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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

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