A. Elbow Anatomy

1. Clinically-relevant features of each bone

**Distal humerus:** Unlike the distal femur, which has a lateral condyle and a medial condyle, the entire aspect of the distal humerus is referred to as the condyle. The small lateral aspect of the humeral condyle is referred to as the capitulum. The larger medial aspect of the humeral condyle is referred to as the trochlea. The olecranon fossa, on the caudal aspect of the condyle, accommodates the anconeal process of the ulna. The radial fossa, on the cranial aspect of the condyle, communicates with the olecranon fossa through the supratrochlear foramen. In the dog, no structures pass through the supratrochlear foramen, and in small dogs this foramen may be absent. Note that cats do not have a supratrochlear foramen. Instead, cats have a supracondylar foramen in the humeral condyle, through which the median nerve and brachial artery pass (important for fracture repair). The lateral epicondyle is a bony protuberance that provides attachment for the lateral collateral ligament and the extensor muscles. The medial epicondyle is a bony protuberance that provides attachment for the medial collateral ligament and several flexor muscles. The medial epicondyle is much larger than the lateral epicondyle.

**Proximal radius:** The proximal aspect of the radius is referred to as the head.

**Proximal ulna:** The proximal extremity of the ulna is the olecranon, which is the insertion site of the triceps brachii muscle. The trochlear (semilunar) notch articulates with the humerus and terminates proximally as the anconeal process. The coronoid process has both a small lateral projection and a larger medial projection, which many authors refer to as the lateral and medial coronoid processes, while other authors prefer the more accurate terms lateral and medial portions of the coronoid process.

2. Joint articulations and movement

**Humeroradial joint:** The capitulum of the humerus articulates with head of the radius.

**Humeroulnar joint:** The trochlea of the humerus articulates with the trochlear (semilunar) notch of the ulna. The humeroulnar joint restricts elbow joint movement to the sagittal plane.

**Radioulnar joint:** The articular circumference of the radius articulates with the radial notch of the ulna. The radioulnar joint allows rotational movement of the elbow joint (pronation and supination).

**Range of motion:** The normal range of motion of the elbow joint is 130 degrees, with approximately 36 degrees as the normal limit of flexion and 165 degrees as the normal limit of extension. Flexion relies on the biceps brachii and brachialis muscles, which are
innervated by the musculocutaneous nerve. Extension relies on the triceps brachii muscle, which is innervated by the radial nerve.

3. Ligaments

**Medial collateral ligament**: Attaches proximally to the medial epicondyle of the humerus. Attaches distally to the radial tuberosity and proximal ulna.

**Lateral collateral ligament**: Attaches proximally to the lateral epicondyle of the humerus. Attaches distally to the proximolateral radius and ulna. The lateral collateral ligament is much stronger than the medial collateral ligament.

**Annular ligament**: Fibrous band that encircles the head of the radius and attaches to the medial and lateral coronoid processes of the ulna.

**Interosseous ligament**: Connects the middle portions of the shafts of the radius and ulna.

B. Components and Clinical Presentations of Elbow Dysplasia

Historically, elbow dysplasia has been considered a syndrome comprised of the following components: ununited anconeal process (UAP), fragmentation of the medial portion of the coronoid process (FMCP), osteochondrosis and osteochondritis dissecans (OCD) of the humeral trochlea, and joint incongruity. Widespread use of arthroscopy has allowed us to be more precise in describing variations of the components of elbow dysplasia classified according to the traditional scheme. As a result, the term “**medial compartment disease**” has been adopted to refer to components of elbow dysplasia affecting the medial aspect of the elbow joint, including but not limited to FMCP, OCD of the humeral trochlea, and joint incongruity. The term “**medial coronoid disease**” has been adopted to refer to pathology of the medial portion of the coronoid process specifically, since we now know that fragmentation is not the only type of pathology affecting this part of the joint.

In general, elbow dysplasia tends to affect large and giant breed dogs. The most commonly affected breeds include the Labrador Retriever, Golden Retriever, Bernese Mountain Dog, German Shepherd Dog, Mastiff, Newfoundland, Rottweiler, and Saint Bernard Dog. Males are affected twice as frequently as females. The reported incidence of bilateral disease is variable, between 25% and 80% depending on the report, and dogs may have more than one component of elbow dysplasia in an individual elbow. Affected dogs typically present with lameness (often worse after exercise) between 5-13 months of age. However, there is a second population of dogs that present later as adults when elbow osteoarthritis (OA) is present and elbow dysplasia was undiagnosed earlier in life.

UAP affects large-breed dogs exclusively. The anconeal process in small-breed dogs does not have a separate center of ossification. Therefore, UAP cannot occur in these breeds. The timing of fusion of the anconeal process varies somewhat among large-
breed dogs; in German Shepherd Dogs, the anconeal process fuses between 16 and 20 weeks of age. On physical exam, dogs with UAP tend to have more pronounced joint effusion (localized to the caudolateral aspect of the joint) than dogs with other components of elbow dysplasia, and dogs with UAP tend to be painful during elbow extension.

Medial compartment disease tends to affect large-breed dogs, but elbow incongruity can affect smaller dogs, especially chondrodystrophic breeds. Dogs with medial compartment disease tend to stand and walk with the forelimbs adducted to reduce weight on the affected medial portion of the elbows. These dogs are often painful during elbow flexion alone and flexion combined with supination. In more chronic cases, the joint may feel thickened (due to periarticular fibrosis), have a reduced range of motion, and/or have crepitus during palpation.

C. Pathogenesis of Elbow Dysplasia

The genetic origin of elbow dysplasia in general is well recognized, but the specific genes involved in the transmission of elbow dysplasia remain largely unidentified. In addition, expression of these genes is likely influenced by environmental factors such as activity and nutrition. Asynchronous growth of the radius and ulna, whether due to genetic disturbances in growth rates or trauma to physes, is a central component in the pathogenesis of several components of elbow dysplasia.

UAP

The pathogenesis of UAP is unknown but may result from the ulna being short relative to the radius, due to either genetic disturbances in growth rates or trauma to the distal ulnar physis. The relatively tall radial head shifts the humerus proximally, leading to excessive force and repeated microtrauma on the anconeal process, which prevents its fusion.

UAP may also occur due to abnormal development of the trochlear (semilunar) notch. A small or misshapen trochlear notch may lead to poor articulation between the ulna and humeral condyle, which increases loading of the anconeal process and in turn prevents its fusion. Finally, some authors propose that UAP may be a manifestation of osteochondrosis. See the section describing osteochondrosis below.

Medial Coronoid Disease

An important study by Danielson et al. (2006) showed that changes in the subchondral bone of the medial portion of the coronoid process precede the development of fissures or fragmentation in the cartilage. In particular, osteocyte loss and large microcracks in the subchondral bone were found and suggest fatigue microdamage as an important factor in the pathogenesis of medial coronoid disease. Asynchronous growth of the radius and ulna may lead to abnormal loading of the elbow joint that in turn results in
the fatigue microdamage. When asynchronous growth results in a radius that is relatively short compared to the ulna, load-bearing forces are transferred from the radial head to the medial portion of the coronoid process. In some cases, the radioulnar incongruity resulting from asynchronous growth of the radius and ulna is visible on diagnostic imaging studies. In other cases, the incongruity may be transient, having been present long enough to cause fatigue microdamage of the medial portion of the coronoid process, but having resolved by the time of diagnosis. Lastly, the incongruity may be localized to the apex of the medial portion of the coronoid process, resulting from abnormal development of the medial portion of the coronoid process rather than asynchronous growth of the radius and ulna.

**Osteochondrosis/OCD**

Osteochondrosis refers to a developmental condition characterized by interrupted endochondral ossification. Endochondral ossification is the process of bone formation that follows a (hyaline) cartilage precursor either in the epiphyses or physes. In developing bone, longitudinal growth occurs from the physes at either end of the bone, but growth also occurs within the epiphysis at either end of the bone. The process of growth within each epiphysis is similar to that of the physis in that 1) there is an ossification center within each epiphysis and 2) there is a cartilaginous layer (deep to the thin articular cartilage) that functions much like a growth plate within each epiphysis. Differences compared to the physis are that the process is radial (rather than linear) and much more vascular in the epiphysis. Understanding these growth patterns is important to understanding how osteochondrosis might occur and how it manifests when it occurs at the articular-epiphyseal junction (a joint) or at a physis.

Clinical manifestations of osteochondrosis at the joint surface, including the humeral trochlea, are widely accepted. Osteochondrosis is most likely a result of focal infarcted cartilage and subsequent necrosis, which interferes with endochondral ossification. As blood vessels are incorporated into the region of ossification, they may become susceptible to damage from local conformational forces and microtrauma. Factors contributing to these forces may be hereditary, nutritional, or associated with rapid growth or high impact activity. Regardless of the cause, once endochondral ossification is interrupted, cartilage fails to ossify and instead a thick focus of cartilage persists. This thickened cartilage is less resistant to mechanical stress and is poorly nourished, and may eventually break off from the underlying subchondral bone as a flap (osteochondritis dissecans or OCD).

Proposed clinical manifestations of osteochondrosis at physes, including UAP, are characterized by persistence of hypertrophic chondrocytes and are not as well accepted as the articular forms of osteochondrosis.

**D. Diagnostic Imaging of the Elbow**
Due to the high incidence of bilateral disease, diagnostic imaging of both elbows is recommended. In addition, it is important to check imaging studies for multiple components of elbow dysplasia. Radiography and computed tomography (CT) are the primary imaging studies used in the diagnosis of elbow dysplasia. Arthroscopy has both diagnostic and therapeutic applications and is discussed in the next lecture.

Standard radiographic views include the standard lateral, hyperflexed lateral, and craniocaudal views. In general, radiography is limited in evaluating the medial portion of the coronoid process and joint incongruity compared to CT. Below is a checklist for systematic review of the standard radiographic views.

## Standard Lateral and Hyperflexed Lateral Views

<table>
<thead>
<tr>
<th>In the region of the...</th>
<th>Check for:</th>
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<tbody>
<tr>
<td>Radial head</td>
<td>Osteophytes</td>
</tr>
<tr>
<td>Medial portion of the coronoid process</td>
<td>Blunt, ill-defined process +/- fragment (normal is a well-defined point)</td>
</tr>
<tr>
<td>Trochlear notch of ulna</td>
<td>Sclerosis (a very common finding)</td>
</tr>
<tr>
<td>Anconeal process</td>
<td>UAP on the hyperflexed view</td>
</tr>
<tr>
<td>Anconeal process, non-articular surface</td>
<td>Osteophytes on the hyperflexed view (one of the earliest sites of OA)</td>
</tr>
<tr>
<td>Joint surface</td>
<td>Congruity on the standard lateral view: radioulnar step, trochlear notch shape</td>
</tr>
</tbody>
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## Craniocaudal View

<table>
<thead>
<tr>
<th>In the region of the...</th>
<th>Check for:</th>
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<tbody>
<tr>
<td>Humeral trochlea</td>
<td>OCD lesion: subchondral defect on the articular margin</td>
</tr>
<tr>
<td>Humeral trochlea</td>
<td>Secondary signs of OCD: sclerosis of the condyle</td>
</tr>
<tr>
<td>Medial and lateral epicondyles</td>
<td>Osteophytes</td>
</tr>
<tr>
<td>Medial portion of the coronoid process</td>
<td>Osteophytes, pointed hook-shaped appearance</td>
</tr>
</tbody>
</table>

CT has become the standard of care in pre-operative imaging of elbow dysplasia and effectively replaces radiography where CT is available. In addition to superiority in diagnosing medial coronoid disease and joint incongruity compared to radiography, CT has the advantages of imaging both elbows in a single study, generally performed with the patient sedated. An important feature of CT is its ability to evaluate the subchondral bone of the medial portion of the coronoid process. This allows us to identify a disease of the medial portion of the coronoid process that may not be identified on arthroscopy alone if the process is not fragmented.
E. References

