Objective…
To study the external and internal anatomy of a representative vertebrate (specifically, a smolt).

Introduction…
Of all vertebrate classes, bony fishes (class Osteichthyes) have both the largest number of species and the largest number of individuals overall. They are cosmopolitan, and are found in both marine and freshwater habitats.

The skeleton of bony fishes is reinforced by a hard matrix of calcium phosphate just as occurs in humans (why they are called bony fishes as opposed to cartilaginous fishes such as sharks). The skin of fishes is covered by flattened bony scales. Glands in the skin secrete mucous that helps to reduce drag during swimming. A typical bony fish has a lateral line system (a row of tiny pits in the skin) on both sides of the body that is sensory in function and help the fish to orient itself within its environment. Bony fish breathe by drawing water over their gills that are located in branchial chambers that are covered by a protective flap called the operculum. Movement of the operculum and contraction of muscles surrounding the gill chambers allow the fish to breathe while stationary. Most bony fish also have a swim bladder, an air sac that helps control the buoyancy of the fish by transferring gases between the swim bladder and the blood.

PART A: External anatomy
INSTRUCTIONS… Label all of the following parts on the given handout using the specified letters.

Obtain a smolt and place it in a dissecting tray. Locate the **[A] operculum (gill cover)** that occurs posterior of the eye on the head. Lift up the posterior free edge of the operculum and you will see the gills located within the branchial chamber. Water is taken in through the mouth, into the pharynx, and is expelled through the gill arches where the water passes over the gill filaments. The blood cells receive oxygen by diffusion as they pass through capillary beds that occur in the gill lamellae of these filaments. The water exits from under the free edge of the operculum.

Dorsal to the mouth on either side are the **[B] anterior incurrent naris** and **posterior excurrent naris**. These open into the nasal sac that is the organ of smell. Water enters this sac through the incurrent naris and exits by the excurrent naris. This keeps a constant passage of water circulating through the nasal sac. Odour particles in the water stimulate the olfactory lining of the sac and trigger the olfactory (smell) stimulus that is transmitted to the brain by the olfactory nerve. Posterior to the nares is the large **[C] eye**. Note the iris (coloured ring) and the pupil (central aperture that admits light to back of eye).

Paired fins occur on the ventrolateral surface of the body: the **[D] pectoral fins** are located just posterior to the operculum; farther back is the posterior set of **[E] pelvic fins**. The pectoral fins are homologous to the fore limbs of tetrapods and the pelvic fins are homologous to the hind limbs of tetrapods. During swimming, the paired fins function mainly as stabilizers. The pectoral fins may also be used in braking. The medial fin (medial = in the midline) situated at the end of the tail is called the **[F] caudal fin** (often referred to as the tail). This fin is always oriented in a vertical plane and is divided into a dorsal lobe and a ventral lobe. In bony fish, the caudal fin is always homocercal (i.e., the dorsal and ventral lobes are of equal size and shape) making this fin symmetrical on both the dorsal and ventral aspects. The caudal fin propels the fish forward through the water. The other medial fins functions mainly as stabilizers. There is an **[G] anal fin** on the ventral midline that occurs just anterior to the caudal fin and just posterior to the tail. As well, on the dorsal midline of the body, there is a **[H] dorsal fin** located about half way down the length of the body. The **[I] adipose fin** is much smaller than the dorsal fin and is located between the dorsal fin and the caudal fin. The adipose fin is soft and fleshy because it lacks the dermal rays (skeletal supports) that occur in all other fins. Not all families of teleosts have an adipose fin but fish such as salmon do have this fin.

Immediately anterior to the anal fin are two body openings on the ventral midline. The anterior opening is the **[J] anus**, through which faecal material from the intestine is expelled. The posterior opening, next to the anal fin, is the **[K] urogenital pore**, through which the eggs of the female, the spermatozoa of the male, and the urine of both sexes are expelled. This arrangement, with the urogenital opening posterior to the anus, is a peculiar feature of bony fishes.

Along either side of the body, about halfway up the lateral body surface is a faint but distinguishable **[L] lateral line** that extends from the operculum to the base of the caudal fin. This structure is comprised of a row of pores that connect to a canal lined with sensory receptors under the skin. The lateral line detects vibrations (movement) in the water and enables the fish to orient itself with respect to nearby objects. The whole body surface with the exception of the head and fins is covered with cycloid **[M] scales** that overlap posteriorly. These scales are formed by the dermis of the skin, and are thus covered by the epidermis (outer layer of the skin). As the fish grows, the total number of scales remains constant. However, a new and larger layer of bone-like tissue – the annual growth ring is formed under the previous growth ring of the same scale. This process continues throughout the life of the fish, thus forming a layered scale that has the appearance of rings when viewed from above. Similar to a tree, growth occurs continuously within each annual ring. Growth during winter is slower due to lower food abundance and lower temperatures. It is these seasonal and annual differences that make it possible to count the number of years that the fish has lived by counting the growth rings on an individual scale.

PART B: Internal anatomy
INSTRUCTIONS…Read through and identify the parts with your partner.

Muscles: Skin one side of the fish completely from the mid-dorsal to the mid-ventral line – begin just behind the gills and finish in the region of the pelvic fins or beyond. The skin is very firmly attached to the underlying muscle so be careful not to remove muscle along with the skin. Delineate the area to be skinned by making shallow incisions using a scalpel. The skin can be peeled using your fingers but can also be wrapped in paper towel to improve the grip, and then pulled off gently. You might find that it is necessary to separate the muscles from the skin using a scalpel as you continue.

Body Cavity and Viscera: Use a scalpel or razor to make a short mid-ventral incision through the body wall, just anterior to the pelvic fins. Be careful not to cut too deeply, so that you can avoid damaging any internal organs. Now hold your scissors as parallel to the ventral surface as possible (use the tips of the scissors only) and cut anteriorly along the mid-ventral line until you reach the gill chambers. Be careful not to damage the heart that lies just anterior to the pectoral girdle (between the pectoral fins). You will have to cut through the middle of this bony girdle using scissors in order to complete this mid-ventral incision. Extend this mid-ventral incision posteriorly through the pelvic girdle (between the pelvic fins) and nearly to the anus; do not cut right to the anus. Now you will proceed to remove the body wall to access the body cavity and organs (see the diagram on your lab sheet to clarify the following cuts). Just anterior to the anus but well posterior to the pelvic fin, make a cut in a dorsal direction up the left side of the body until you reach the lateral line. Next, make a similar cut, on the same side of the body, beginning immediately posterior to the base of the pectoral fin until you reach the lateral line. Next, make a longitudinal cut (along the length of the body) along the lateral line to connect your two previou incisions, thereby removing all of the body wall from the mid-ventral line to the lateral line. The body cavity or coelom will now be exposed along with the viscera (organs within the coelom). You should now locate a large, transparent, colourless, balloon-like structure called the swim bladder (air bladder). This structure occupies the whole dorsal portion of the coelom for the entire length of the body cavity. The swim bladder is filled with air and will collapse if punctured. The entire coelom is lined by a thin, transparent sheet of tissue called the peritoneum. The peritoneum that lines the wall of the coelom is the parietal peritoneum whereas that covering all the viscera, including the swim bladder, is the visceral peritoneum. The visceral peritoneum is continuous with the parietal peritoneum by way of the transparent mesenteries that suspend the viscera from the dorsal wall of the coelom.

Digestive system: Note the J-shaped stomach located in the anterioventral part of the coelom. The stomach opens by means of a one-way valve, the pylorus, into the intestine. The intestine extends back straight through the coelom to the anus. You will notice the presence of many pyloric caecae covering the outside of the pyloric part of the stomach. These are diverticula (narrow, blind sacs) that greatly increase the secretory area of the stomach. They may be covered by a considerable amount of white adipose tissue (fat). Immediately anterior to the stomach is the liver, a brownish organ that connects to the anterior end of the intestine by the bile duct. This duct contains a greenish liquid called bile that is produced by the liver, stored in the gall bladder, and is released into the intestine to aid in digestion. The pancreas in most bony fish is a diffuse organ. It consists of bits of tissue scattered throughout the adipose tissue that surrounds the pyloric caecae. The pancreas will be difficult to identify.

Urogenital system: The kidneys run along the dorsal body wall for the entire length of the coelom and can be observed through the transparent swim bladder. The two kidneys lie close together and appear as a medial, dark red band. The swim bladder is situated ventral to and immediately against the kidneys. The gonad is a long white organ that extends most of the length of the swim bladder and coelom and occurs lateral to the swim bladder. This organ is the ovary in the female (producing eggs) and the testis in the male fish (producing spermatozoa). It is suspended from the dorsal wall of the coelom by a mesentery. As in most bony fishes, fertilization is external.

Circulatory system: The heart is located in the pericardial cavity, just anterior to the liver. Note that the pericardial cavity is completely walled off from the rest of the coelom. The coelom is thus divided into two compartments: the more anterior pericardial cavity; and, the peritoneal cavity that contains all of the other viscera. The heart consists of two chambers, a small dorsal atrium, and a larger ventral ventricle. Dorsal to and opening into the atrium is the dark, thin walled sinus venosus that receives unoxygenated blood returning from body tissues. This unoxygenated blood passes from the sinus venosus into the atrium and from there through the atrioventricular valve and into the ventricle. The ventricle then pumps this blood anteriorly through the ventral aorta. From the ventral aorta afferent branchial arteries enter the gills where the blood is oxygenated (see the respiratory system below for details). Once oxygenated the blood is collected by the efferent branchial arteries. Some of this blood is pumped anteriorly into the head through paired carotid arteries; the rest is pumped posteriorly through the dorsal aorta that runs along the dorsal midline of the coelom, between the kidneys. Segmented pairs of arteries arise from the dorsal aorta to supply blood to the myomeres and other parts of the body wall.

Respiratory system: On one side of the fish, remove the operculum completely by cutting through its base at the anterior end using scissors. The gills will now be exposed. Locate the gill arch and the stiff, finger-like gill rakers that project from the anterior (inner) border of the arch into the pharynx. Note the long, red gill filaments that are arranged in two rows along the posterior or outer border of the gill arch. These gill filaments projecting outward and backward into the branchial chamber (the cavity that contains the gill filaments and is covered by the operculum). Each gill filament is oriented horizontally and itself is comprised of hundreds of gill lamellae that are oriented vertically. Fish have a closed circulatory system, and gas exchange with the environment (in this case water) occurs in specialized regions of the body called respiratory surfaces. The respiratory surfaces occur in the gills of fish, specifically the gill lamellae. The lamellae are comprised of a single layer of epithelial cells that surround a net of blood capillaries. The blood becomes oxygenated by diffusion of dissolved oxygen as the water passes over the gill lamellae. Remember from last week that common features of respiratory surfaces include: a large surface area to facilitate gas exchange; they are very thin to facilitate the process of diffusion (diffusion is effective only over short distances); they are moist because gases must be dissolved in water before they can diffuse (fish live in water so this is redundant here); and, they are highly vascularized (contain a high density of thin-walled blood vessels called capillaries) to facilitate diffusion of gases into blood for circulation.