Biology Data Book

Second Edition

VOLUME I

COMPILED AND EDITED BY

Philip L. Altman and Dorothy S. Dittmer

Federation of American Societies for Experimental Biology

BETHESDA, MARYLAND

Embryos were raised at constant temperature in circulating water, from three hours after fertilization. **Age** = time from fertilization, according to Ballard [7]; within a given batch under uniform conditions, variation is insignificant; ranges are for batches of eggs from various breeding colonies. **Size** = average measurements of *Salmo gairdneri:* blastodisk diameter for stages 6-10, length of body axis for stages 14-23. *S. salar* tends to run ∿10% larger, *Salvelinus fontinalis* ∿10% smaller. For additional information on salmonids, consult references 10,14,15,17,20,21,26,29, and 39. For stages of development of other bony fishes, consult the following references: *Acipenser,* [16]; *Brachydanio,* [19]; *Carassius,* [9]; *Fundulus,* [3,27,34]; *Gadus,* [11,33]; *Gasterosteus,* [35]; *Gobius,* [6]; *Ictalurus,* [2]; *Oryzias,* [13,32]; *Perca,* [12,25]; *Polyodon,* [8]; *Serranus,* [38]; *Symbranchus,* [37]; and *Xiphophorus,* [36].

	Stage	Age: *Salmo gairdneri* at 7°C	Age: *S. gairdneri* & *S. salar* at 10°C	Age: *Salvelinus fontinalis* at 10°C	Size mm	Identification of Stage
		Cleavage, Blastodisk, & Preparation for Epiboly [22-24]				
1	1	.....	.....	.....	.....	Activation: elevation of zona radiata (chorion); gathering of 1st blastomere (bipolar differentiation)
2	2	12-20 hr	9-10 hr	8-10 hr	.....	2 cells
3	3	.....	16 hr	10-12 hr	.....	4 cells
4	4	36 hr	24 hr	18-20 hr	.....	8 cells
5	5	50 hr	24-36 hr	24 hr	.....	16-32 cells
6	6	3-4 da	2-3.5 da	24-48 hr	1.5	Mulberry blastodisk: cobbled surface; random internal movement of blastomeres; appearance of periblast
7	7	7-8 da	3.5-5.5 da	2-6 da	2-3	Blastodisk flattening; earliest spread; 1st internal convergence of a few axis cells
		Major Morphogenetic Movements: Epiboly & Convergence 1/ [4,5,22,24,28]				
8	8	9-10 da	4.5-6.5 da	4-8 da	2.5-3.5	Appearance of embryonic shield, germ ring, & a subgerminal cavity (variable cavities become confluent in *Salvelinus fontinalis)*
9	9	11 da	7-7.5 da	9-10 da	3.5	Germ ring 2/3 of the way from animal pole to yolk equator; neural groove on shield
10	10	12 da	7-8.5 da	11 da	.....	Germ ring at yolk equator; formation of axial strand & neural keel, 1st 10 pairs of somites, & Kupffer's vesicle; later endoderm becoming an epithelial sheet & notochord separating from neural plate
11	11	13 da	7-9 da	12 da	.....	Germ ring ½ of the way from yolk equator to vegetal pole; 10-20 pairs of somites; appearance of brain vesicles & optic masses
12	12	14 da	9-10 da	.....	.....	Germ ring narrowing toward vegetal pole; yolk plug ⩾ head width; 15-25 pairs of somites; nasal & lens placodes; optic masses becoming hollow vesicles; anteriorly, segregation of primitive kidney ducts from somites & lateral plates
13	13	15-17 da	10-11 da	13-13.5 da	.....	Yolk plug usually closed; >25 pairs of somites; trunk-tail mound not raised; optic cups; pharyngeal pouches reach ectoderm

1/ Contrary to most accounts, there is no invagination from the surface, and the germ ring is not a blastopore [4,5].

continued

Part VII. Salmonid Fishes

Stage		Age			Size mm	Identification of Stage
		Salmo gairdneri at 7°C	*S. gairdneri* & *S. salar* at 10°C	*Salvelinus fontinalis* at 10°C		
	Organogenesis [1,18,22,24,30,31]					
14	14	16-18 da	10.5-12 da	14-15 da	2.3-3	Trunk-tail mound raised, but not undercut; brain ventricles starting to inflate; heart tube forming; otic placodes becoming vesicles; pronephric swellings
15	15	21 da	11-15 da	16 da	3.5-4.5	Trunk-tail bud undercut, but shorter than brain; 1st heartbeat & trunk movement; gut cavity beginning to appear; 3 pairs of branchial segments detectable; mats of pectoral mesenchyme first visible; lateral line sprouts passing pectoral level; disappearance of Kupffer's vesicle
16	16	.....	13-16 da	.....	.....	Free trunk-tail as long as whole brain; cloacal region free from yolk sac; precloacal somites (38 pairs) complete, plus 10 pairs of postcloacal somites; head not undercut; spontaneous C-coil of trunk; pectoral mounds; gut tube completed; evagination of liver; first indication of tail fin; blood corpuscles loosening in the intermediate cell mass
17	17	.....	15-16 da	19 da	.....	Slight ridges on pectoral mounds; free trunk-tail shorter than axis attached to yolk sac, but longer than brain & pectoral spinal cord; up to 20 pairs of caudal somites; heart bent to left side; blood flowing through 1st aortic arch & over dorsal yolk sac; separate right & left stomodeal plates; hypophysis forming; patent cloaca
18	18	.....	16-18 da	.....	6	Pectoral ridges expanding to disk-like rims; free trunk-tail as long as attached part of body; head undercut to eye level; 4 pairs of branchial segments visible; up to 30 pairs of caudal somites; tail straightening; 1st eye pigment; epiphysis
19	19	.....	17-22 da	25 da	6.7	Pectoral fins now vertical disks, nearly circular, larger in diameter than ears, but smaller than eyes; head undercut to upper jaw level; stomodeal plates joined, but mouth not open; otolith granules in otic vesicles; tail tip still unsegmented
20	20	.....	17-22 da	28 da	7	Eye pigment, vitelline veins, & heartbeat first visible through eggshell; pectoral fin diameter equal to that of eye; mouth open; operculum rims encroaching on hyobranchial clefts; blood flowing in 3-4 branchial aortic arches & liver sinusoids; segmentation completed to tail tip; cerebral hemispheres forming; anal & urinary apertures separate; 1st trunk pigment in *Salvelinus,* but not in *Salmo*
21	21	.....	22-25 da	37 da	8	Inside eggshell, tail not quite reaching around to head; operculum beginning to overhang 1st gill segment; 1st gill slits open; liver mass smaller than eye, visible in dorsal view; 1st head & trunk pigment in *Salmo;* in Stage 21A, mesenchyme concentrations appearing first in caudal & anal fins; no pectoral fin movement or yellow bile; in Stage 21B, pectoral fins twitching, bile in gut, & mesoderm condensing in dorsal fin
22	22	.....	25-27 da	42 da	10	Inside eggshell, tail tip reaching around to midbrain; swimming movements; pectoral fins waving rhythmically; operculum extending past 1st gill segment; yolk mass changing from spherical to oval; head free back to pericardium; mesenchyme concentrations in pelvic fins; in Stage 22B, all gill slits open, liver mass larger than eye, pelvic fins becoming ridges, jaws becoming motile, & all gill segments covered by operculum; fin rays developing in caudal fin (heterocercal stage)

continued

28. CHARACTERIZATION OF DEVELOPMENTAL STAGES

Part VII. Salmonid Fishes

Stage		Age			Size mm	Identification of Stage
		Salmo gairdneri at 7°C	*S. gairdneri* & *S. salar* at 10°C	*Salvelinus fontinalis* at 10°C		
23	23	.....	33 da+	53 da	16	Inside eggshell, tail tip reaching nearly to cerebellum; rhythmic breathing movements; beginning of hatching; pelvic fins growing down as lobes; yolk mass elongating & shrinking; fin rays developing in anal & dorsal fins; gill filaments; cartilaginous neural arches; gas bladder; Mauthner's cells in metencephalon

Contributor: Ballard, William W.

References

[1] Agassiz, L., and C. Vogt. 1845. Mem. Soc. Sci. Natur. Neuchatel 3.
[2] Armstrong, P. B. 1962. Stages in the Development of *Ictalurus nebulosus.* Syracuse Univ. Press, N.Y.
[3] Armstrong, P. B., and J. S. Child. 1965. Biol. Bull. 128:143.
[4] Ballard, W. W. 1966. J. Exp. Zool. 161:193,201,211.
[5] Ballard, W. W. 1968. Ibid. 168:67,257.
[6] Ballard, W. W. 1969. Pubbl. Sta. Zool. Napoli 37:1.
[7] Ballard, W. W. Unpublished. Dartmouth College, Dep. Biological Sciences, Hanover, N.H., 1971.
[8] Ballard, W. W., and R. G. Needham. 1964. J. Morphol. 114:465.
[9] Battle, H. I. 1940. Ohio J. Sci. 40:82.
[10] Battle, H. I. 1944. Can. J. Res. D22:105.
[11] Bonnet, D. D. 1939. Biol. Bull. 76:428.
[12] Chevey, P. 1925. Bull. Biol. Fr. Belg. 59:147.
[13] Gamo, H., and I. Terajima. 1963. Gyoruigaku Zasshi 10:31.
[14] Garside, E. T. 1959. Can. J. Zool. 37:689.
[15] Garside, E. T. 1966. J. Fish. Res. Bd. Can. 23:1121.
[16] Ginsberg, A. S., and T. A. Detlaff. 1969. Development of Sturgeons. Nauka, Moscow.
[17] Hayes, F. R., et al. 1953. Can. J. Zool. 31:42.
[18] Henneguy, F. 1888. J. Anat. Physiol. 24:413.
[19] Hisaoka, K. K., and H. I. Battle. 1958. J. Morphol. 102:311.
[20] Ignatieva, G. M. 1970. Sov. J. Develop. Biol. 1:20.
[21] Ignatieva, G. M., and N. N. Rott. 1970. Wilhelm Roux Arch. Entwicklungsmech. Organismen 165: 103.
[22] Knight, A. E. 1963. Trans. Amer. Fish. Soc. 92:344.
[23] Kopsch, F. 1899. Arch. Mikrosk. Anat. 51:181.
[24] Mahon, E. F., and W. S. Hoar. 1956. J. Morphol. 98:1.
[25] Mansueti, A. J. 1964. Chesapeake Sci. 5:46.
[26] Oellacher, T. 1872. Z. Wiss. Zool. 22:373.
[27] Oppenheimer, J. M. 1937. Anat. Rec. 68:1.
[28] Pasteels, J. 1936. Arch. Biol. 47:205.
[29] Pelluet, D. 1944. J. Morphol. 74:395.
[30] Price, J. W. 1934. Ohio J. Sci. 34:287.
[31] Price, J. W. 1935. Ibid. 35:40.
[32] Roth, L. 1962. In R. Rugh, ed. Experimental Embryology. Ed. 3. Burgess, Minneapolis. p. 364.
[33] Ryder, J. A. 1872. U.S. Fish. Comm. Rep. 10:453.
[34] Solberg, A. N. 1938. Progr. Fish Cult. 40.
[35] Swarup, H. 1958. J. Embryol. Exp. Morphol. 6:373.
[36] Tavolga, W., and R. Rugh. 1947. Zoologica (New York) 32:1.
[37] Taylor, M. 1913. Quart. J. Microsc. Sci. 59:1.
[38] Wilson, H. V. 1891. U.S. Fish. Comm. Bull. 9:209.
[39] Ziegler, H. E. 1892. Thesis. Univ. Freiburg im Breisgau, Germany.

PubMed comprises more than 30 million citations for biomedical literature from MEDLINE, life science journals, and online books. Citations may include links to full-text content from PubMed Central and publisher web sites.Â All Databases Assembly Biocollections BioProject BioSample BioSystems Books ClinVar Conserved Domains dbGaP dbVar Gene Genome GEO DataSets GEO Profiles GTR texts. Biology data book. by. Altman, Philip L., ed; Katz, Dorothy Dittmer, joint ed.Â Borrow this book to access EPUB and PDF files. IN COLLECTIONS. Books to Borrow. Books for People with Print Disabilities. Internet Archive Books. Scanned in China. Uploaded by Tracey.Gutierres on July 25, 2011. Biology books for free online reading: biological sciences, biochemistry, genetics, microbiology, botany.Â Data Mining in Medical and Biological Research by Eugenia G. Giannopoulou, 2008, 320 pages, 15MB, ZIP/PDF. Deep Subsurface Microbiology by Andreas Teske et al., 2015, 305 pp, multiple formats. The Descent of Man by Charles Darwin, 2004.