Introduction
The term “fundus” describes the part of the posterior segment of the eye that is viewed with the ophthalmoscope – it shouldn’t be confused with the “retina”, as the latter structure is not solely responsible for what you see with the ophthalmoscope. In fact the neurosensory retina is mostly translucent and, under normal circumstances, should hardly be visible.

Marked variation in the ophthalmoscopic appearance of the fundus exists both within and between species. It is imperative that the clinician is familiar with this range of normal variation if incorrect diagnosis is to be avoided. It can take years of practice to become proficient in ophthalmoscopic interpretation of fundus lesions, BUT……

FUNDOSCOPIC INTERPRETATION WILL BE MUCH EASIER IF YOU UNDERSTAND THE BASIC ANATOMY OF THE STRUCTURES YOU ARE EXAMINING, AND THE FUNDAMENTAL PATHOLOGIC PROCESSES THAT CAN AFFECT THEM!

Components of the ocular fundus (from interior to exterior) are:

- vitreous
  - seldom entirely optically clear

- neurosensory retina
  - inner limiting membrane more or less visible as a “sheen”
  - myelination of nerve fiber layer may extend in “plumes” outward from the optic disc / papilla
  - retinal vasculature lying within the inner retina (exact depth and pattern depending on species). Retinal venules tend to be larger and more prominent than arterioles.
    - Holangiotic – a well-vascularized neurosensory retina with a variable number of vessels extending from the optic disc in an approximately spoke-like pattern (eg. dog, cat)
    - Merangiotic- a moderately vascular retina – blood vessels extend medial and lateral to the optic disc (rabbit)
    - Paurangiotic – very sparsely vascularized retina (eg. horse)
    - Anangiotic – no blood vessels are present in the neurosensory retina (eg. birds, reptiles, amphibians). In avian species, a highly pigmented and pleated structure, the pecten, plays an important role in the nutrition of the inner retina.
  - The grayish, translucency of the neurosensory retina is largely related to the most densely packed cell layers i.e. the outer nuclear layer (photoreceptors) in most commonly examined domestic species
  - Optic nerve head / papilla – normal extent of myelination of axons and of visibility of “pores” of the lamina cribrosa is dependent on species

- retinal pigment epithelium
  - outermost layer of the retina
  - variably pigmented
  - lacks pigment overlying the tapetum and shows variably mottled pigmentation in a sparsely pigmented “window” extending beyond the margins of the tapetum

- choroid
  - The choroid is a highly vascular tissue, with supporting stroma that contains variable amounts of pigment.
  - tapetum within the inner choroid
    - Although roughly triangular in shape, the tapetum varies considerably in extent and color between individuals. The margins between tapetal and non-tapetal fundus are also variably distinct or mottled.
Variability in color often corresponds to varying degrees of thickness/development on histologic section.

In species such as the dog and cat, in which animals are born with relatively immature eyes, the tapetal layer is generally not fully developed until 3-4 months of age.

Lacking in some species and absent in individual animals from species that normally possess a tapetum, e.g. may be absent in subalbinotic animals.

- **choroidal pigment** – variable
- **visibility of choroidal vasculature highly variable**
  - the choroidal vessels are relatively broad, straight and somewhat radial in orientation
  - choroidal vessels contain highly oxygenated blood and are therefore lighter red than the retinal venules.
  - Small blood vessels (i.e. capillaries) that penetrate the tapetum at right angles - connecting main choroidal vessels with the choriocapillaris layer- may be observed “end-on” as small dots in the tapetum, called “Stars of Winslow”.

- **sclera**
  - only visible where tapetum absent and choroid and RPE lack pigment
  - long posterior ciliary arteries and/or vortex veins may be visible if RPE and choroid poorly pigmented

**NORMAL OPHTHALMOSCOPIC FEATURES**

1) **CANINE FUNDUS**

- **Tapetal fundus** - a bright, shiny sweep of color, roughly triangular in shape, which occupies the superior area of the fundus where RPE lacks pigment and there are tapetal cells present beneath choriocapillaris. The retina is essentially transparent, so the ophthalmoscopic appearance is of retinal blood vessels against a background of tapetum.

- **Non-tapetal fundus** – typically pigmented (dark grey / brown) area inferior to the disc and peripheral to the tapetum where RPE contains melanin, and retinal blood vessels are observed against a background of RPE and choroidal pigment.

- **Optic disc** - generally circular and white/pink due to myelination of nerve fibres/ optic nerve. Typically located at the junction of tapetal and non-tapetal fundus. A small grey spot at the centre of the disc is the normal “physiologic pit” (where the hyaloid artery attached).

- **Retinal vasculature** - usually 3-5 major veins which converge at the disc, deviating slightly at its margins, and may anastomose on its surface to a variable degree, forming a complete or partial circle. Slightly narrower diameter major retinal arteries (about 12-20 in number) emerge at the disc and follow the course of the retinal veins. Arterioles and venules branch throughout the fundus. Superio-temporal and inferio-temporal vasculature tends to curve around and “embrace”, rather than traverse, the area of greater photoreceptor density- known as the “area centralis” – superior-lateral to the optic disc.

**Normal variations**

- **tapetal fundus** - coloration varies greatly between individuals- ranging from yellow, through orange, green and blue. The tapetal borders are often a slightly different color than the rest of the tapetum- e.g yellow tapetum with a blue/green border. The extent of the tapetum may also vary - tending to be small in small breed dogs and larger in large breed dogs. The tapetum may be absent - particularly in albinotic/ subalbinotic dogs. Tapetal development is incomplete in puppies up to 12-14 weeks of age - in which the future tapetal region first appears dark grey, changing to violet/ lilac and then bright blue before achieving its definitive adult color. The margins of the tapetum may be clearly demarcated or irregular and broken up (the latter being particularly prevalent in long-haired breeds). Islands of pigment may be visible within the tapetal fundus and islands of tapetum may be visible within the non-tapetal fundus. The far periphery of the tapetum may appear somewhat dull / gray, an appearance that is more prevalent in some breeds than others.

- **non-tapetal fundus** - Immediately inferior to the tapetum, pigmentation of the RPE tends to be less dense within a narrow band – about 1 disc diameter wide – than in the remainder of the non-tapetal
Degrees of pigment dilution in the RPE and choroid lead to variations ranging from reddish-tan (common in dogs with pale, yellow irises) to a red striped appearance characteristic of blue-eyed, dogs. This appearance is due to an absence of pigment in the RPE, thus exposing the underlying choroidal blood vessels, which are observed against a background of choroidal pigmentation. Choroidal vessels have a more orange appearance than the retinal vasculature and are oriented approximately radially and roughly parallel to each other. This “tiger-stripe” appearance is even more accentuated in animals that lack choroidal pigmentation, where the choroidal vessels are viewed against the white background of the underlying sclera. The latter appearance is most commonly associated with blue eyes and merle coat color.

- **optic disc** - although the optic nerve is circular in cross-section, the shape of the disc may vary as a result of myelin extending beyond the margins of the optic nerve head. In normal dogs, the rest of the disc may bulge anteriorly if heavily myelinated (by 2-3D) and will appear raised relative to the adjacent fundus. It is not uncommon for the disc to have an oval, triangular or irregular outline. This is most exaggerated in Golden retrievers and GSDs and is termed “pseudopapilledema”. This may be distinguished from pathological changes by observing the course of retinal blood vessels (which should not be significantly deviated over the edge of the disc) and identification of the normal “physiologic pit”. Some dogs have a hyper-reflective crescent around the disc, known as conus (the only instance of “normal” hyper-reflectivity), while others demonstrate a ring of pigment around the disc. The optic cup is difficult to evaluate in dogs because of the extensive nature of myelination.

- **retinal vasculature** - the number of major blood vessels may vary, as does the extent of anastomosis on the surface of the optic disc. Tortuosity of the retinal vasculature may be a normal feature in some individuals. The superior-temporal and inferio-temporal vascular arcades “embrace” the area centralis lateral to the optic disc.

2) FELINE FUNDUS

- **tapetal fundus** - very large, bright tapetum. Usually yellow / green. May have prominent stars of Winslow. A diffusely mottled gray region/ streak within the tapetal fundus is often seen transiently at the onset of fundoscopy in this species. The area centralis tends to look very slightly more “granular” than the surrounding tapetal region of the fundus.

- **non-tapetal fundus** - much less variation than in the dog, although “subalbinism” may occur in light-coated, white, and color-point cats.

- **optic disc** - small and round disc, situated within the tapetal fundus - 1-2 optic disc diameters within its ventral border. The optic disc appears darker grey/pink than that of the dog, because myelination does not occur before the nerve axons exit the globe at the lamina cribrosa. Only rarely is pre-laminar myelination of retinal nerve fibers seen in the cat. The disc may be surrounded by pigment or conus (hyper-reflectivity), although the latter is seen less frequently than in dogs. The lamina cribrosa is not prominent except in pathologic states.

- **retinal vasculature** - typically 3 pairs of arteries/veins - with no anastomosis on the surface of the disc and fewer arterioles than dog.

3) EQUINE FUNDUS

- **tapetal fundus** - Extensive tapetum. Variation in tapetal colour common, often clearly demarcated zones of varying tapetal colour within a single fundus e.g. blue / yellow. Stars of Winslow are very prominent in this species. Often choroidal and scleral vessels may be observed as bluish or reddish streaks, or lines of dots, through the tapetum.

- **non-tapetal fundus** - varying degrees of pigment dilution may be observed. Not uncommon to observe broad bands of lesser pigmentation, that can extend into the tapetal fundus

- **optic disc** - horizontally oriented, ellipsoidal, non-myelinated disc (with prominent lamina cribrosa) situated quite ventrally within the non-tapetal fundus. Notching of the disc may be noted at about 6 o’clock position. Pigmentation may surround the disc, and rarely pigmentation may be incorporated in the disc. Pre-laminar radiating medullated fibers are uncommonly seen in this species.

- **retinal vasculature** - a paurangiotic fundus with 30-60 retinal blood vessels radiating from the disc but extending only 1- 1.5 disc diameters into the surrounding fundus. Vessels may appear slightly more sparsely distributed at the 6 o’clock position.
4) RUMINANT FUNDUS
- tapetal fundus - usually bluish/green or greenish/yellow with very prominent “stars of Winslow”
- non-tapetal fundus - usually darkly pigmented
- optic disc - poorly myelinated, so relatively dark, with prominent lamina cribrosa. The disc is typically located on the ventral margin of the tapetum and is slightly horizontally oval in shape. In cattle, an occasionally in sheep, the inferior disc is poorly myelinated and appears pigmented, resulting in a bean shape. A prominent bump (Bergmeister’s papilla) or vermiform structure, representing a remnant of the hyaloid artery, is not unusual at the center of the disc.
- retinal vasculature - a holangiotic fundus with twisting together of the dorsal retinal artery and vein.

5) PORCINE FUNDUS
- NO TAPETUM PRESENT
- usually fairly darkly pigmented
- optic disc - usually ovoid, with prominent lamina cribrosa
- retinal vasculature- holangiotic fundus

GENERAL FUNDUSCOPIC ABNORMALITIES

1) Altered tapetal reflectivity
- *Increased reflectivity* of the tapetum signifies thinning of the neurosensory retina.
  - The tapetum is viewed through a thinner tissue layer than normal and consequently appears to have a brighter, “metallic” sheen. This is most pronounced where there is significant loss of photoreceptors and their nuclei.
- *Decreased reflectivity* of the tapetum signifies:
  - a thickening (due to infiltration, edema, disorganization or folding) of the neurosensory retina overlying the tapetum. As less light is able to pass back through the neurosensory retina from the tapetum, the tapetum may appear “gray”, discolored or “dull”.
  - Altered pigmentation of RPE cells
  - Subretinal exudates, infiltrates or retinal detachment
  - Infiltration or degeneration within the tapetum (choroid) itself will also reduce its reflectivity and/or color

2) Altered Pigmentation
- Proliferation, migration and aggregation of RPE cells and/or choroidal melanocytes represent a non-specific response to insults such as inflammation, injury and degenerative processes.
- Black / dark brown melanin pigment should be distinguished from the lighter brown/tan “lipofuscin” which accumulates in spots and patches in animals with vitamin E deficiency or “central PRA”.
- Must distinguish this from normal variation – certain variants are common in specific breeds.

3) Vascular changes
- Attenuation, i.e. narrowing, of retinal blood vessels occurs secondary to retinal degeneration.
  - This is most readily observed in smaller vessel branches in the peripheral fundus, and affecting the smaller arterioles around the optic disc.
  - The major venules “disappear” last although their caliber may be reduced earlier in the degenerative process.
  - Note that the vessels are still present, just “closed down” and no longer perfused.
- Peri-vascular “cuffing” with inflammatory cells
  - may be observed in disorders such as FIP.
- Lipemia retinalis can be a feature of hyper-lipidemia, particularly with hyper-chylomicronemia, particularly where accompanied by anemia, the retinal vasculature may appear pale-pink. This appearance tends to be most pronounced in the peripheral, non-tapetal fundus.
Changes may be seen in the retinal vasculature in response to systemic disease - such as hyperviscosity syndrome, hypertension, and diabetic retinopathy with local endothelial cell hypoxia and pericyte damage contributing to vessel leakage characterized by focal edema, hemorrhages, toruosity, variability in vessel caliber (copper wire appearance), aneurysms and/or engorgement.

Hemorrhage may occur as a result of local or systemic vascular disease, e.g. hypertension, vasculitis, or may reflect a systemic coagulopathy. The appearance of hemorrhages may offer clues to their location, but this is seldom of value in establishing a specific diagnosis.

- “Keel” shaped hemorrhages represent “pre-retinal” hemorrhages trapped between the inner retina and posterior vitreous. In animals with vitreous degeneration / liquefaction, this blood would be distributed within the vitreous.
- Flame –shaped hemorrhages indicate hemorrhages within the innermost retina, tracking along between axons in the nerve fiber layer.
- Dot-blot, round hemorrhages typically lie within the retina
- Large, dark, “splotch” hemorrhages are generally sub-retinal (between neurosensory retina and RPE, or within the choroid)

Choroidal infarction may be seen leading to dull, wedge-shaped areas e.g. in acute, severe glaucoma or metastatic carcinomas. However, complete occlusion of retinal blood vessels is far less common in animals than in humans.

### 4) Detachment

- The neurosensory retina is only firmly attached at the optic disc and, anteriorly, at the ora ciliaris retinae, where it merges with the pars plana of the ciliary body.
- Between these points, the attachment is relatively weak - relying on the close apposition of RPE and the support of the vitreous.
- Retinal detachment almost always reflects separation of the neurosensory retina from the RPE, as the RPE remains attached to the underlying choroid.
  - Areas of detachment/exudates may appear as focal gray areas within the tapetal fundus (with local reduction in tapetal reflectivity) or non-tapetal fundus (where they appear paler than the surrounding area).
  - Evaluate the course of the retinal blood vessels carefully, retinal detachment will cause them to deviate from their original course. When using a direct ophthalmoscope, elevated regions will require selection of positive lenses to bring them into focus.
  - More extensive retinal detachments will no longer be within the normal plane of the retina and will appear as gray sheets and folds, with surface blood vessels, that are progressively out of focus as they billow towards the observer.
  - May be associated with vitreous degeneration or hemorrhage
- Raised, dull areas of apparent retinal detachment may occasionally represent choroidal elevation by infiltrates or hemorrhage.
- Retinal tears can require careful evaluation to identify. Their extent and location should be characterized methodically. Those with rounded, blunted, curled edges are generally of relatively long-standing and may be less amenable to surgical intervention due to contracture of epi-retinal membranes.

### 5) Optic Nerve Head Abnormalities

- Small size = atrophy or hypoplasia…or “micropapilla” if at the small end of the spectrum of “normal”?
  - The hypoplastic optic nerve head is typically small, round and gray/white to dark gray in appearance, the retinal vasculature is generally of normal caliber.
  - Optic nerve hypoplasia is distinguished clinically from “micropapilla” by subjective assessment of PLR and visual function, both of which should not be impacted in cases of “micropapilla”, which likely represents the functional end of the optic nerve hypoplasia spectrum.
  - Optic nerve degeneration is seldom observed in dogs and cats in the absence of at least peri-papillary vascular attenuation or altered pigmentation and hyper-reflectivity. The margins of the degenerate optic disc often appear shrunken and crenated with loss of myelin.
• **Glaucomatous Optic Nerve Cupping:**
  o While cupping of the optic nerve head (cup to disc ratio of >0.3) is considered a major diagnostic parameter in human glaucoma, estimation of the cup to disc ratio in dogs is challenging, due to the extent of myelination that complicates interpretation of the margins of the cup and neuroretinal rim, and corneal edema that accompanies IOP elevation in this species. In advanced glaucoma, loss of myelin reveals the lamina cribrosa structure (“Laminar dot sign”) and leads to darkening of the disc. However, in acute glaucoma in dogs, the optic nerve head often appears congested and swollen (see below).

• **Colobomatous defects**
  o May be typical (6 o’clock) or atypical based on location. As these lesions are depressed relative to the rest of the fundus, they appear out-of-focus, but generally have sharply demarcated margins and may appear blue / gray in contrast to more normal regions of the optic nerve head. They may contribute to an “enlarged” appearance of the optic nerve head if involve the adjacent choroid and retina.

• **Enlargement** may reflect infiltration (e.g. inflammation or neoplasia) or papilledema related to increased intracranial pressure. Swelling and enlargement of the optic nerve head is also seen early in the case of canine acute congestive glaucoma. True swelling should be distinguished from so-called “pseudopapilledema” due to normal pronounced myelination by considering the following questions:
  o Are margins distinct and sharply demarcated or ill-defined?
  o Is the physiologic pit no longer visible?
  o Is there hemorrhage evident? (particularly overlying the disc and in the nerve fiber layer)
  o Is there involvement of the retina, choroid and or adjacent vitreous?
  o Are there any other clinical / neurologic signs?

**PEARLS OF WISDOM:** Some words of advice

ALWAYS describe lesions in detail, AT THE TIME of your examination. Don’t rely on your memory to make notes or drawings later. Don’t rely on photographs alone – digital files can be inadvertently deleted and if using photographic film, images may not turn out as hoped.

Given the very broad range in the appearance of the normal fundus, it can be very difficult to distinguish between normal and abnormal based on funduscopic appearance alone.

Challenge yourself to explain the funduscopic appearance in terms of underlying histopathology. If you cannot do this, it is more likely that the appearance represents a normal variant.

Consider other ophthalmoscopic features that one might expect to see in association with the appearance you are confronted with. Similarly, there may be involvement of other ocular structures or even systemic signs of disease. If you cannot identify any other features of disease, it is more likely that the appearance represents a normal variant.

Still can’t decide?

If suspect inherited disease, e.g. “PRA”, consider ERG and / or molecular genetic testing.

Use higher magnification and/or change your angle of viewing

Use of a red-free (ie green) filter can be helpful in delineating smaller blood vessels (particularly in horses) and can help to distinguish between hemorrhage (which will look completely black with a red-free filter) and pigmentation.

Consider other means of evaluating the fundus, e.g. by fluorescein angiography, OCT or confocal laser scanning ophthalmoscopy with auto-fluorescence imaging, if these are accessible to you

If possible take photographs to document the appearance of the fundus. At very least document the appearance by a detailed description and accurate, labeled drawings.
Many pathologic disorders are progressive. The only way to determine progression is to evaluate on more than one occasion. Depending on the nature of the suspected disease process, you may wish to schedule re-evaluation in days, weeks, months or even after a year.

Seek a second opinion – this is easy to do and not a sign of weakness!!