



Virtual Library needed for teratology

– *relaunching of Society's website coming soon!*




THE
TERATOLOGY
SOCIETY

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Search

About TS | News & Info | Meetings | Membership | Publications | Resources | Student & Postdoc Corner | Career Center

Birth Defects Research ■ Education ■ Convention



- Home student
- About page
- News (owned by SAC)
- Meetings
- Jobs
- Links
- Student Affairs

Meetings


Submission for the 48th Annual Meeting, Monterey, California is available now.


Awards

The FASEB MARC Program provides funding for travel awards to support the participation of Faculty/ Mentors and Students, and Poster/Platform (Oral) Presenters at selected scientific meetings and conferences.

48th ANNUAL MEETING

JUNE 28-JULY 2, 2008





Members only

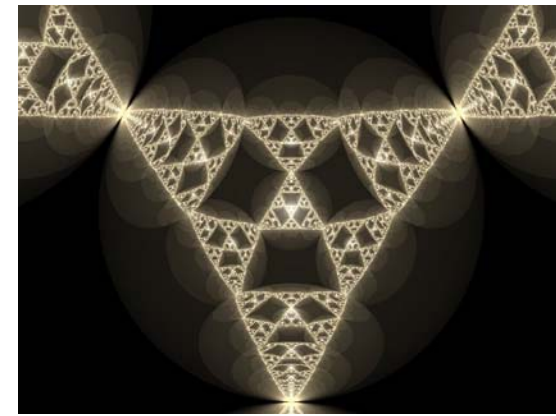
Fair Use Doctrine in education:

<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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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](#)

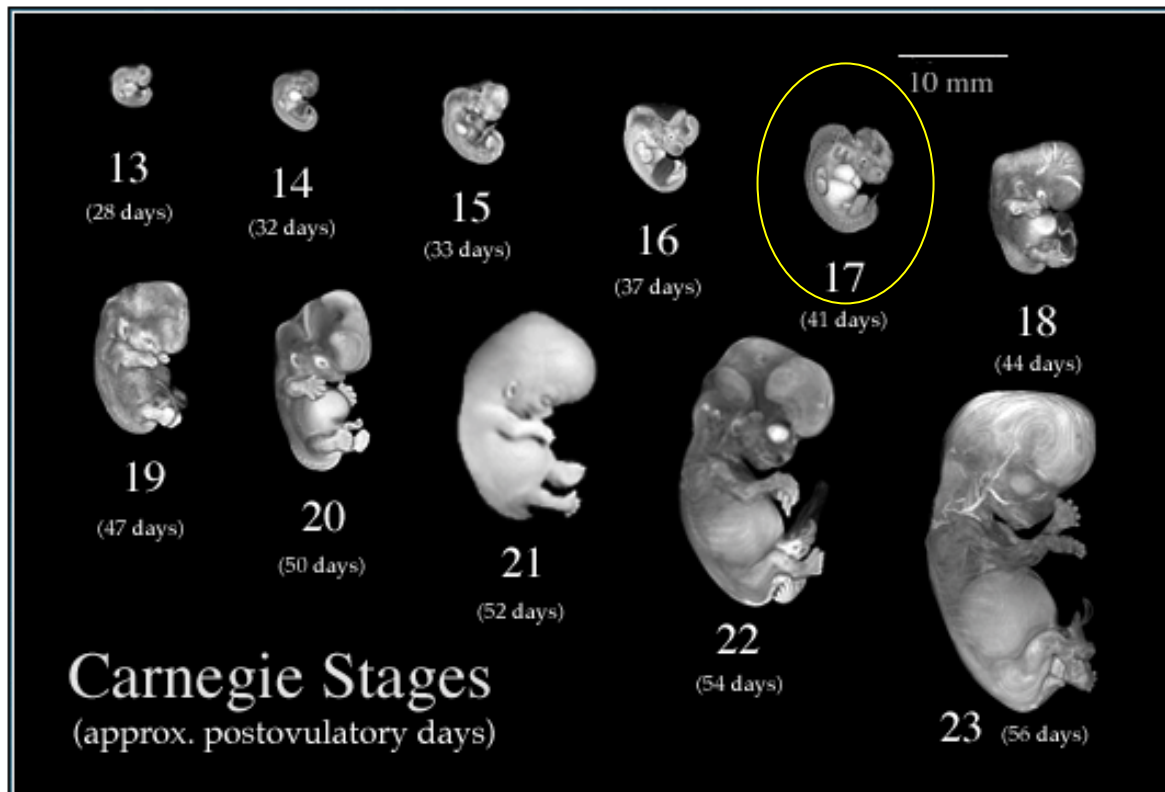
[Project](#)

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View Sample Images by Selecting an Embryo Below



Carnegie Stage 17 Samples

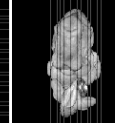
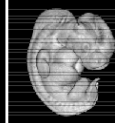
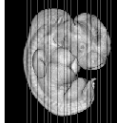
Carnegie Stage 17 Samples
at postovulatory days




About Carnegie Stage 17
Most embryos at stage 17 are approximately 41 postovulatory days old and measure 11-14 mm in length. Distinguishing criteria for this stage include distinct digital rays in the hand plate, a rounded digital plate in the foot, a complete complement of hillocks on the mandibular and hyoid arches, distinct nasofrontal grooves, and a slight indication of a lumbar curvature.

Notice:
This specimen does not represent normal development. The caudal neural tube has failed to close properly. Also, the MRI data suggest that this specimen was slightly dehydrated during imaging (evident in the medulla and hindbrain).


MRI Slice Selector




Sample Animations




Rotation Animation
(256 KB QuickTime file)




Neural Tube Rotation 1
(288 KB QuickTime file)




Neural Tube Rotation 2
(416 KB QuickTime file)




Heart Rotation
(256 KB QuickTime file)




Liver Rotation
(332 KB QuickTime file)



Stomach Rotation
(416 KB QuickTime file)






Eye Rotation
(256 KB QuickTime file)



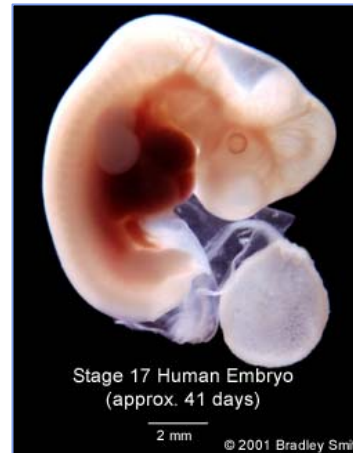
Pouch Tachyphasic
(600 KB QuickTime file)

Optical Images



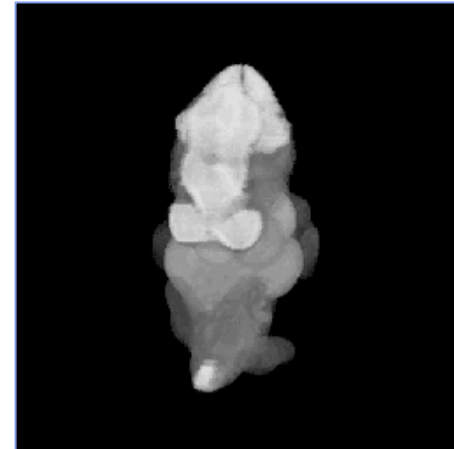
[Home](#) [About](#) [Project](#) [Technical](#) [Links](#) [Contact Info](#)

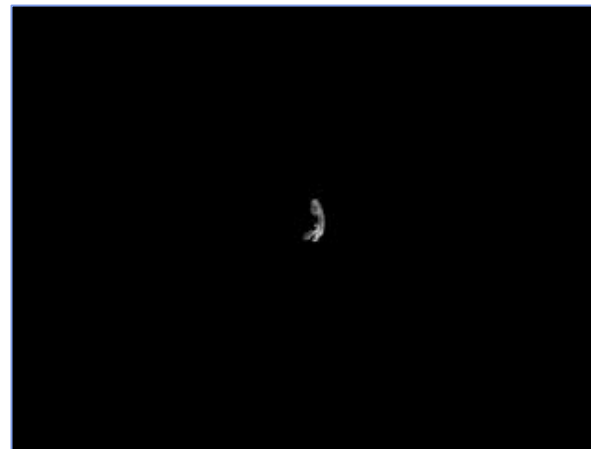
© 2003 Bradley L. Smith



Stage 17 Human Embryo
(approx. 41 days)

2 mm © 2001 Bradley Smith






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

Online textbooks

Clinical Human Embryology

Cases

- Hydatidiform Mole
- Sirenomelia
- Spina Bifida
- Syndactyly
- Hirschsprung's Disease
- Congenital Diaphragmatic Hernia
- Tracheoesophageal Fistula
- Patent Ductus Arteriosus
- Goldenhar Syndrome
- Cervical Fistula
- Bilateral Cleft Lip/Palate
- Congenital Hearing Loss
- Impaired Vision
- Bilious Vomiting
- Renal Agenesis
- Hydrometrocolpos



Subjects

- Fertilization / Implantation
- Gastrulation
- Somites and Neurulation
- Limb Formation
- Peripheral Nervous System
- Body Cavities
- Lung Development
- Heart Development
- Head and Neck Development
- Development of Oral Cavity
- Face / Palate Development
- Development of the Ear
- Development of the Eye
- Development of the Gut
- Kidney Development
- Genital Development

Kyle E. Rarey, PhD
Lynn J. Romrell, PhD

Timeline of Development (wks)

← 1 2 3 4 5 6 7 8 9 10 11 12 13 20 32 38 →

[Index](#) [Glossary](#) [Help](#) [Start](#)

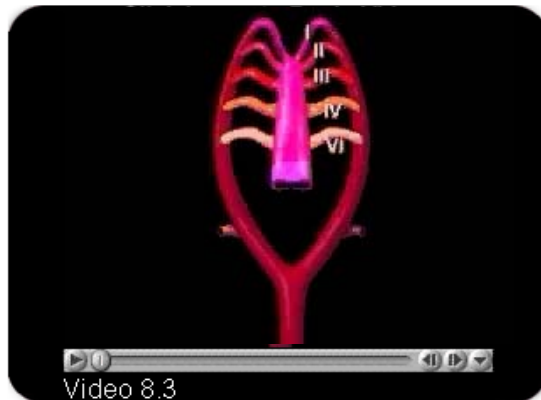
Release 1.0 © 2001 [Kyle E. Rarey, PhD](#) and [Lynn J. Romrell, PhD](#)

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

Chapter 8: Heart Development, discussion of aortic arches

[Home](#)[Index](#)[Glossary](#)[Help](#)[Chapter](#)[Page](#)

Chapter 8: Patent Ductus Arteriosus - Heart Development

[Clinical Presentation](#) [Objectives](#) [Discussion](#) [Clinical Significance](#) [Quiz](#) [References](#)

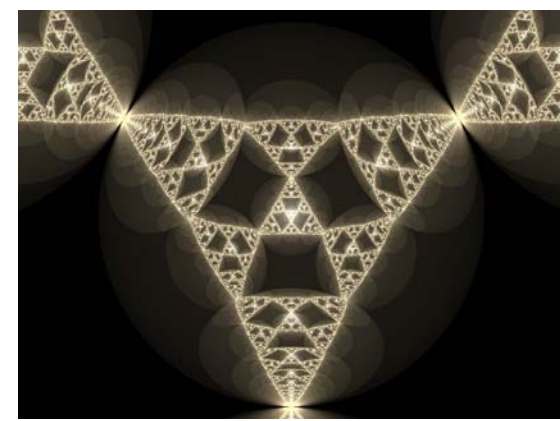
Arterial Outflow Tract

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 arteriosus 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

WWW: EDUCATIONAL USES FOR TERATOLOGISTS

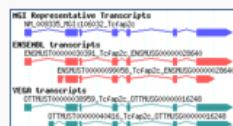


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Explore MGI

All Search Tools

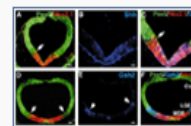
Genes



Phenotypes



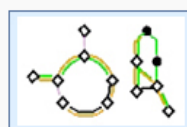
Expression



Function



Pathways



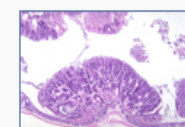
Strains / SNPs

Variation Type	DBV/J	FVB/NJ	129/SvEv	Allele Summary (all strains)
SNP	G	G	A	A/G
SNP	C	C	T	C/T

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](#).



Tour the new MGI website

[About](#) [Help](#) [FAQ](#)

[Home](#) [Genes](#) [Phenotypes](#) [Experiments](#)

[Search](#) [Download](#) [More Resources](#) [Submit Data](#) [Find Mice \(IMSR\)](#) [Contact Us](#)



MP term: **abnormal eye development**
 Synonym: **eye development abnormalities**
 MP id: **MP:0001286**
 Definition: **malformation or arrest of differentiation of the visual system**
 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 periorbital 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 +](#)

Mammalian Phenotype Browser

[Tour the new MGI website](#)

[About](#) [Help](#) [FAQ](#)

[Home](#) [Genes](#) [Phenotypes](#) [Expression](#) [Function](#) [Pathways](#) [Strains / SNPs](#) [Orthology](#) [Tumors](#)

[Search](#) [Download](#) [More Resources](#) [Submit Data](#) [Find Mice \(IMSR\)](#) [Contact Us](#)

[Quick Search](#)

Gene Expression Database (GXD)

GXD collects and integrates the gene expression information in MGI. Its primary emphasis is on endogenous gene expression during mouse development.

Access Data

Search for references on gene expression during development.

[Gene Expression Literature Query](#)

Search for detailed gene expression assay results.

[Gene Expression Data Query](#)

Search for genes expressed in some anatomical structures and/or developmental stages but not in others.

[Gene Expression Data Expanded Query](#)

Search or browse for anatomical structures; includes links to associated expression results.

[Mouse Anatomical Dictionary Browser](#)

Search the Edinburgh Mouse Atlas for anatomical terms and query for associated expression data.

[EMAGE Section Browser](#)

Search for expression information based on tissue or cell-line origin of cDNAs.

[cDNA Clone Query](#)

FAQs

How do I...

- ... find expression data for a specific gene and tissue? [FAQ](#)
- ... find expression data for a tissue during development? [FAQ](#)
- ... find genes expressed in one tissue but not another? [FAQ](#)
- ... find references that report expression data for a gene at a specific age? [FAQ](#)

[More FAQs](#)

GXD Includes 11 Jun 2008

- 10,070 Genes studied in expression references
- 7,743 Genes with expression assay results
- 369,165 Expression assay results
- 60,047 Expression images
- 29,892 Expression assays
- 1,190 Mouse mutants with expression data

[More...](#)

Gene Expression News 22 May 2008

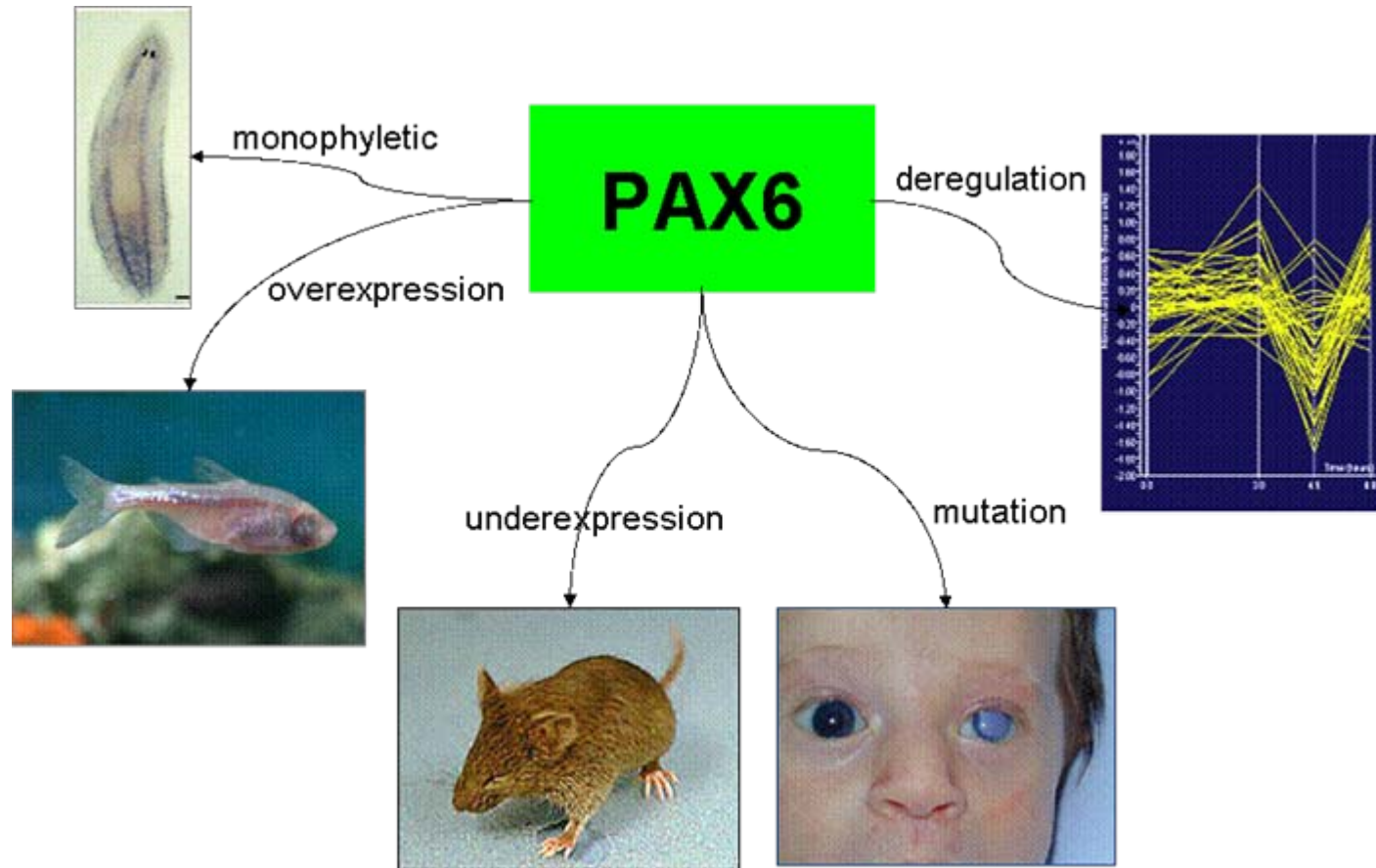
- The layout of the Expression section of gene detail pages has been improved, and links to gene pages at the Allen Brain Atlas, a database of gene expression patterns in the adult mouse brain, have been added.
- Gene Expression Data summaries have been revised to make accessing the detailed expression data more intuitive. The links to the detailed data are now in the first column of the page and have been re-labeled data. Additionally, a camera icon has been added to indicate when images of the primary data are available by following the data link.

4 genotypes with 4 annotations displayed

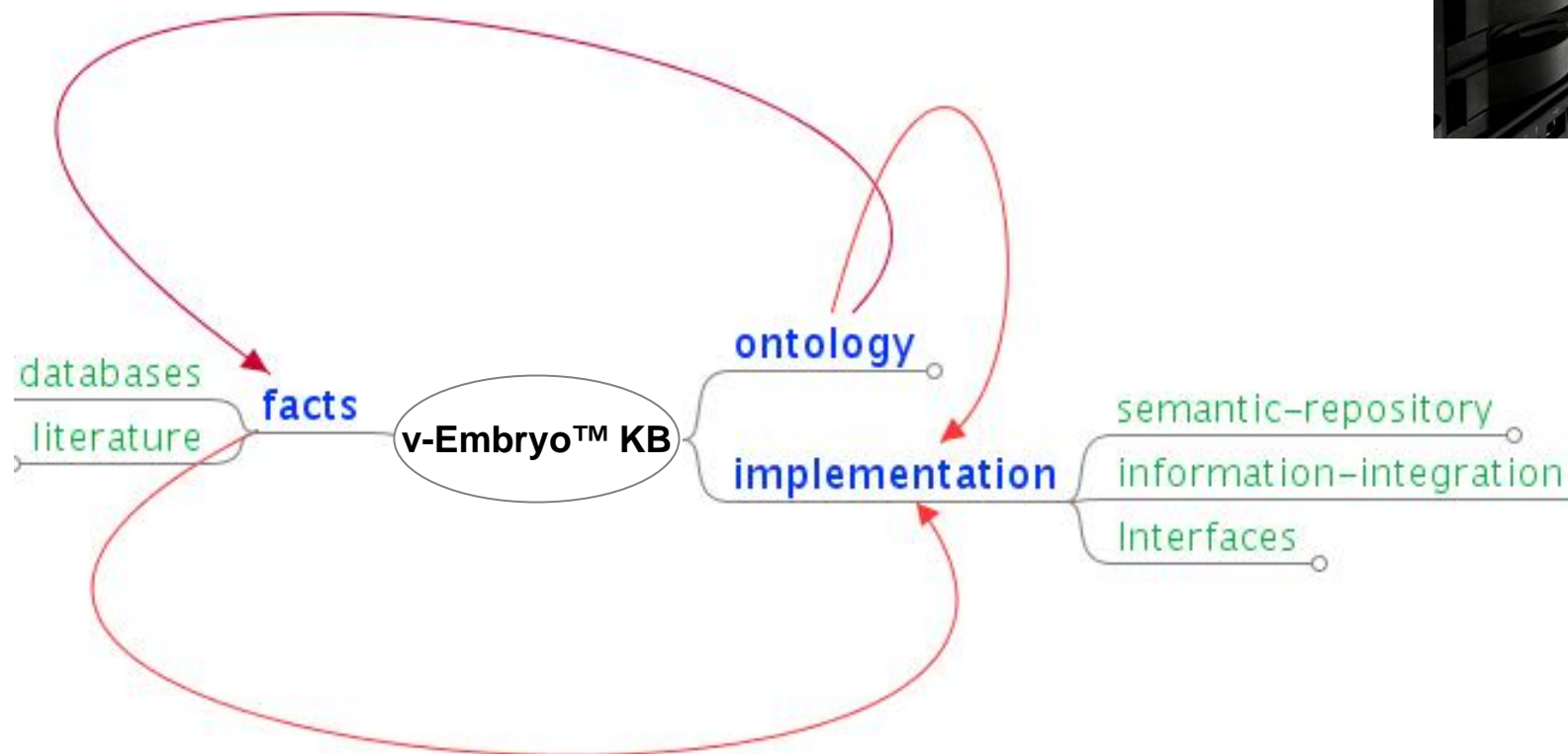
Searched Term: [aniridia](#)

Allelic Composition (Genetic Background)	Annotated Term	
Mab21l1^{tm1Nao}/Mab21l1^{tm1Nao} (involves: C57BL/6)	aniridia	1:82312
Pax6^{Sey-Dey}/Pax6⁺ (C3H/HeJ-Pax6 ^{Sey-Dey})	aniridia	1:10820
Pax6^{tm1Gfs}/Pax6^{tm1Gfs} (involves: 129S7/SvEvBrd)	aniridia	1:76576
Tcfap2a^{tm1Will}/Tcfap2a^{tm1Will} (involves: Black Swiss)	aniridia	1:52402

Pax6 roles in eye development from analysis of the scientific literature



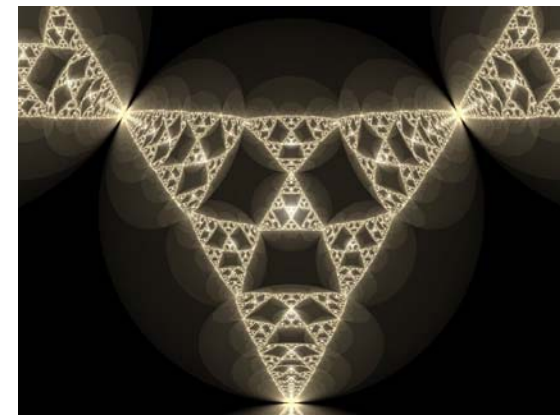
v-Embryo™ Knowledgebase: normal and abnormal embryogenesis



Source: Imran Shah, NCCT – EPA

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

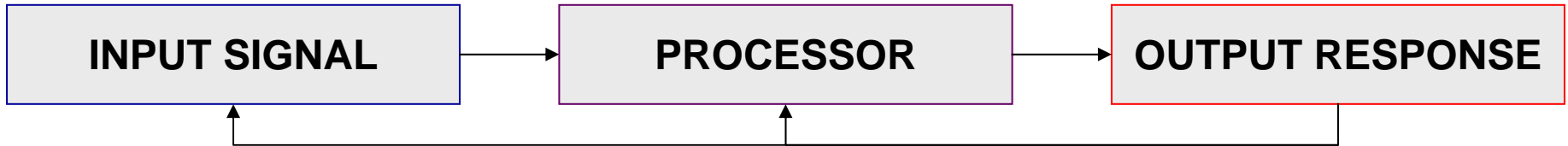
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Developmental signaling pathways:

integrating these data at a systems level



Developmental Signals

Wnt, TGF β , 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

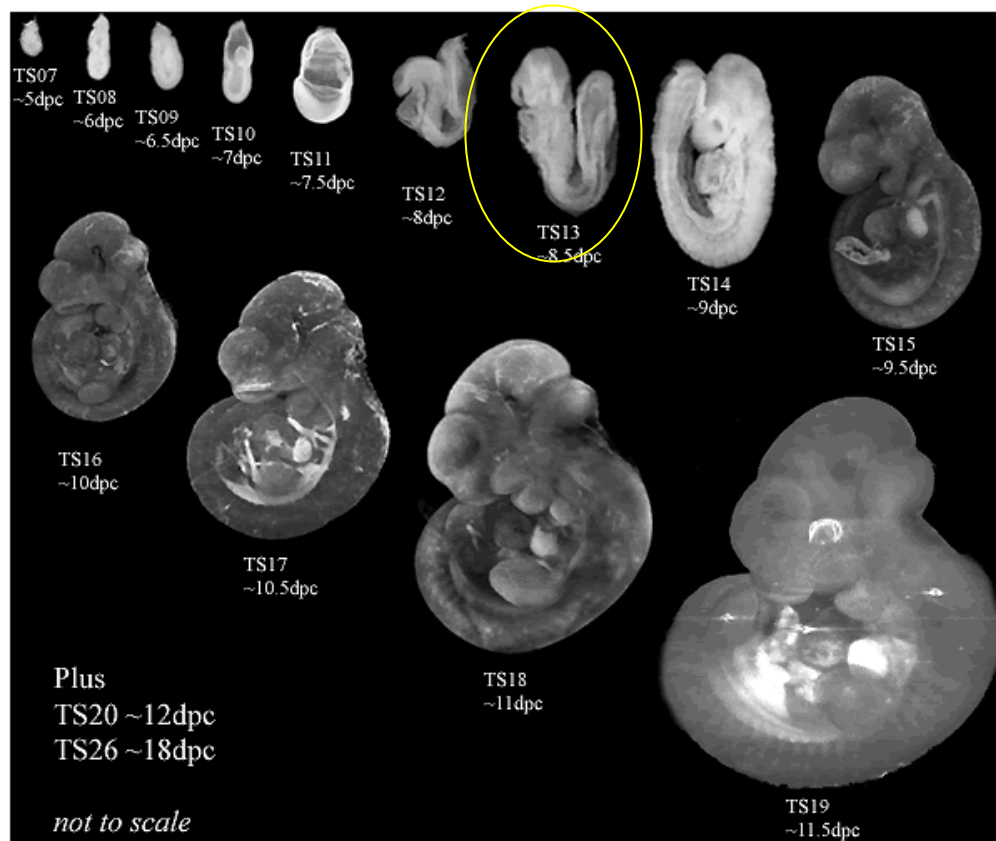
patterning
proliferation
apoptosis
differentiation
adhesion
motility
shape
ECM remodeling

Edinburgh Mouse Atlas Project

emap

3D digital atlas | theiler stage selector

HOME 3D DIGITAL ATLAS IMAGE 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

emap <http://genex.hgu.mrc.ac.uk/> 3D digital atlas | TS14

HOME 3D DIGITAL ATLAS EMAGE DATABASE RESOURCES CONTACT SITE SEARCH

☐ 3D Navigation ☒ Navigation Window ☒ Section Window ☒ Anatomy Window Theiler Stage: TS14

No component selected



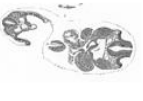
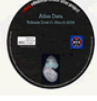
TS14

- embryo
 - branchial arch
 - cavities and their linings
 - ectoderm
 - limb
 - mesenchyme
 - notochord*
 - organ system
 - cardiovascular system
 - nervous system
 - sensory organ
 - ear
 - eye
 - nose
 - visceral organ
 - primitive streak
 - tail bud
 - extraembryonic component*

< Contract Expand >

More Theiler 14 (E9) resources:

[Information on this model](#) [Help with the Browsers](#) [FAQ](#)

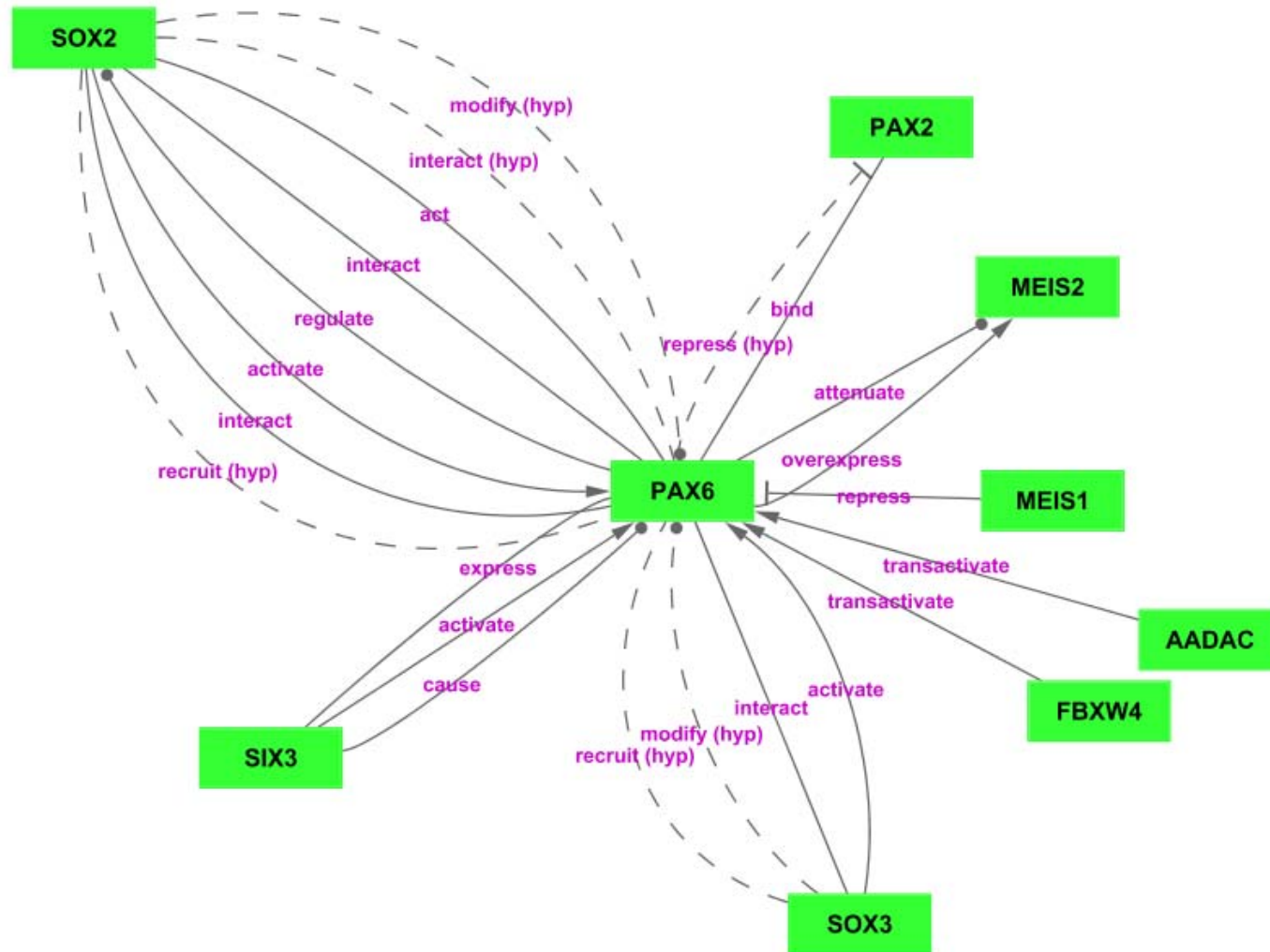
Stage Definition	Section Movies:	Embryo View:	High-resolution Section Images:	Anatomy Nomenclature Database	CD-ROM
	Transverse ~Frontal ~Sagittal	 More		Java Browser Plain Text XML	

Web page contact: genexweb@hgu.mrc.ac.uk Last modified: 01/03/2004

63 genes (TS12-18)
captures 2164 PMIDs

No.	Gene 1	Gene 2	Search 1	Search 2	PMID	Web link	Title	Authors	Read	Relevant	How Informative
1	cyc	shh	total or embryo	mouse or mic	1274302	http://www.ncbi.nlm.nih.gov/pubmed/1274302	A temperature-sensitive	Taga J, Yanu	Y	Y	N
2	cyc	shh	total or embryo	mouse or mic	1002887	http://www.ncbi.nlm.nih.gov/pubmed/1002887	Chen et al. et al. et al.	Chen J, Yanu	Y	Y	N
3	cyc	shh	total or embryo	mouse or mic	1004427	http://www.ncbi.nlm.nih.gov/pubmed/1004427	Two distinct cell populations	Chen J, Yanu	Y	N	N
4	cyc	shh	total or embryo	mouse or mic	894041	http://www.ncbi.nlm.nih.gov/pubmed/894041	Expression of cell and	Chen J, Yanu	Y	N	N
5	cyc	shh	total or embryo	mouse or mic	8074416	http://www.ncbi.nlm.nih.gov/pubmed/8074416	Complex expression of	Chen J, Yanu	Y	N	N
6	shh	shh	total or embryo	mouse or mic	1773484	http://www.ncbi.nlm.nih.gov/pubmed/1773484	Shh in the MDH10	Chen J, Yanu	Y	N	N
7	shh	shh	total or embryo	mouse or mic	10001036	http://www.ncbi.nlm.nih.gov/pubmed/10001036	Vasf1, a novel homeo-	Chen J, Yanu	Y	Y	N
8	shh	shh	total or embryo	mouse or mic	865080	http://www.ncbi.nlm.nih.gov/pubmed/865080	Sonic hedgehog is not	Schauer H, Yanu	Y	N	N
9	shh	shh	total or embryo	mouse or mic	15100370	http://www.ncbi.nlm.nih.gov/pubmed/15100370	Shh regulates the exte	Chen J, Yanu	Y	N	N
10	shh	shh	total or embryo	mouse or mic	17470265	http://www.ncbi.nlm.nih.gov/pubmed/17470265	Shh is a secreted	Chen J, Yanu	Y	N	N
11	shh	shh	total or embryo	mouse or mic	17169116	http://www.ncbi.nlm.nih.gov/pubmed/17169116	Shh is a secreted	Chen J, Yanu	Y	N	N
12	shh	shh	total or embryo	mouse or mic	18034303	http://www.ncbi.nlm.nih.gov/pubmed/18034303	A role for GHRH in ear	Wu S, Yanu	Y	Y	N
13	shh	shh	total or embryo	mouse or mic	14711874	http://www.ncbi.nlm.nih.gov/pubmed/14711874	Shh has essential	Chen J, Yanu	Y	Y	N
14	shh	shh	total or embryo	mouse or mic	12970747	http://www.ncbi.nlm.nih.gov/pubmed/12970747	Shh in the MDH10	Chen J, Yanu	Y	N	N
15	shh	shh	total or embryo	mouse or mic	12758174	http://www.ncbi.nlm.nih.gov/pubmed/12758174	Shh in the MDH10	Chen J, Yanu	Y	N	N
16	shh	shh	total or embryo	mouse or mic	18047810	http://www.ncbi.nlm.nih.gov/pubmed/18047810	Shh is a secreted	Chen J, Yanu	Y	N	N
17	shh	shh	total or embryo	mouse or mic	11458394	http://www.ncbi.nlm.nih.gov/pubmed/11458394	Shh promotes the for	Chen J, Yanu	Y	Y	N
18	shh	shh	total or embryo	mouse or mic	10001036	http://www.ncbi.nlm.nih.gov/pubmed/10001036	Vasf1, a novel homeo-	Chen J, Yanu	Y	Y	N
19	shh	shh	total or embryo	mouse or mic	10051661	http://www.ncbi.nlm.nih.gov/pubmed/10051661	Ectopic bone morpho-	Chen J, Yanu	Y	N	N
20	shh	shh	total or embryo	mouse or mic	8831640	http://www.ncbi.nlm.nih.gov/pubmed/8831640	Zebrafish contains two	Chen J, Yanu	Y	Y	N
21	shh	shh	total or embryo	mouse or mic	865080	http://www.ncbi.nlm.nih.gov/pubmed/865080	Sonic hedgehog is not	Chen J, Yanu	Y	N	N
22	shh	shh	total or embryo	mouse or mic	1257965	http://www.ncbi.nlm.nih.gov/pubmed/1257965	Shh in the MDH10	Chen J, Yanu	Y	N	N
23	shh	shh	total or embryo	mouse or mic	1254482	http://www.ncbi.nlm.nih.gov/pubmed/1254482	Shh in the MDH10	Chen J, Yanu	Y	N	N
24	shh	shh	total or embryo	mouse or mic	12143024	http://www.ncbi.nlm.nih.gov/pubmed/12143024	The homeobox gene	Chen J, Yanu	Y	Y	N
25	shh	shh	total or embryo	mouse or mic	17629448	http://www.ncbi.nlm.nih.gov/pubmed/17629448	Shh in the MDH10	Chen J, Yanu	Y	N	N
26	shh	shh	total or embryo	mouse or mic	17470265	http://www.ncbi.nlm.nih.gov/pubmed/17470265	Shh is a secreted	Chen J, Yanu	Y	N	N
27	shh	shh	total or embryo	mouse or mic	17060777	http://www.ncbi.nlm.nih.gov/pubmed/17060777	Shh activation of Pa	Chen J, Yanu	Y	Y	N
28	shh	shh	total or embryo	mouse or mic	18026466	http://www.ncbi.nlm.nih.gov/pubmed/18026466	Undertanding the	Chen J, Yanu	Y	Y	N
29	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
30	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
31	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
32	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
33	shh	shh	total or embryo	mouse or mic	12710953	http://www.ncbi.nlm.nih.gov/pubmed/12710953	Shh in the MDH10	Chen J, Yanu	Y	Y	N
34	shh	shh	total or embryo	mouse or mic	1254482	http://www.ncbi.nlm.nih.gov/pubmed/1254482	Shh in the MDH10	Chen J, Yanu	Y	N	N
35	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
36	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
37	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
38	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
39	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
40	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
41	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
42	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
43	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
44	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
45	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
46	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
47	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
48	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
49	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
50	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
51	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
52	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
53	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
54	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
55	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N
56	shh	shh	total or embryo	mouse or mic	10052601	http://www.ncbi.nlm.nih.gov/pubmed/10052601	The involvement of	Chen J, Yanu	Y	N	N

EXAMPLE: Pax6 network in eye development

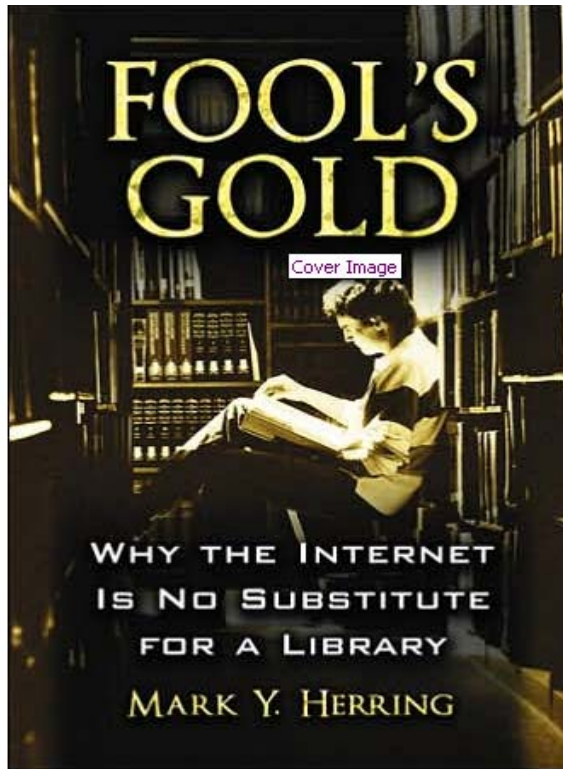


VIRTUAL WORLD: open discussion forum led by Avatars in the virtual-reality world of 'Second Life'



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