Differential Diagnoses for Diseases of Poultry Based on Organ Systems and other outlines

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Table of Contents:

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I. Introduction

Poultry are a diverse group of species of birds that are raised primarily for meat and eggs but sometimes for feathers, skin and oil also such as ratites. These species comprise of chickens, turkeys, ducks, geese, pheasants, quail, squabs (young pigeons), Guinea fowl, partridges and ratites (ostrich, rhea and emu). Knowledge about the type of birds, their anatomy and how they are managed helps one to understand the type and kind of diseases different birds are susceptible. In certain types of bird species that are raised for egg production or meat, such as commercial poultry, infectious diseases can spread rapidly among birds housed in a confined space. Poultry can also be raised in small numbers as backyard flocks for eggs and meat, as hobby and pet birds. Their numbers are increasing rapidly. They are often exposed to natural elements and are often not vaccinated, may lack proper nutrition and lax biosecurity that can lead to frequent viral, bacterial, parasitic and nutritional diseases. Backyard poultry can also be a source of diseases to the commercial poultry. In addtion to the different management practices that are used for raising poultry, genetics and nutrition play a significant role in the initiation and outcome of a disease. There is also increased demand for poultry raised as antibiotic free and organic which can lead to unintended consquences.

These outlines on differential diagnoses and diseases in poultry is based on organ systems. Diseases of the respiratory and gastrointestinal systems are some of the most important and common diseases seen in commercial poultry and may constitute more than 2/3rd of all the diseases one may encounter. It should also be pointed that finding a combination of etiologies or diseases is a norm in commercial poultry and probably in backyard poultry.

Included in this handout are also a few other miscellaneous outlines. All these outlines should help the poultry veterinarian, diagnostician, pathologists as well as the students to formulate differential diagnoses on various diseases quickly depending on the clinical signs and lesions and to collect appropriate specimens for various laboratory tests to provide accurate, rapid, and cost effective results to the clients. These tests may include FA, serology, bacteriology, mycology, virology, biotechnology, parasitology, histopathology including immunohistochemistry, toxicology, nutritional analysis, electron microscopy, cytology, hematology, serum chemistry and pathogenesis studies.

The outlines provided here on the diseases of poultry and others are a collection of outlines compiled over 30 years and are in different formats prepared for various presentations. These outlines are by no

means complete and those who are interested in learning more are advised to review a few references provided at the end of this outline as well as others.

II. Avian Reaction to tissue injury - Inflammation

- Reaction is rapid in birds, 36 hours
- Leakage of fibrin and fibrinogen common in early exudate
- Intense granulomatous reaction (12 hours)
  - – Coagulum of eosinophilic debris, degranulating heterophils, macrophages and giant cells
- Macrophages, heterophils and thrombocytes are active phagocytes
- Pus is caseous but liquefaction can occur
- Birds respond with granulomatous inflammation to many insults
- Acute inflammatory reaction in birds involve edema, congestion and vascular changes mediated by basophils and mast cells
  - – 1-3 hours: basophils, heterophils and monocytes
  - – 2-6 hours: basophils degranulate and die
  - – 6-12 hours: lymphocytes, monocytes, macrophages
  - – 12-36 hours: lymphocytes, macrophages, giant cells
    - √ Acute reaction peak by 12 hours (when giant cells appear)
  - – 36-72 hours: regeneration and repair
    - √ Fibroblasts, secondary lymphoid follicles, plasma cells
    - √ Chronic reaction with caseation, macrophages, giant cells, granuloma formation

Cells involved in inflammation

- **Heterophils**: have lance-shaped granules, lack myeloperoxidase and alkaline phosphatase, have β-glucuronidase and acid phosphatase
  - – Very phagocytic
  - – Granules tend to round up in tissues, difficult to identify
- **Eosinophils**: have spherical granules
  - – Function is not known, delayed type IV hypersensitivity?
  - – Associated with eosinophilic enteritis in turkeys due to ascarid
- **Basophils**: contain histamine, involved in acute inflammation
- **Thrombocytes**: small round to oval cells with clear cytoplasm and small round nucleus (looks like small lymphocyte), phagocytic
- **Monocytes**: precursors to cells of MPS, phagocytic, can fuse to form multinucleated giant cells
  - – Make monokines; IL-1, IL-2, (IL-4?), IL-6, IL-8, (IL-10?), (IL-12?), IL-15, IL-16, IL-17, IL-18, TNF, G-CSF, gamma interferon
- **Lymphocytes**: various morphologies involved in subacute inflammation including plasma cells

Coagulation

- Extrinsic system active and efficient but intrinsic system relatively weak
- Tissue thromboplastin (III) and platelets play important role
- Has a vitamin K dependent factor similar to mammalian factor IX
  - – Plasma thromboplastin and Hageman factor may be lacking
  - – Low levels or absence of factors V and VII
- Fibrinogen (I), prothrombin (II), antihemophiliac factor (VIII) and Stuart factor (X) are present

- Clot retraction is very slow in birds
  - Has thrombolytic mechanism and t-PA activation for fibrinolysis

Complement

- Not well understood
- Classical complement (CCP) and alternate complement pathways (ACP) are present
- A few components have been identified such as C1, C3, B
  - may lack C2 and C4.
- Factor B in chickens may play a dual role in ACP and substituting for C2 in CCP
- Differences in C components may exist among avian species

III. Respiratory System:

Diseases affecting the respiratory and digestive systems in poultry are some of the most common diseases seen in the farms. These two systems may account for nearly 70 % of all the cases seen in a diagnostic laboratory or in the poultry farms. Disease of the respiratory system in general is not only one of the most complex but also one of the most economically important problems in the field where chickens and turkeys are raised indoors and intensively. This outline will cover the common viral, bacterial, fungal, parasitic, nutritional, toxic and miscellaneous diseases affecting the respiratory system of chickens and their diagnoses by histopathology. However, in the field it is very rare that chickens or turkeys are confronted with one single etiology such as a virus or bacteria or parasite or fungi, *etc*., but a combination of various disease agents. The diseases of the respiratory system are also greatly influenced by the environment they are in as well as various management factors including vaccinations Chilling and overheating also influence respiratory diseases. Regardless of whatever management practices are used, genetics and nutrition play a significant role in the initiation and outcome of a disease.

Briefly the **anatomy** of the respiratory system in poultry consists of external nares, nasal passages (turbinates and sinuses), choana (palatine cleft), larynx, syrinx, bronchi (primary,), lungs which are covered by pleura and contains secondary and tertiary or parabronchi (with atria and air capillaries) and air sacs. Other organs that are either directly or indirectly connected with the respiratory system include pharynx leading to the eustachian tubes and middle ears, conjunctiva including *membrana nictitans* (3^{rd} eyelid), gland of Harder, lacrimal gland and nasal or salt gland. Most of these organs are lined by cuboidal or ciliated columnar epithelium and contain lamina propria and goblet cells. Gland of Harder located behind the eye and is an important gland that contain plasma cells that secrete antibody (IgA) which along with the mucocilliary system in the nasal cavity, trachea and bronchi provides a major defense mechanism to the respiratory system.

Clinical signs due to respiratory disease range from nasal and ocular discharge, gasping or open mouth breathing, wheezing, snick with various mortalities in a flock can be observed. Rarely the birds may not have any clinical signs and die acutely such as in Bird flu and Newcastle disease. Similarly **gross and microscopic lesions** due to respiratory diseases range from fibrinous to lymphoplasmacytic airsacculitis, pleuritis, pneumonia, sinusitis/rhinitis, laryngitis, tracheitis and conjunctivitis. Collapse or flattening of the trachea is common in turkeys and rare in chickens due to *Bordetella avium*.

A t**entative diagnosis** of diseases of the respiratory system can be made based on history, clinical signs and gross and microscopic pathology. **Confirmatory diagnosis** can be made based on virus, bacterial and fungal isolation, serology, fluorescent antibody test, immunohistochemistry and Polymerase Chain Reaction (PCR). Epidemiology of a disease or a disease agent can be studied by sequencing or other molecular techniques of the etiologic agent such as IBV, ILT, MG, MS. Diagnosis of nutritional and toxicological diseases can be made by analyzing the feed or liver and serum from birds in certain diseases.

The basic **histopathological** lesions of the respiratory system to injury are similar to those that occur in other organs in general and can be non-specific. However, according to one reference 82.3 % of the diagnosis of viral diseases in chickens may be made based on histopathological lesions or lack of them. In spite of such a high correlation histology provides guidelines as to possible etiology and it is important that isolation, molecular techniques and other tests should be done to confirm the diagnosis. Further the lesions in the respiratory tract can be complicated due to the involvement of multiple etiologic agents such as viruses, bacteria, fungi, parasites, nutritional deficiencies, ammonia exposure, *etc.* It should be stressed that it is extremely rare to find a single cause of respiratory disease but a combination of different etiologies when one is dealing with commercial poultry with clinical problems.

The **histopathologic al** lesions seen in the avian respiratory system can be divided in to those that involve the epithelial cells and those that involve the lamina propria. Those changes that involve epithelial cells consist of loss of cilia, increased number of goblet cells, squamous metaplasia, hyperplasia and necrosis of epithelial cells. Other changes in the epithelial cells include viral inclusion bodies and attaching bacteria at the tips of the cells. The changes in the lamina propria include edema, hemorrhage, congestion of vessels, infiltration of inflammatory cells (heterophils, lymphocytes, plasma cells, macrophages, lymphofollicular reaction including lymphoid nodule formations), fibrosis, necrosis

and hypertrophy of cells lining the mucous glands. Occasionally neoplastic lymphocytes can be observed in the lamina propria such as in Marek's disease.

Catarrhal sinusitis/rhinitis, tracheitis, bronchitis and conjunctivitis are primarily seen in acute mild or transient viral infections without complications by bacteria such as E. coli and others or ammonia. Examples include Infectious bronchitis virus (IBV), Avian Paramyxovirus (APMV-1), low pathogenic avian influenza (LPAI), mild form of Infectious Laryngotracheitis ("Silent ILT"), avian metapnuemovirus, Histologically the lesions include deciliation in the trachea and and primarily lymphoplasmacytic inflammation of the mucosa in the upper respiratory tract and bronchus and conjunctiva.. Occasionally interstitial pneumonia characterized by infiltration of lymphocytes can be observed with IBV and APMV-1. In cases such as in Newcastle disease, highly pathogenic avian influenza (HPAI) due to serotypes H5 and H7 including Bird flu (H5N1) and infectious laryngotracheitis (ILT) hemorrhages alone or in combination with fibrinonecrotic exudate can be seen in the conjunctiva and upper respiratory tract. . In cases of ILT, syncytia with intranuclear inclusion bodies can be observed in the mucosa or in the sloughed cells of the lumen most commonly in the upper respiratory tract. Similar lesions can also be seen commonly in the conjunctiva and also in the bronchi. In cases of poxvirus infection, lesions are usually seen in the upper respiratory tract and conjunctiva and the lesions are generally proliferation of epithelial cells many of which contain eosinophilic intracytoplasmic inclusion bodies. It is not uncommon to find intranuclear inclusions in the epithelial cells of the upper respiratory tract in of young turkeys.

In uncomplicated cases of mycoplasmosis in chickens and turkeys the histological lesions tend to be lymphoplasmacytic inflammation of the upper and lower respiratory tracts including the air sacs and formation of lymphoid nodules in subacute to chronic cases. Lesions due to *E. coli* in the air sacs and pleura are usually fibrinosuppurative in nature. However, *E. coli* and other bacteria such as *P. multocida, Staphylococcus aureus , M. avium* cand other bacteria causes granulomatous inflammation characterized by a focus of caseous necrsosis in the centre which in turn is surrounded by mulinucelated giant cells that are often associated with a few to numerous bacteria. Similar lesions can also be observed in the lungs and air sacs and sometiems in the syrinx due to aspergillosis associated with intralesional fungi. Congestion, edema and fibrinosuppurative inflammaiton can be seen in birds infected with *Ornithobacterium rhinotracheale*.
Pulmonary edema and congestion can also be observed in chcikens and turkeys

Below is a list of various disease agents and diseases that can cause respiratory disease in poultry primarily in chickens and turkeys:

Viruses
Infectious bronchitis - Coronavirus
Avan Paramyxovirus -1 and Newcastle disease
Avan Paramyxoviruses- 2 and 3.
Avian influenza - Orthomyxovirus
Infectious Laryngotracheitis (ILT) – Gallid herpersvirus 1.
Swollen head syndrome/Turkey rhino tracheitis – Avina Metapneumovirus.
Fowl Pox – Poxvirrus
Adenovirus (Group II in turkeys)
Reovirus
Marek's disease – Herpersvirus (lymphoma in lungs), , *etc.*
Retrovirus (J virus)

Bacteria:
Salmonella sp. (S. Pullorum/ S. Gallinarum.)
E. coli (Colibacillosis)
Mycoplasma gallisepticum
Mycoplasma synoviae
Mycoplasma meleagridis (turkeys)
Pasteurella multocida
Ornithobacterium rhinotracheale
Avibacterium paragallianrum
Bordetella avium (*B. hinzii* occasionally)
Staphylococcus aureus (tyrkey poults)
Gallibacterium anatis
Riemerella anatipestifer (Ducks and turkeys)
Chlamydophila psittaci (turkeys)
Streptococcu sp.
Pseudomonas aeruginosa
Mycobacterium avium
Others:

Fungi:
Aspergillus (*A. fumigatus, A. flavus*)
Ochroconis (Previously Dactylaria)

Parasites:
Cryptosporidiosis
Leucocytozoon sp.

Neoplasia
Lymphoma (Marek's and retroviruses)
Bronchogenic carcinoma
Metastatic adenocarcinoma from ovary, *etc.*
Hemangioma/sarcoma
Sarcoma's, adenoma's and others

Nutritional:
Vitamin A deficency

Toxic:
Ammonia
Teflon (Polytetrafluoroethylene - PTFE)
Cotton defoliants
Ionophores (degeneration of tracheal muscles)
Formaldehyde

Metabolic/genetics:
Pulmonary hypertension syndrome (Ascites)
Dilated cardiomyopathy

Others:
Trauma
Foreign bodies (plant material/feed, dust, carbon, *etc*.)
Hypersensitivity (Anaphylactic shock)
Faulty and spray vaccination
Others.

IV. Digestive System including Liver and Pancreas

Brief considerations (Intestine):
Understanding of anatomy and physiology of the gastrointestinal tract is essential.
Know the differences in the anatomy especially changes in the length of villi among duodenum, jejunum, ileum, ceca (paired), colon, rectum and cloaca.
Differences in the mucosa of colon, rectum and cloaca, esophagus and crop.
Payer's patches, cecal tonsils and Meckel's diverticulum - (GALT)
Cells in the lamina propria (lymphocytes, plasma cells, heterophils, eosinophils, APUD cells).
Blood vessels in the lamina propria, muscular layers and serosa.
Other cells: enterocytes, goblet cells, Paneth cells, M cells, intraepithelial mononuclear or lymphocytes, Microvilli.
Crypts (rapidly dividing cells), cells in the tips of the villi (mature cells) and crypt to villus ratio.
Smooth muscle layers
Myenteric plexi (nerves and ganglia).

Note: intestine is prone to rapid autolysis; collect tissues for histopathology within five minutes after euthanasia or death of the bird (especially for diagnosing AEEC, also for electron microscopy (DEM, TEM, SEM)).
Sectioning: cross section 'vs' longitudinal, open or not to open the lumen

Gross:
Serosa:
- red spots in proximal intestine (Extramedullary hematopoeisis)
- pale serosa
- distension (segmental)
- congestion/hemorrhage/ hyperemia
- enlarged Meckel's diverticulum
- parasites (round worms, tapeworms, *etc*.)

Mucosa:
- hyperemia
- hemorrhage
- increased mucus (catarrhal)
- watery contents
- edema
- fibrin, pseudomembrane, cecal cores
- necrosis
- combination of the above
- greenish (eosinophilic enteritis or autolysis, bile stain, *etc*.)

Microscopic changes:
- increased cellularity of the lamina propria (heterophils, eosinophils, mononuclear cells, giant cells…)
- hemorrhage, fibrin, thrombi
- edema
- blunting/scalloping/fusion/widening of villi
- necrosis/apoptosis (enterocytes, cells in the lamina propria)
- pyroptosis (death of macrophages)
- effacement of enterocytes (AEEC), exfoliation of enterocytes, vacuolation, *etc*.
- crypt dilation, necrosis, debris
- crypt cell hyperplasia, change in crypt to villi ratio
- goblet cell hyperplasia (PAS positive)
- lymphoid hyperplasia
- increased number of interepithelial lymphocytes
- vasculitis, fibrin thrombi, medial hyperplasia
- necrosis and inflammation of the smooth muscle layers
- serositis/peritonitis
- pigmentation (hemosiderin – iron stain)
- erythrophagocytosis
- amyloidosis
- mineralization
- neoplasia
- dilated lymphatics
- microorganisms including parasites/protozoa, bacteria, viruses and viral inclusions, fungi (candida, Macrorhabdus, zygomyces, aspergillus as an extension from airsacculitis/peritonitis).

Note: in commercial field cases; combination of etiologies or diseases is very common and almost a rule

Differential diagnoses:

Viruses and Viral Diseases:
1. Pox
2. Marek's disease (lymphoid tumors)
3. Avian Paramyxovirus -1 (END)
4. Orthomyxovirus (HPAI)
5. Herpesvirus of ducks (DVE)
6. Adenovirus type II of turkeys (HEV)
7. Coronavirus (turkeys)
8. Rotavirus (groups A and D – poult enteritis)

9. Astrovirus (poult enteritis)
10. Enterovirus (poult enteritis)
11. Reovirus (malabsorption syndrome)
12. EEE (Ratites, turkeys experimental)
13. Polyomavirus (Goose haemorrhagic nephritis – Europe)
14. Novel Birnavirus (Transmissible proventriculitis)
15. Adenovirus type I (IBH)
16. Novel Picornavirus (Turkey Viral Hepatitis)
17. Hepatitis E virus (Hepatitis Splenomegaly Syndrome)
18. Retroviruses (LL, REV, Myelocytomatosis, etc.)
19. Duck Hepatitis I (Picornavirus)
20. Duck Hepatitis II (Astrovirus)
21. Hepadnavirus (Ducks)
22. Avian Encephalomyelitis virus (Pancreas)
23. Parvovirus (infectious bill atrophy in ducklings)

Bacteria and Bacterial Diseases:

1. Salmonellosis (*S.* Ppullorum/S. Gallinarum, S. Typhimurium, S. Arizonae, *etc.*)
2. *E. coli* (AEEC, Coligranuloma)
3. *C. perfringens*
4. *C. colinum*
5. *C. sordellii*
6. Mycobacteriosis (*M. avium*)
7. *P. multocida* (ducks)
8. *Erysipelothrix rhusiopathiae*
9. *Brachispira pilosocoli*
10. *C. difficile* (ostrich)
11. *Lawsonia intracellularis (emu)*
12. Yersinia pseudotuberculosis
13. Listeriosis
14. Chlamydiosis
15. Mycoplasmosis (MG, MS)
16. Staphylococcosis
17. Streptococcosis
18. Vibrionic hepatitis
19. *Eubacterium tortuosum*
19. Others

Mycotic Diseases:

1.Candida sp.
2. Zygomyces
3. Megabacteria (*Macrorhabdus ornithogaster*, ascomycetous yeast)

Parasitic Diseases:

Protozoa

1. Coccidiosis (Eimeria sp.)
2. Cryptosporidia sp.
3. *Histomonas meleagridis* (Blackhead)
4. *Cochlosoma anatis*
5. Hexamitiasis (Spironucleus)

6. Trichomoniasis
7. Amebiasis
8. Toxoplasmosis
9. Blastocystis (Protista?)
10. Others

Nematodes

1. *Capillaria annulata, C. contorta*
2. *Capillaria caudinflata, C. obsignata*
3. *Tetrameres americana* (proventriculus)
4. *Dispharynx nasuta* (proventriculus)
5. Amidostomum sp. (gizzard)
6. *Cheilospirura hamulosa* (gizzard)
7. *Ascaridia galli*
8. *Ascaridia dissimilis* (turkeys)
9. *Heterakis gallinarum*
10. *H. isolonche*
11. *Trichostrongylus tenuis*

Cestodes and Trematodes

1. *Davainea proglottina*
2. *Raillietina tetragona*
3. *R. echinobothridia* (nodules in intestine)
4. *Amphimerus elongatus* (fluke in liver, pancreas and bile ducts of ducks and turkeys)
5. Schistosoma sp. Many species of billharzia (medial hypertrophy of vessels in the intestine of waterfowl)

Nutrition:

1. Vitamin A deficiency (squamous metaplasia)
2. Fine feed (oral ulcers)
3. Vitamin E (gizzard myopathy)
4. Selenium (pancreatic fibrosis)
5. Biotin (Hepatic and renal lipidosis)
6. Methionine ?(Hepatic lipidosis in turkeys)
7. Hemorrhagic fatty liver syndrome (nutrition?)
8. Manganese (Short beak)
9. Niacin (black tongue)

Neoplasia:

1. Lymphoma of virus induced (Marek's, LL, REV, etc.)
2. Squamous cell carcinoma
3. Salivary gland adenocarcinoma
4. Proventricular adenocarcinoma
5. Myxosarcoma (gizzard)
6. Intestinal adenocarcinoma
7. Bilary carcinoma
8. Metastatic adenocarcinoma (ovary/oviduct)
9. Hemangiosarcoma
10. Others

Toxicity:

1. Quaternary ammonium

2. Copper and copper sulfate
3. Trichothecene mycotoxins (T2)
4. Dicalcium phosphate
5. Photosensitization
6. Cantharidin (blister beetle consumption in Emu's).
7. Hypersalinity (ducks on hypersaline lakes)
8. Arsenic, organic
9. Lead (dilation of crop/proventriculus due to vagus degeneration, gizzard erosions)
10. Zinc (gizzard erosions)
11. Biogenic amines (gizzerosine – gizzard erosions)
12. Vitamin D (soft tissue mineralization - proventriculus)
13. Selenium (beak deformity)
14. Phenol and chlorinated hydrocarbons (including PCB's and PBB's)
15. Aflatoxins
16. Fumonisin
17. Rodenticides (Diphacinone, zinc phosphide, *etc*.)
18. Ethoxyquin (phorphyrin in liver)
19. Others

Others:

1. Amyloidosis
2. Visceral urate deposition (gout)
3. Iron storage disease
4. Protophorphyrin accumulation
5. Hepatic fibrosis (ascites syndrome, right heart failure, constrictive pericarditis)
6. Mucopolysacchridosis type IIIB (Emu)
7. Traumatic ventriculitis (foreign body)
8. Cloacal/intestinal prolapse (Cannibalism, rodents)
9. Crop/esophagus impaction
10. Improper beak trimming (neuroma)
11. Pendulous crop
12. Anomalies
13. Others

V. Nervous system:

Malformations:
Encephalocele (Silky, Polish, *etc*.)
Hydrocephalus
Hydranencephaly
Cerebral/cerebellar Hypoplasia

Metabolic/genetics:
Peripheral neuropathy (WLH chickens – *B*19* haplotype)
Mucopolysaccharidosis type IIIB – Emu's
Paroxysmal chicks
Congenital Loco
Scoliosis

Epilepsy (Silky, Fayoumi)
Hypoglycemia

Bacteria:

Salmonella sp. (S. arizonae, S. Pullorum, S. Typhimurium, etc.)
E. coli
Clostridium botulinum
Mycoplasma gallisepticum
Mycoplasma synoviae
Riemerella anatipestifer
Chlamydophila psittaci
Enterococcus hirae
Listeria monocytogenes
Pasteurella multocida
Ornithobacterium rhinotracheale
Staphylococcus sp.
Streptococcu sp.
Pseudomonas aeruginosa

Viruses

Avian influenza - Orthomyxovirus
Avian encephalomyelitis - Picornavirus
APMV-1 – Newcastle disease
Marek's disease - Herpersvirus
Reticuloendotheliosis group – Retrovirus
Avian Lymphoid Leukosis group – Retrovirus (RAV-4, ALV-J)
ALV- A (cerebellar hypoplasia, glioma, astrocytoma)
Reovirus
Parvovirus (cerebellar hypoplasia)
Bunyavirus (ostrich)
EEE – Alphavirus
WEE – Alphavirus
Highland J virus - Alpha virus
Israel turkey meningoencephalitis virus – Flavivirus
West Nile virus (geese) - Flavivirus

Fungi:

Aspergillus (*A. fumigatus, A. flavus*)
Ochroconis (Previously Dactylaria)
Zygomyces

Parasites:

Sarcocystis
Toxoplasma
Trichomonas
Malaria
Haemoproteus (Quail)
Cerebrospinal nematodiasis
Schistosoma

Neoplastic

Lymphoma (Marek's)

Glioma's (Retrovirus)
Pinealoma
Astrocytoma (Retrovirus)
Choroid plexus carcinoma

Nutritional:
Vitamin E
Vitamin B1
Vitamin B2
Vitamin B6
Thiamin
Pantothenic acid
Folic acid
Biotin
Vitamin B12

Toxic:
Salt
Organophosphates
Carbamates
Hydrocarbons
Lead
Ionophores (Monensin, Lasalocid)
Arsenilic acid
Zinc
Mercury
Amprolium
Dinitolomide (coccidiostat)
Avian Vacuolar Myelinopathy (*Hydrilla sp.*)
Poison Hemlock

Others:
Trauma
Faulty vaccination (in the neck/thigh)
Degenerative Myelopathy
Spondolisthesis
Spondylitis
Vascular problems

Etiologies for Neuritis in Chickens:

Viruses/diseases:
Marek's disease (Herpesvirus)
Retroviruses: Reticuloendotheliosis virus and ALV – J
Newcastle disease (END) - Avian Paramyxovirus-1
Highly pathogenic Avian Influenza (Orthomyxovirus)
Avian Encephalomyelitis (AE – Picornavirus)
Reovirus (CNS signs)
Bacteria: rare
Parasites: Toxoplasma

Nutritional:
Riboflavin (B2)
Thiamin (B1)
Perosis (Niacin, pantothenic acid, Vit. B12)
Others?
Toxic:
Lead, mercury, organic arsenicals
Organo phosphates, Chlorinated hydrocarbons
Ionophores – Lasalocid, Monensin
Genetic:
Peripheral neuropathy (WLH chicken, *B19* haplotype)
Others:
Faulty vaccination

VI. Special Senses:

Birds in general have excellent visual and good auditory systems. They also have sense of smell (olfaction), taste (gustation), chemicals (chemesthesis mediated by trigeminal chemoreceptors), temperature and pressure mediated through various receptors. There are various receptors and types of corpuscles dsitributed thorugh out the body more numerous in some locations like skin, tongue, oral cavity, face, beak, head, *etc*. Four types of mechanosensitive sensory corpusles are found mostly in the skin of birds. These include Herbst corpuscles (similar to Pacinian corpuscles in mammals) most common in the skin, Merkel cell receptors, Grandri corpuscles in aquatic birds and Ruffini endings. There are also free nerve endings in the skin which are thought to serve thermoception and nociception (pain). Other than the pathology of visual and auditory senses very little is known about the pathology of other senses in birds.

A Bird's Eye View of Avian Ocular Anatomy and Diseases:
Characteristics

- Finest ocular organ in the animal kingdom
- Birds can recognize constellations for stellar orientation and navigation
- Have high resolving power for the perception of movements
- Excellent visual acuity
- Displays basic pattern of organization found in vertebrate eyes
- Has incorporated many adaptations to improve its visual abilities
- Birds are capable of
  - color discrimination (Tetrachromatic color vision)
  - pattern recognition
  - vision in bright and dim light
  - under-water accomodation
  - sun orientation
  - UV light perception
  - spatial frequency (160 frames per second)

1. Anatomy –salient features

- Eyeball is accommodated in the spacious laterally directed orbit

- Its bony limits are formed by the lacrimal bone, the interorbital septum, the orbitosphenoid and the *parsorbitalis* of the orbital bone
- There is a gap in the orbital ring, which is bridged by the ligamentum mandibulare longum
- Eyes are large and their shape can be flat, globose and tubular
- Scleral ossicles and cartilage present
- Striated muscles in iris and ciliary body
- Pectinate ligament is well developed
- Retina is thicker and has areas and fovea(s)
- Avascular (anangiotic) retina
- Afoveate, uni- or bifoveate retina
- Annular pad and a fluid-filled cleft in the lens
- Pecten is present
- Has large nictitating membrane
- Glandula lacrimalis, small or absent
- Gland of Harder present in the orbit, contains plasma cells in the interstitium
- Nasal gland present in the orbit
- There is no tapetum
- Conjunctiva associated lymphoid tissue (CALT)

a. Eye size

- Avian eye is both relatively large and absolutely large
  - are large relative to the skull and has large orbit with displacement of the brain caudally
  - in a few birds, the combined weight of the eyes is greater than the weight of the brain
- Largest eye of land vertebrates: ostrich
  - has bulbar axial length : 50 mm
- Finches and warblers: 6 - 8 mm

b. Eye shape

- Three types:
  - **Globose**: diurnal species; crow
  - **Flat**: majority of avian species
  - **Tubular**: owls and some eagles
- Difference lies in the relative proportions of their axial and equatorial diameters
- Tubular eyes have the greatest visual acuity

c. Components

Eyeball (globe)

- Made up of three tunics:
  - External fibrous tunic - cornea and sclera
  - Middle vascular tunic (uvea) - iris, ciliary body and choroid

- Internal sensory tunic - retina

- Pectinate ligament
- Refractory media:
  - Cornea
  - Aqueous humor
  - Lens
  - Vitreous body

External Fibrous tunic

- **Sclera**
  - Consists of a cartilaginous lamina and a fibrous layer
  - Cartilaginous lamina attaches to the posterior portion of the scleral ossicles
  - Scleral ossicles:
    - ✓ Are a group of bones, which form a complete ring of overlapping plates.
    - ✓ Vary in number between 10 - 18, majority have 15
    - ✓ Can be pneumatic in large eyes and vary in shape
    - ✓ Reinforce the ciliary body
    - ✓ Permit a more powerful accommodative function

- **Cornea**
  - Is a refractive component made up of several layers:
    1. The multilayered anterior epithelium
    2. The anterior limiting membrane
    3. The Bowman's layer
    4. The substantia propria
    5. The posterior limiting membrane
    6. The single layer posterior epithelium

Middle vascular tunic (tunica media)

- **Iris** - Regulates amount of light
  - It is situated in front of the lens
  - It projects into and divides the space behind the cornea into anterior and the posterior chambers
  - Anteriorly covered by a single layer of epithelium
  - Posteriorly covered by two to several layers of pigmented epithelium.
  - Iris (cont)
  - The anterior and posterior layers enclose blood vessels, connective tissue and striated muscle fibers
  - Two layers of muscle fibers; circular constrictor and radial dilator fibers
  - Color in iris
    - ✓ Dependent on amount and color of fat

- **Ciliary body -** Accommodation
  - It is interspersed between the choroid and the iris
  - It is a ring-shaped plate, which carries numerous little folds, the ciliary processes
  - Its basal lamina contains muscles of accommodation and is attached along with the pectinate ligament to the sclera
  - It contains numerous blood vessels and the stroma contains pigmented connective tissue
  - The ciliary processes as a whole form the corona ciliaris, gradually increase in height towards the lens and fuse with the lens capsule

- **Choroid** - nourishes retina
  - It is a black pigmented layer, which lines the greater part of the eyeball. It is made up of several layers:
    1. *Lamina suprachoroidea* - a loose structure containing pigment cells. It connects choroid to the sclera
    2. *Lamina vasculosa* - carries large blood vessels
    3. *Lamina capillarium* - has dense capillary network
    4. *Lamina basalis* - basal lamina

Internal sensory tunic

- **Retina**
  - It is similar to other vertebrates in its organization and stratification
  - It is avascular in birds
  - It is a direct continuation of the brain and it consists of two parts:
    1. An external nonsensory single layer of cuboidal epithelium containing pigment
    2. An internal transparent, much thicker neuroepithelium, containing several types of neurons and glial cells
  - Retina is relatively thicker in birds compared to other vertebrates (ten distinct layers):
    1. The inner limiting membrane
    2. The nerve fiber layer
    3. The ganglion cell layer
    4. The inner plexiform (reticular) layer
    5. The internal nuclear layer
    6. The external plexiform (reticular) layer
    7. The external nuclear layer
    8. The external limiting membrane
    9. The layer of rods and cones
    10. The pigment cell layer
  - It has fascinating array of photoreceptors, specialized areas, fovea(s), oil droplets, visual pigments, and centrifugal fibers
    - ✓ Areas represent as circumscribed thickenings of the sensory retina
      - Involves thinner and longer visual cells
      - Helps in improved resolving power (visual acuity)
      - Are well-developed in diurnal birds
      - Can be present as single or two and sometimes three
      - Are located in central (nasal) and lateral (temporal) areas
      - Shape can be oval or circular and linear
    - ✓ Fovea is a depression within a central or lateral area or both
      - Area may exist without a fovea, but a fovea is found only within an area
      - Foveas are caused by a radial displacement of the more internal layers of the retinal area
      - Results in shallow saucer-shaped or deeper funnel-shaped (convexiclivate) cavities
      - Visual cell density is greater in the fovea than elsewhere in an area
      - A 1:1 ratio between cones and ganglion cells can exist
      - Deeper the fovea, the greater the magnifying power
      - It is a sensitive directional focus indicator and may indirectly help in navigation

- **Pecten** (pecten oculi)
  - Is unique to birds
  - It is a vascular body projecting from the retina into the vitreous body at the point of exit of the optic nerve

- It consists almost exclusively of capillaries and extravascular pigmented stromal cells
- It lacks both muscular and nervous tissue
- Types of pecten
- Three main morphological types of pecten are recognized:
  1. **Conical**: recognized only in kiwis
  2. **Vaned**: ostrich, rheas and tinamous
  3. **Pleated**: rest of the avian species
- Functions of the pecten: Controversial. Some of the proposed functions are:
  1. **Nutritional** – appears to be the primary function
  2. Heating element of the eye
  3. A movement detector by means of perceiving small shadows
  4. A screen against bright light
  5. A regulator of intraocular pressure
  6. A sensor of magnetic fields
  7. Improvement for visual acuity
  8. A sextant to measure the angle of the elevation of the sun
  9. Secretion (GAG's)
  10. Many others have been proposed

Pectinate ligament

- An extensive trabecular elastic fiber network better developed in avian species than in mammals
- This network bridges the angle between the cornea and iris and sclera and ciliary body
- The network is lined by endothelium and it encloses the space of Fontana, which forms the connection between the chambers of the eye and the canal of Schlemm
- Canal of Schlemm is a circle of veins within the sclera by which aqueous humor is returned to the blood circulation

Refractory media

- **Cornea** (*see above*)
- **Lens**
  - Transparent and biconvex
  - Posterior surface more convex than anterior surface
  - Shape can be altered and has a homogenous capsule
  - Anterior surface has a single layer of cuboidal or columnar epithelium, which increase in length towards the equator until they finally become hexagonal prisms
  - These prisms combine to form the annular pad, which surrounds the equator of the lens like a belt
  - Fully mature prismatic cells retain their nuclei, whereas cells forming the body of the lens lose their nuclei as they develop into the elongated lens fibers
  - Fluid-filled cleft is present between the annular pad and the body of the lens
- **Vitreous body**
  - It is a gelatinous transparent body, which fills the space in the bulbus behind the lens and the ciliary body
  - Its function is to stabilize the internal pressure of the bulbus
  - Its fluid component amounts to more than 90% of its total mass
  - The stroma consists of delicate branching fibrils which condense to form the membrana vitrea

Optic nerve

Accessory organs

- Eyelids
  - Feathered (e.g., ostriches, rheas, and owls) or unfeathered in pigeons, parrots and passeriformes
  - Two eyelids
    - ✓ Upper eyelid
      - Short and thick
    - ✓ Lower eyelid
      - Longer, thinner, and highly mobile
      - Supported by a connective tissue plate situated between the skin and conjunctiva
  - Nictitating membrane (third eyelid)
    - ✓ It is a conjunctival fold, transparent to opaque and milky white in color
    - ✓ It is elastic and forms a pouch in which eye sits
    - ✓ The membrane moves transversally across the front of the eye
    - ✓ In pigeons, the corneal surface has cilia, which act as a delicate brush
- Glands
  - Gland of the nictitating membrane (Harder's gland)
    - ✓ Gland is large and irregular in shape and extends on the nasal side of the orbit
    - ✓ It secretes into the space between the eyeball and the nictitating membrane, the conjunctival sac
    - ✓ Has large number of plasma cells in the interstitium producing antibody
  - Nasal or salt gland: present in the orbit but not a part of the lacrimal apparatus (supraorbital gland - marine birds)
    - ✓ Lies dorsomedially to the eyeball and it is ovoid and yellowish
    - ✓ Its duct pierces the frontal bone and enters the nasal cavity
    - ✓ It excretes hypertonic salt solutions, presumably through a stimulus from the osmolality of the plasma
- Lacrimal apparatus or gland
  - Located in the ventrotemporal part of the orbit and is covered by conjunctiva
  - Its secretion empties directly beneath the lower eyelid
  - It may have single duct or multiple ducts
  - It is small in aquatic birds, large in others and absent in owls
- Orbital fasciae
- Oculomotor muscles
  - Four straight - globe
  - Two oblique - globe
  - Several - eyelid
- Conjunctiva associated lymphoid tissue (CALT)
  - Component of mucosal immunity
  - Appears shortly after hatching
  - Located most prominently in longitudinal folds and fissures of the lower eyelid
  - Some present in the upper eyelid especially clustered around the opening of nasolacrimal duct
  - Composed of lymphoid nodules bound by epithelium on one side
  - Epithelium is comprised of flat cells containing intraepithelial lymphocytes and lack goblet cells

2. Avian Eye - Pathology

a. Introduction

- It has not received extensive study by veterinarians/pathologists. Reasons:
  - Few primary ocular conditions
  - Lack of knowledge of eye diseases, clinical and pathological
  - Unique structure of the avian eye, different terminology
  - Eye size in relation to body size
  - Extra organ to deal with
  - Difficult to take out, lengthy processing, needs decalcification of scleral ossicles
  - Does not explain cause of death or problem
  - Prone to autolysis

b. Clinical Signs

- Eye - dullness, hyphema, hypopyon
- Conjunctiva - reddening, lacrimation, ocular discharge (exudate)
- Eyelids - swelling, blepharospasm, photophobia (closing)
- Size of the globe - micro and macro
- Aqueous flare, corneal opacity/ulcers, cataracts and inflammation
- Blindness - running in to objects

c. Mydriasis

- Difficult to achieve because of striated muscles in iris, compounds used include:
  - Tubocurarine - injection was effective but not topical (partial)
  - Vecuronium bromide - topical was effective
  - Alcuronium chloride - topical was effective but resulted in paralysis
  - Pancuronium bromide - topical, inconsistent
  - General anesthetics; ketamine and xylazine, very effective

d. Avian Eye – Fixation and processing

- **Fixatives**
  - Boun's solution (Picic acid, glacial acetic acid and formaldehyde)
  - Alcohol (Absolute alcohol, chloroform, glacial acetic acid)
  - 10 % neutral buffered formalin, most practical fixative
  - For better fixation formalin may be injected in to larger eyes
  - Harden eye in a series of alcohols at concentrations (50 %, 75 % and 95 % for 24 hours each)
  - Trim the eye to a suitable size and place it in decalcifying (of scleral ossicles) solution for 1 to 2 days depending on the size of the eye and the species of the bird
  - Trim from posterior (keeping optic nerve in the middle) aspect to the middle of cornea
- Processing and sectioning
  - Most difficult organ to section, every effort should be made to reduce creation of artifacts
  - Retinal detachment common

Avian Eye - as models

- Accommodation
- Myopia

- Glaucoma
- Developmental/Genetics
- Teratology
- Disease

Genetic models

- Chicken
  - Microphthalmia
  - Retinal dysplasia
  - Keratoconus
  - Hyperplastic lens epithelium
  - Coloboma of iris
  - Cataracts
  - Ocular anomalies
- Japanese quail:
  - Ring retina
  - Scleral ectasia
  - Glaucoma
  - Cataract
- Slate turkey
  - Secondary angle closure glaucoma
- Canary
  - Cataracts
- Pigeon
  - Microphthalmia
- Emu
  - Mucopolysaccharidosis type IIIB (Sanfilippo B syndrome)

Microphthalmia

- Four models
  - Barred Plymouth Rocks, autosomal recessive, lethal gene
  - Brown Leghorns, dominant with incomplete penetrance, failed to survive to maturity
  - New Hampshire, autosomal recessive
  - Mutant chickens, autosomal recessive

Retinal Dysplasia

- Many models:
  - Smyth chicken (Delayed Amelonotic - DAM)
    - ✓ Used as model for vitiligo and others
  - Rods and cones (rc/rd)
  - Partial dysplasia and degeneration (rdd)
  - Blindness, enlarged globe(Beg)
  - Retinopathy (rt)
  - Retinal dysplasia in B-line(rd-B)

e. Anomalies of the Avian Eye

- Microphthalmia/anophthalmia
- Optic nerve hypoplasia/atrophy
- Corneal edema, corneal and scleral ectasia
- Cataracts, cystic spaces in lens, aphakia
- Retinal dysplasias
- Eyelid malformations
- Others; scleral ossicles anomaly
- Albinism

Causes

- Genetics
- Nutrition
- Toxicity
- Environment
  - Temperature
  - Humidity
  - Turning of eggs, position of eggs
  - Oxygen supply
  - Overcrowding and others

f. Bacterial diseases

- *E. coli*
- *Salmonella* sp. (*S. arizonae*, *S. typhimurium*, *S. pullorum*)
- *Chlamydophila psittaci*
- *Mycobacterium* sp. *(avium, genavense and tuberculosis*)
- *Mycoplasma* sp. (MG, MS, *etc.*)
- *Pasteurella multocida*
- *Ornithobacterium rhinotracheale*
- *Bordetella avium* (turkey coryza)
- *Avibacterium* (*Haemophilus*) *paragallinarum* (chicken coryza)
- *Riemerella anatipestifer*
- *Staphylococcus* sp., S*treptococcus* sp.
- *Pseudomonas aeruginosa*
- *Erysipelothrix rhusiopathiae*
- Others: *C. botulinum, Gallibacterium anatis. Corynebacterium, Klebsiella, Yersinia, Nocardia, Listeria*, Coxiella sp., etc.

g. Fungal diseases

- Aspergillosis: *A. fumigatus, A. flavus*
- Candidiasis: *C. albicans*, etc.
- Ochraconosis (Previously Dactylariosis): *D. gallopava*
- Favus: *Microsporum gallinae*
- Others: *Histoplasma encapsulatum, Cryptococcus neoformans, Malassezia* sp. *etc.*

h. Viral Diseases

- Pox - pox virus
- Newcastle disease - Avian paramyxovirus -1 (APMV-1)
- APMV-3 of psittacines and passerines
- Psittacine herpesviruses
- Herpesvirus (cytomegaly) of Finches
- Polyomavirus of psittacines and passerines
- Circovirus of pigeons and psittacines
- Marek's disease – herpesvirus
- Retroviruses – J subgroup of ALV, RE virus
- Duck viral enteritis - herpesvirus
- Infectious laryngotracheitis - herpesvirus
- Avian encephalomyelitis - picornavirus
- Avian influenza - orthomyxovirus
- Infectious bronchitis - coronavirus
- Parvoviruses of ducks and geese
- Papillomavirus
- Metapneumovirus
- Adenovirus
- West Nile Virus
- Avian Bornavirus (PDD)
- Reovirus, *etc*.

i. Parasitic diseases

- *Oxyspirura mansoni* (nematode)
- *Philophthalmus gralli* (trematode)
- *Toxoplasma gondii*
- *Leucocytozoon* sp.
- *Sarcocystis* sp.
- *Cryptosporidia* sp.

- *Trichomonads*
- Others: Atoxoplasma-like, Microsproidia, Hemoproteus, Hemosporozoa, *Plasmodium* sp. *Histoplasmodium*, Filaria, Mites, Cyathostoma, Schistosoma, *etc*.

Others (Protista): Rhinosporidiosis: *R. Seeberi*

j. Nutritional diseases

- Vitamin A deficiency
- Vitamin E deficiency
- Pantothenic acid deficiency
- Biotin deficiency
- Zinc deficiency
- Others: Tyrosine

k. Toxicities

- Ammonia
- Vitamin A
- Ionophores
- Heavy Metals (lead)
- Spring Parsley and other plants
- Ammeline
- Quaternary ammonium
- Others; Hydrogen peroxide, Sulfur, Kerosene, Warfarin, Creosote, Glycine, *etc*.

l. Neoplasia

- Not common
- Lymphoma (Marek's disease virus)
- Sarcoma, J virus
- Carcinoma
- Melanoma, retinoblastoma, medulloepithelioma
- Others; Papilloma, osteosarcoma, *etc*. Extension of carcinoma of adenohypophysis

m. Trauma

n. Diseases of genetic or unknown etiology

- Microphthalmia/anophthalmia
- Retinal dysplasia
- Cockatiel conjunctivitis
- Lovebird eye disease
- Mynah bird keratitis

- Amazon punctate keratitis
- Cataracts
- Glaucoma
- Amyloidosis
- Gout
- Eyelid malformations
- Cryptophthalmia (Atresia of eye lids – bilateral, eyelids reduced in length, but normal in conformation, lack of palperbral fissures. Most common in cockatiels, members of same clutch,
- Retinal detachment in Pheasants
- MPS type IIIB (Sanfilippo B) in Emu's
- Amelanotic eye in turkeys and chickens
- Intraocular ossification (chickens)
- Blepharoconjunctivitis in turkeys
- Eye-notch syndrome in chickens
- Cataracts and optic nerve hypoplasia in turkeys
- Conjunctivitis and uveitis in chickens
- Others; Synophthalmia, Scleral inclusion cysts, Conjunctival cysts, Corneal dystrophy, Crystalline deposition in Cornea, *etc*.

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Bird Ear: anatomy and diseases:

1. **Avian hearing characteristics**
    a. Hearing after vision, second most important sense in birds
    b. Warning, social and detecting prey
    c. Songbirds have the most complex auditory communication signals
    d. Hunting owl has the best acuity in acoustically locating a target in three-dimensional space

2. **Avian Ear. Not well studied because;**
    a. Difficult to access (except external ear)
    b. Does not explain cause of clinical signs (except neurological) or death
    c. Complex anatomy of the inner ear
    d. Difficult to trim and process, needs decalcification
    e. Extra organ to deal with
    f. Diseases not well known or described

3. **Avian Ear – used as a model to study**
    a. Effect of sound/noise on ears
    b. Ototoxicity
    c. Hair cell regeneration
    d. Genetic conditions

4. **Anatomy: External, Middle and Internal Ears**

External Ear:

a. No external sound-collecting structures (aerodynamically disadvantageous)
b. Openings located ventral and caudal to eye
    – exception woodcock and snipe (ventral to eye)
c. Openings asymmetrical in nocturnal birds
d. Ear opening covered by auricular feathers
    – exception Casuariformes, some vultures and ibises
e. Short canal extending vertically and caudally from external acoustic meatus to tympanic membrane
    – acoustic meatus very large in owls, communicates with air spaces
f. In diving birds very narrow and can be closed
g. Lined with epidermis and contains glands that secrete waxy material
    – number of glands, up to 25?
h. Lymphoid tissue, normal (External Ear Assoc. Lymphoid Tissue – EEALT?)
i. Tympanic membrane:
    – separates the external from middle ear, convex in birds
    – external surface epidermis, internal surface epithelium

Middle Ear:

a. Air filled funnel-shaped cavity between tympanic membrane and inner ear
    – connects to oropharynx via Eustachian (auditory) tube

- communicates with air cavities
- communicates with left and right tympanic cavities via air sinuses (esp. in owls)
- lined by cuboidal epithelium

b. Contains single rod-like ossicle called columella (similar to stapes in mammals)
- extends across tympanic cavity
- forms direct connection between tympanic membrane and perilymph of inner ear
- is composed of bone and cartilage (similar to stapes in mammals)
- rod-like body terminates in a flat oval base in the vestibular window
- Paratympanic organ also present (contains hair cells, may act as a baroceptor)

Inner Ear:

a. Composed of Bony and Membranous labyrinths, and Vestibular and Cochlear organs
b. Bony labyrinth is formed by spongy bone
- cavity of bony labyrinth encloses membranous labyrinth

c. Membranous labyrinth:
- surrounded by perilymph and contains endolymph
- contains semicircular canals, utriculus, sacculus
- contains sensory areas of thickened epithelium; maculae, crests, papillae

d. Vestibular organ - equilibrium
- system of receptors sensitive to head movements
- Includes utriculus, sacculus and lagena

e. Cochlear organ - hearing
- short and slightly curved, larger in owls
- cochlear duct filled with endolymph
- contains sensory epithelium (basilar papilla)
- basilar papilla consists of ciliated hair cells and supporting cells

5. Causes of Ear Problems in Birds: Most neglected area and organ

a. Infectious
- Bacteria, viruses, fungi, parasites

b. Noninfectious
- Genetics, sound/noise, nutritional, toxic, trauma, plant material, tumors

c. Hemorrhage
d. Failure to open external auditory meatus

6. Clinical Manifestations of Ear Problems in Birds

a. Can vary from none to severe
b. Primarily neurological
- middle and inner ear infections

c. Discharge from external ear
d. Anorexia, ill thrift, loss of weight, weakness, *etc*.

7. Diagnosis:

a. Clinicians: can use endoscope/otoscope to examine the external ears.
Dr. H. Wilson diagnosed bacterial otitis externa in 7/229 neonatal macaws by use of otoscope which were other wise not suspected (2000 AAV proceedings).
Difficult to diagnose otitis media and otitis interna.

b. Pathologists: cut across the lower bone coronal keeping external ears just in front, requires decalcification and proper trimming and sectioning, difficult to section the external, middle and inner ears on the same plane. Occasionally one can section brain

along with the ears to see extension of inflammation of the meninges to the vestibulocochlear nerve and inner ear. Anatomy of inner ear is complex and all parts may not be present in the same section and will require step cutting.

8. Specific causes of otitis in birds

Infectious- Bacteria

E. coli, Pseudomonas sp.
P. multocida, Riemerella anatipestifer
Salmonella sp. (*S. arizonae*)
Staphylococcus/ Streptococcus
Mycoplasma sp., Klebsiella sp.
Mycobacteria sp., Chlamydophila
Enterococcus sp. *Proteus mirabilis,*
Chlamydophila psittaci
Others.

Infectious – Viruses

Avian Paramyxoviruses (1 and 3).
- APMV-1 in pigeon's otitis interna can be the only lesion
- APMV-3 in passerines and psittacines

Marek's disease (Herpesvirus)
Polyomavirus (otitis interna)
Psittacine Herpesvirus
Pigeon Herpesvirus
Poxvirus (otitis externa and otitis media)
Avian Encephalomyelitis – Picorna virus
Proventricular Dilatation Disease – Avian Bornavirus
Others

Infectious - others

Fungi:
Candida
Trichophyton gallinae (Favus)
Others

Parasites

Cryptosporidia
Mites
Protocalliphora avium (Diptera) in the external ear canals of raptors
Other fly larvae
Others

Non Infectious Diseases

Anomalies (Failure to open – external ears)
Nutritional - Vitamin A deficiency (Squamous metaplasia of glands in external ear), others?
Toxicities: Aspirin, Retinoic acid, aminoglycosides, Enrofloxacin
Tumors – rare.
Hemorrhage – middle ear. Real or agonal?
Plant material – very common in external ear, can carry bacteria and debris.
Photosensitization (Parsley induced) in ostriches

Trauma
Xanthoma – common in cranial (bone) air spaces
Genetics (Basilar papillary dysplasia in Belgian Water Slager canaries, audiogenic and photogenic reflex epilepsy in Fayoumi chickens)
Others

9. Otitis Externa: is very common

a. External ear continuous with the skin externally
   i. Prone to entry by various infectious and non infectious agents through the external opening.
   ii. Changes such as acanthosis, hyperkeratosis, epidermitis/dermatitis, ulcers, *etc.* are common
   iii. Glands can go hyperplasia/hypoplasia, vacuolation, squamous metaplasia (vitamin A deficiency), *etc.*
   iv. Bacterial diseases are most common but pox virus (chickens), herpesvirus (pigeons/doves), fungi, mites, larvae of flies can gain entrance.

10. Otitis Media: is common

a. Middle ear infection can extend from the Eustachian tube or from the external ear. Extension from inner ear (otitis externa) is very rare.
   i. Inflammation of the air spaces of the surrounding bone is also common
   ii. Otitis media due to *Pasteurella multocida* (also called cranial form of fowl cholera) is common in turkeys and chickens.
   iii. Other bacteria can also gain entrance through oropharynx.
   iv. Poxvirus (Canaries) and herpesvirus (psittacines) have also been observed.
   v. Hemorrhage common but difficult to determine if real or agonal?
   vi. Xanthoma of the air spaces (bone marrow-cranium) common.

11. Otitis interna: not uncommon.

a. Inflammation of the brain can extend in to the inner ear through the VIIIth cranial nerve.
b. Extension from middle ear is rare.
c. Other modes; septicemia or viremia
   i. Otitis interna due to APMV-1 in pigeons and due to APMV-3 in psittacines and passerines is common.
   ii. Bacterial infections such as due to *S. arizonae* in turkey poults are common.
   iii. Other viruses and bacteria can also cause otitis interna
   iv. Ganglionitis of the vestibulocochlear ganglia is common due to various viral diseases.

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VII. Integumentary System (Skin and Feathers): Anatomy and Diseases

A) Avian Integument – Introduction

Forms the external layer of the body and is composed of skin, feathers and other structures

- Skin and Feathers – unique structures with many adaptations
  - – Feathers – Unique to birds and are a prominent feature of birds anatomy
    - √ Variation in color and types
    - √ Insulation, flight, appearance, camouflage, secondary sexual characteristics, water repellent
    - √ Use in culture, religion, human use, *etc*.
- Other Structures – include beak, nails, comb, wattle, snood (turkeys), ear lobes, cere, shields (coots, gallinules), knob (goose), casque (cassawaries), helmet (guinea fowl), modified comb such as head plumage (crests, bristles), scales (shank and feet), webbing in feet (ducks), foot pads and glands (uropygial gland near the tail and glands in the external ear)
- Skin, beak, nails and feathers – present in all birds.

These vary in pigmentation, shape, texture, function, location and number

B) Anatomy – Salient features

- Structure
  - – Epidermis
    - √ *Stratum corneum*

    - √ *Stratum germinativum*
    - √ *S. transitivum*
    - √ *S. spinosum*
    - √ *S. basale*
- Dermis
  - – Superficial
  - – Deep
    - √ *S. compactum* (dense layer)
    - √ *S. laxum* (loose layer; apterial muscles)
  - – Loose dermis permits accumulations of fluid (edema), blood (hematoma), and exudate (cellulitis) beneath the epidermis
  - – Herbst corpuscles (pressure receptors) present in dermis adjacent to feathers
  - – Subcutis (subcutaneous fat and muscles)
  - – Fat pads found in specific areas of body
  - – Vascular beds in dermis of legs for heat conservation
    - √ Penguins brood eggs on feet
  - – Erectile tissue often present in facial appendages

- Characteristics of avian skin
  - – Feathers instead of hair, feathered (pterylae) and unfeathered tracts or regions (apteria)
    - √ *Remiges* (primary and secondary flight feathers)
    - √ *Tectrices* (contour feathers that cover the bases of the flight feathers)
    - √ *Rectrices* (tail feathers)
  - – No adnexal glands; uropygial (preen) gland at base of tail (holocrine, not present in all avian species), cerumen glands in ear canal, few glands around vent; entire skin surface is secretory
  - – Thin; rete pegs absent or reduced except at certain dermo-epidermal junctions
  - – Scales (scutes [*scuta*], scutella, reticula, cancella), horny structures, and appendages (wattles, snood, comb, ear lobes, etc.)
- Specialized areas of integument
  - – Rictus – commissure of beak
  - – Facial appendages; highly vascularized, erectile, heat exchange, display
  - – Foot pads; spurs (*calcaria*); claws (*ungues*), scales (*podotheca* – unfeathered, scaled skin of the foot)
  - – Beak (*rhamphotheca*) – thick keratin and free and keratin-bound calcium
    - √ Cere – base of upper beak
    - √ Egg tooth – on tip of beak of newly hatched bird
  - – Sensory receptors
    - √ Herbst corpuscles – mechanoreceptors, numerous in beak
    - √ Grandry corpuscles (beak tip, aquatic birds)
    - √ Merkel cells
  - – Brood patches – highly vascularized area in abdominal skin; present in both males and females
- Feathers
  - – Invagination of epidermis into dermis
  - – Arrangement
    - √ Pterylae – feather tracts
    - √ Apterylae – area without feathers
    - √ Pterylosis – implantation point of each feather follicle in the skin
  - – Types
    - √ Contour – majority of the body
    - √ Coverts – on the wings, tail and around ears
    - √ Remiges – primary and secondary feathers of wings
    - √ Retrices – large flight feathers of the tail
    - √ Downs – small and fluffy feathers with a very short or absent rachis . Natal downs are

present at or soon after hatch. Definitive downs occur on various parts of the body as part of immature and adult plumage.
- √ Powder downs - specialized down feathers that disintegrate producing powder (keratin). Not present in all birds.
- √ Semiplumes – feathers with a long rachis
- √ Bristles – stiff, tapered rachis with no barbs
- √ Filoplumes – fine hair-like feathers

– Structure
- √ Calamus (quill)
- √ Rachis (shaft)
- √ Vane
  - → barb
  - → barbule
- √ Dermal papilla, epidermal collar
- √ Umbilicus (proximal, distal also superior, inferior)
- √ Pulp caps

– Degeneration, necrosis, edema, and hemorrhage normal immediately subjacent to pulp cap; inflammation in deeper pulp is abnormal

- Sternal bursa – synovial structure in subcutis over anterior keel of chickens and turkeys (see musculoskeletal system), develops with age
- Functions of integument
  - – Resistance to infection; normal avian skin remarkably resistant
  - – Temperature control (cooling primarily via respiratory system)
  - – Display – mating, social rank, *etc*.
  - – Flight; diving
  - – Sensory perception

C) Diseases

- Has not received extensive studies nor well characterized

Reasons:

Wide variation in anatomy of skin and its appendages
Large numbers of species of birds (9300 species, more than 22,000 subspecies,166 families in 27 orders)
Few primary skin and feather conditions
Lack of knowledge or observation of diseases
Lesions hidden by feathers
Reagents (IHC, FA) not easily available
Difficulty in fixation – skin tends to curl-up and feathers tend to float in formalin
Extra organ to deal with
Does not explain the cause of death most of the time
Prone to trauma
Value of the bird
Economics (individual 'vs' flock; cellulitis, squamous cell carcinoma, Marek's disease in broiler chickens, tumors in pet/exotic birds, *etc*.)
Undesirable traits eliminated at primary breeder level
Paucity of pathologists/histopathologists

- Factors which influence diseases
  - – Management and environment
    - √ Poultry raised in commercial or back yard setting
    - √ Pet and exotic birds – aviary, pet shops or individual pet birds
    - √ Free flying birds
    - √ Birds in captivity (zoos)
  - – Genetics and nutrition

– Disease agent (virus, bacteria, parasites, *etc*.)

- Diseases of the integument can be primary or secondary to systemic diseases or disease of specific organ such as liver, pancreas, kidneys, gastrointestinal, hemopoietic, endocrine, *etc.*
- Malnutrition probably plays a big role in diseases of the integument – diseases of malnutrition are probably underdiagnosed

E) Avian skin reaction to injury: Acanthosis, Acantholysis, hyperkeratosis, parakeratosis, dyskeratosis, hypertrophy, ballooning degeneration, hyperplasia, spongiosis, macule, papule, pustule(?), ulceration, fibrinosuppurative or fibrinoheterophilic, granulomatous, *etc.*

Genetic Diseases

- Avian Ichthyosis (chicken)
- Scleroderma (UCD - L200, White Leghorn Chicken)
- Autoimmune Vitiligo (Smyth line chicken)
- Albinism
- Others

Bacterial Diseases

- Gangrenous dermatitis – clostridia (usually *C. septicum*; *C. chauvoei* and *C. perfringens* less common), *Staphylococcus*, other bacteria; follows wounds
  – Immunosuppression a common predisposing factor (infectious bursal disease and/or chicken infectious anemia in chickens)
- Erysipelas (*Erysipelothrix rhusiopathiae)* – trauma, wounds, vasculitis, thrombosis.
- Fowl cholera – chronic, chickens, abscesses in facial appendages. Similar lesions also can by caused by *Staphylococcus*.

- Cellulitis
  – Inflammatory Process ("Cellulitis"); Chickens; *E. coli* infection
  – Turkeys; fowl cholera; *Clostridium perfringens* Type A involving tail
  – Chickens; swollen head syndrome – viral/bacterial interaction, *E. coli*
- Dermatitis – *Staphylococcus*, *E. coli* common causes; acute, edematous lesions typical of *Pseudomonas* infection
  – "Necrotic" dermatitis of turkeys
- Folliculitis – bacterial infections, usually caused by staphylococci
- Pododermatitis – trauma, contact with wet litter
- 'Bumblefoot' – foot pad abscess, trauma, staphylococci
- Other
  – Mycobacteriosis – psittacines and ratites, often periorbital, *M. tuberculosis* (human TB), *M. avium*, or *M. genavense*; local invasion or systemic disease; focal, multifocal or diffuse thickening of skin; histiocytes ('epitheliod cells'), occ. giant cells → histiocytic granulomas, caseous necrosis, acid-fast bacilli
  – Actinomycosis – granulomas
  – Virulent *Mycoplasma synoviae* (vasculitis)
  – *Mycoplasma iowae* → "clubbed" down in embryo (also seen in riboflavin deficiency and overcrowding during incubation)

Mycotic Diseases

- Favus -- *Microsporum gallinae*

- Yeast infections
  - *Rhodotorula*
  - *Candida sp. (C. albicans, C. glabrata, etc.)*
- Candidiasis – foot pad ulceration, dermatitis
- Keratinophilic mycosis of turkeys ("Scurfy Dermatosis") – organisms morphologically compatible with *Malassezia*
- Mycotic dermatitis – *Aspergillus, Mucor, Candida*
- Nodular dermatomycosis – *Candida* + *Aspergillus*
- *Geotrichum* – necrosis and dermatitis of feet and legs of flamingos
- Feather mycosis
- Superficial mycosis of turkeys
- *Penicillium cylcopium* – beak infection Macaw
- Cutaneous rhinosporidiosis – swans

Viral Diseases

- Avian pox: not the same as chicken pox in humans, which is caused by a herpes virus.
  - Dry form - Lesions generally occur in unfeathered areas of the skin
  - Wet form occurs in the mucus membranes of the digestive and reproductive systems).
  - Occasionally lesions in feathered parts of the body
  - Characteristic histologic changes
    - √ Epithelial cell hyperplasia
    - √ Ballooning degeneration
    - √ Eosinophilic intracytoplasmic inclusions (Bollinger bodies)
- Virulent influenza/Newcastle disease viruses
  - Vesicles rupture to form ulcers
  - Edema, hyperemia, hemorrhage due to vasculitis
- Pigeon Paramyxovirus – Folliculitis
- Swollen head syndrome – infectious bronchitis virus (coronavirus), avian metapneumovirus → secondary bacterial infection → facial cellulitis (see C.4)
- Marek's disease – skin form
  - Intranuclear inclusions in epidermal cells
  - Lymphoid foci in dermis associated with follicles; initially inflammatory (small lymphocytes primarily) followed by transformation (pleomorphic lymphocytes including blast cells); normal tissue invaded and replaced
  - Pulpitis
- Other cutaneous or blepharitis herpesvirus infections
  - Pacheco's disease – small skin ulcers, blepharoconjunctivitis, typical inclusions present
  - Cytomegalic-like herpesvirus infection – cockatoos & macaws most affected, proliferative nodules or flattened plaques on feet and legs, epidermal hyperplasia, acanthosis, large intranuclear inclusion bodies surrounded by a clear zone
  - Herpesvirus infection in finches – blepharitis and conjunctivitis. Large cytomegalic cells with intranuclear inclusions
  - Pigeon herpesvirus – blepharoconjunctivitis with intranuclear inclusions
  - Infectious laryngotracheitis of chickens - blepharoconjunctivitis with intranuclear inclusions
- West Nile virus – folliculitis in psittacines, canaries and others
- Avian leukosis virus
  - Lymphosarcoma – dermal
  - Hemangiomas

  - Myeloid leukosis – feather pulp
- "Nakanuke" – feathering defect caused by reticuloendotheliosis virus, post-cyclophosphamide treatment, radiation, T2 toxin, *etc.*
- Rous sarcoma (transmissible myxosarcoma) – interaction with trauma/ inflammation
- Chick anemia virus – blue wing disease (type of severe gangrenous dermatitis)
- Hemorrhagic enteritis virus (Type II adenovirus) – SQ hemorrhages, turkeys
- Malabsorption syndrome/Poult enteritis complex – poor feathering & skin pigmentation
- Polyomavirus (Papovaviridae)
  - Budgerigar fledgling disease
    - √ Loss of feathers – "French Molt"
    - √ SQ hemorrhages
    - √ Karyomegalic intranuclear inclusion bodies in feather follicle and epidermal cells
  - Hemorrhagic nephritis enteritis of geese
    - √ SQ edema and ascites
- Viral papillomas – papovaviruses
  - Passerines -- feet, rictus, face
  - African grey parrot -- proliferative skin lesions, hyperplastic epithelium, large nuclei but no distinct inclusion bodies, virus on EM
    - √ Cloacal papilloma's – associated with herpesvirus-like and herpesvirus sequences
- Psittacine beak & feather disease (avian circovirus) – feather and beak abnormalities, large basophilic (morula/botryoid) intracytoplasmic inclusions in feather epithelium and pulp, intranuclear inclusions less common. Also inclusions in the epidermal cells.
- Infectious bill atrophy – parvovirus, ducklings (see Digestive 1)
- Calicivirus – vesicular lesions; white tern chick

Parasites

- Malaria (*Plasmodium*) – dermatitis of eyelids
- *Leucocytozoon* – meronts in feather pulp
- Sarcocystosis – folliculitis in a psittacine
- Fowl mites
  - *Dermanyssus*
  - *Ornithonyssus*
- Uropodidae – pseudoparasites, harmless scavenger mites
- Scaly leg, scaly face, "Tassel foot", and depluming mites; *Knemidocoptes* spp.
- Epidermoptic mites
  - *Myialges* spp.
  - *Epidermoptes bilobatus*
  - *Microlichus avus*
- Trombiculidae (chigger) infestation
- Quill, feather mites (Analgesidae, Pterolichidae, Proctorphyllodidae, Cheyletidae)
- Subcutaneous mites – *Laminosioptes cysticola*
- Fowl ticks
  - Soft ticks – *Argas* spp., *Ornithodoros* spp. less common
  - Hard ticks – primarily "seed" ticks
  - Tick paralysis can occur
  - Mortality from hemorrhage & blood loss
  - Vector for disease organisms, esp. *Borrelia, Aegyptianella*

- Lice – all chewing lice in order Mallophaga; numerous genera and species
- Stick-tight flea – *Echidnophaga gallinacea*
- Biting insects
  - – Bugs – bedbugs, assassin bugs, bird bugs
  - – Fire Ants
  - – Diptera
    - √ mosquitos – arboviruses, poxvirus, malaria (*Plasmodium*)
    - √ biting midges (Culicoides) – *Haemoproteus* vector
    - √ black flies (Simulidae) – *Leucocytozoon* vector, filarids
    - √ louse flies (Hippoboscidae) – *Haemoproteus* vector
    - √ others – most biting flies will attack birds
- Myiasis – ear canal of owls, nestlings *Protocalliphora;* bluebirds *Philornis;* wound myiasis, geese, turkeys, *Wohlfahrtia, Lucilla*
- Leeches – also mucosal surfaces (mouth, eye, nares, pharynx, etc.-caused by species in genus *Theromyzon*)
- Skin fluke – *Collyriculum*
- Cercarial dermatitis – *Trichobilharzia*, ducks (Blair & Islam, 1983)
- Subcutaneous filarids
  - – *Avioserpens* - SQ fibrous tumors in ducks
  - – *Ornithofilaria* - ducks & geese
  - – *Pelecitus* - pigeons, psittacines
  - – *Singhfilaria* - wild turkeys & quail
  - – *Splendidofilaria* - grouse

Nutrition/Metabolic

- Calcium/vitamin D_3 deficiencies – rickets, beak flexibility
- B-vitamin deficiencies – marked acanthosis, hyperkeratosis, crust formation, secondary bacterial infections, assoc. dermal inflammation. Commissure of mouth, scales, and feet affected.
  - – Biotin deficiency – moderate to marked lesions; hyperkeratosis; parakeratosis absent to minimal
  - – Niacin deficiency – mild to moderate lesions
  - – Pantothenic acid deficiency – hyperkeratosis and parakeratosis
- Riboflavin deficiency – clubbed down, embryo
- Lysine deficiency
- Amino acid deficiency
  - – “Dry Wing" in ducks
- Vitamin A deficiency – plantar corn, "bumblefoot" , hyperkeratosis – epidermis and feather follicles, squamous metaplasia, glands of the external ear
- Vitamin E deficiency
  - – Exudative diathesis
  - – Pansteatitis (see also fatty liver-kidney syndrome)
- Feather achromia – deficiencies of lysine, folic acid, iron (fowl), choline, riboflavin (cockatiel)
- Segmental dysplasia – "stress marks"; indicative of episodes of acute stress; experimentally induced by single injections of glucocorticoids, which decreases growth and increases protein breakdown
- Zinc deficiency – feathers involved; hyperkeratosis → follicle atrophy → fibrosis results in feather atrophy and loss
- Xanthoma and xanthomatosis; cholesteomas

- Fatty liver-kidney syndrome – congested ("pink") SQ fat
- Halofuginone (coccidiostat) – decreased skin strength, increased tears; Mechanism: interference with incorporation of proline in collagen
- Hypothyroidism – feather loss, atrophy of skin and feather follicles, silki feathers in 'Obese' strain of chicken (model for autoimmune thyroioditis)
- Atherosclerosis of axial artery in the pulp – manifestation of atherosclerosis of major vessels and other vessels in a psittacine
- Feather loss – androgen or estrogen deficiencies
- Chronic liver disease – associated with beak overgrowth
- Calcinosis circumscripta – focal to multifocal circumscribed focal to coalescing, soft, white, chalk-like deposits

Neoplasia (see also Marek's disease, LL, REV)

- Papillomas – viral etiology in African grey parrots (papillomavirus). Herpesvirus-like and herpesvirus sequences associated with cloacal papilloma's
- Squamous cell carcinoma
  - Dermal squamous cell carcinoma ("keratoacanthoma"); chickens, lesions spontaneously regress, genetic predisposition
  - Uropygial gland – differentiate from adenocarcinomas
  - Beak – typical tumor, germinal area along margin
- Uropygial gland adenoma/adenocarcinoma
- Basal cell tumors (pteryloepithelioma ['feather folliculoma'], carcinomas (rare)
- Lipoma/liposarcoma (lipomas common, liposarcomas rare)
  - Osteolipoma
  - Hemangiolipoma
  - Myelolipoma (see Hemopoietic & Lymphoid System)
- Hemangioma / hemangiosarcoma
- Fibroma / fibrosarcoma / myxofibroma /myxoma
- Malignant melanoma – beak margin, typically pigmented
- Undifferentiated sarcoma/other sarcomas – can be assoc. with tattoos
- Other
  - Hemangiopericytoma
  - Mastocytoma
  - Malignant melanoma
  - Granular cell tumors – PAS+ cytoplasmic granules
- Teratoma – subcutaneous tissue in an African Grey Parrot
- Undifferentiated neoplasia

Toxicities

- Photosensitization – plants of genera *Ammi* and *Cymopterus*
- Vesicular dermatitis – ergot
- Ulcerative dermatitis – trichothecene mycotoxins
- Radiomimetic feather lesions ("nakanuke") – trichothecene mycotoxins
- Fire ant (*Solenopsus invicta*) stings
- Selenium toxicosis – acquired beak deformities
- Ammonia - blepharoconjunctivitis

Management

- Hyperproteinemia from high humidity in hatcher
- Dry gangrene – frostbite, other; sloughing of affected tissues
- Burns/trauma/cold/other physical agents [microwave radiation] – coagulative necrosis, zone of demarcation between affected and unaffected tissue; inflammation, hemorrhage, *etc*.
- Bruising – green discoloration; hemoglobin --> biliverdin
- Feather picking
- Persecution/cannibalism
- Predation
- Foreign bodies
- Lacerations/punctures
- Contact dermatitis – moisture
- Scabby hip syndrome
- Focal ulcerative dermatitis – turkeys
- Pododermatitis
- "Galls"
- Poisonous bites and stings
- Granulomatous cellulitis – cervical, tail, oil emulsion vaccines
- Beak necrosis
- Overgrowth of beak, nails
- Lipogranulomas – obesity
- Sternal bursitis (non-infectious)
- Dehydration

Unknown/Other

- Feather follicle cysts (folliculomas) – genetic in certain strains of canaries
- Epidermal inclusion cysts – filled with keratin; neck, breast, and back of older laying hens
- Follicular keratosis – atrophy of feather, follicle fills with keratin from follicular epithelium and becomes distended
- Frizzle feather and other genetic feather disorders
- Slow feathering
- Subcutaneous emphysema
- Congenital baldness (apterylosis)
- Cyanosis, anemia, icterus, methemoglobinemia, dehydration, *etc*.
- Melanosis – abnormal green to gray discoloration of shanks and black pigmentation of abdominal wall
- Eosinophilia/facial edema
- Allergies – cutaneous hypersensitivity, Arthus reaction
  - Amazon foot necrosis – self-mutilation possibly due to delayed hypersensitivity reaction
  - Perivascular and/or perifollicular lymphoid and plasma cell infiltrates are common in birds with idiopathic skin diseases
- Cere hyperkeratosis (brown atrophy) – normal with aging in many species especially budgerigars
- Foot/toe pad hyperkeratosis
- Ichthyosis
- Dermolytic mechanobullous disease – ostriches, genetic?
- Vent gleet – associated with respiratory disease, acidic urine
- Preen gland adenitis – ducks, cause?
- Polyfolliculosis – multiple feathers from one follicle, psittacines, pruritis clinically

- Constricted toe syndrome – nestling parrots affected; band of connective tissue encircles a toe impairing circulation and resulting in necrosis
- Collagen lysis – breakdown of collagen provokes an intense granulocytic (? eosinophilic) reaction
- Split wing syndrome

Table 1. Mites in Birds (Note: many others are not listed)

Name	Common Name	Species of birds affected
Dermanyssus gallinae*	Red mite (Roost mite, Poultry mite)	Chickens, turkeys, pigeons, canaries, wild birds
Ornithonyssus sylviarum*	Northern Fowl mite	Chicken, turkeys, wild birds
O. bursa	Tropical Fowl mite	Poultry, pigeons, Mynah
*Knemidocoptes mutans**	Scaly-leg and scaly-face mites	Poultry
*K. pilae**	Scaly-leg and scaly-face mites	Psittacines
Procnemidokoptes janssensi	Scaly-leg and scaly-face mites	Love birds
K. jamaicensis	Scaly leg mite	Canaries, finches, other passerines
Knemidocoptes gallinae	Depluming mite	Chickens, pigeons, pheasants
K. laevis	Depluming mite	Pigeons
Neocnemidocoptes gallinae	Depluming mite	Pheasants and others
Epidermoptes bilobatus	Skin mite	Chickens
Myialges nudus	Skin mite	Grey-cheeked parakeets
Harpyrynchus sp.	Skin and feathers	Passerines
Syringophilus hipectinatus	Feather and quill mites	Poultry, wild birds
S. columbae	Feather and quill mites	Pigeons
(*Dermoglyphus sp., Analges sp., Mengninia sp., Freyana sp)*	Feather and quill mites	Chickens, turkeys
Paraglopsis sp.	Feather and quill mites	Psittacines, finches
*Sternostoma tracheacolum** (Neonyssus, Rhinonyssus)	Respiratory tract mite (trachea, lung, air sac)	Passerines (canaries, finches), psittacines, poultry, pigeon
Cytodites nudus	Air sac mite (bronchi, lungs, air sac)	Poultry, pheasants, pigeons, canaries, *etc.*
Laminosioptes cysticola	Cyst mite (skin, subcutis, muscle, abdominal viscera and lungs)	Chicken, turkeys, pigeons, pheasants geese
Hypopial mites	Areolar subcutaneous, connective tissue	Pigeons
Family Trombiculidae (*Neoschonagastia americana*)	Chiggers	Poultry (Southern US), turkeys, wild birds, chickens

* Most common

VIII. Immune System:

Bacteria

Septicemia involving spleen, bursa of Fabricius, thymus and bone marrow

1. *E. coli.*
1. *Salmonella sp.*
2. *Pasteurella multocida*
3. *Staphylococcus sp.*
4. *Streptococcus sp.*
5. *Mycobacterium avium*
6. *Yersinia psedutuberculosis*
7. Others: Listeria

Fungus

1) *Aspergillus fumigatus and A. flavus*

Virus

1. Marek's disease
2. Infectious bursal disease (Birnavirus)
3. Chicken Infectious anemia (genus – Gyrovirus, family – *Circoviridae*)
4. Avian Leukosis (Retrovirus)
5. Reticuloendotheliosis (Retrovirus)
6. Exotic Newcastle disease
7. Highly pathogenic Avian Influenza
8. Hemorrhagic Enteritis of turkeys (Adenovirus Group II)
9. Marble Spleen Disease (Adenovirus Group II)
10. Reovirus isolates
11. Duck Enteritis (Herpesvirus)
12. Alphaviruses (Bunyavirus)
13. Turkey Coronavirus

Parasite

1. Cryptosporidia
2. Leucocytozoon
3. Malaria

Toxicity

1. Cyclophosphamide
2. Trichothecenes (T-2)
3. Aflatoxins
4. Lead
5. Sulfonamides

Nutrition

1. Vitamin A
2. Vitamin E/selenium

Neoplasia

1. Lymphoma
2. Thymoma
3. Sarcoma
4. Carcinoma (serosal implantation)
5. Histiocytosis ?

IX. Urogenital Systems:

Anomalies:

1) Renal aplasia/hypoplasia, dysplasia
2) Renal cysts.
3) Cystic right oviduct, two functional oviducts
4) Ovarian/oviductal cysts, ovarian hypoplasia
5) Misovulation- ovum deposited in body cavity
6) Internal/abdominal laying
7) Testicular hypoplasia (WLH, turkey)
8) Testicular degeneration/atrophy – Japanese quail (with Muscular dystrophy)
9) Hermaphrodite/intersex
10) Others:

Metabolic:

1. Perirenal hemorrhage (turkey)
2. Hemochromatosis
3. Fatty liver and kidney syndrome
4. Amyloidosis.
5. Articular urate deposition (Gout)
6. Urolithiasis
7. Atherosclerosis
8. Others:

Virus and viral diseases:

1. Marek's disease (lymphoid tumors)
2. Retroviruses (LL; inclusion bodies, REV, Myelocytoma)
3. Infectious bronchitis virus (IBV)
4. Avian Nephritis virus (Astrovirus)
5. Avian Paramyxovirus -1 (END/NDV) and 3.
6. Orthomyxovirus (HPAI)
7. Adenovirus group II (HEV with IN inclusions in turkeys)
8. Egg Drop Syndrome (EDS 76 in chickens) – Duck adenovirus
9. Avian Encephalomyelitis virus (Picornavirus)
10. Avian Metapneumovirus (TRT in turkeys)
11. Hepatitis E virus in chickens
12. Flavivirus (WNV in ducks and geese)
13. Alphaviruses (WEE, EEE, Highland J)
14. Others

Bacteria and bacterial diseases:

1. Salmonellosis (*S.pullorum/S.gallinarum, S. typhimurium, S. enteritidis*, etc.)
2. Colibacillosis
3. Staphylococcosis
4. Pasteurellosis (*P. multocida, P. gallinarum*)
5. *Riemerella anatipestifer*
6. *Ornithobacterium rhinotracheale*
7. Mycoplasmosis
8. *Erysipelothrix rhusiopathiae*
9. Mycobacteriosis
10. Streptococcosis
11. Enterocccus sp.
12. Others

Mycosis:

1. Aspergillosis
2. Zygomyces
3. Candida sp. (geese)
4. Others.

Parasites:

1. Renal coccidia (geese and ducks)
2. Toxoplasmosis
3. Cryptosporidiosis
4. Leucocytozoonosis
5. Sarcocystosis
6. Hemoprotozoa
7. Cestodiasis (waterfowl)
8. Aberrant ascarids (oviduct)
9. Trematodes/Schistosoma of billharzia sp. (waterfowl), *Prosthogonimus machorchis.*
10. Ciliates (oviduct – waterfowl)

Nutritional:

1. Ca, P and Vitamin D3 deficiency (Egg shell quality)
2. Vitamin A def (Squamous metaplasia)
3. Biotin def (Fatty liver and kidney syndrome, fatty change in myocardium)
4. Vitamin E/Selenium
5. Others

Neoplasia:

1. Virus induced neoplasia (lymphoma and others)
2. Renal tumors (embryonal nephroma, tubular adenoma, adenocarcinoma)
3. Ovarian carcinoma (chicken used as a model)
4. Oviductal carcinoma
5. Leiomyoma of mesosalpinx

6. Granulosa cell tumor
7. Arrhenoblastoma, dysgerminoma, luteoma, thecoma
8. Ssarcoma's (fibrosarcoma, others)
9. Hemangioma/sarcoma
10. Metastatic adenocarcinoma (rare)
11. Mixed tumors, Met Melanoma
12. Teratoma of testes
13. Sertoli cell tumor, Seminoma, Leydig cell tumor
14. Others

Toxicity:

1. Heavy metals (lead, zinc, cadmium, arsenic)
2. Antibiotics (Gentamycin, amikacin, tetracyclines, sulfonamides, etc.)
3. Sodium (cystic testes, hydropericardium, ascites)
4. Mycotoxins (Citrinin, ochratoxin, oosporein, aflatoxins, etc.)
5. Furazolidone, mercury
6. Diclofenac (NSAID)
7. Sodium carbonate/citrate/calcium carbonate
8. Plants (Oak, *etc*.)
9. Hypervitominosis D3 (nephrocalcinosis)
10. Toxic fat syndrome (dioxins, PCB's)
11. Excess protein
12. Others

Others:

1. Dehydration
2. Visceral urate deposition (Gout)
3. Phallus/oviductal prolapse
4. Egg bound condition
5. Chronic renal disease
6. Others:

Table : Differences between Visceral and Articular urate deposition (Gout) in Birds

	Visceral gout (Visceral urate deposition)	Articular gout (urate deposition)
1. Onset:	It is usually an acute condition but can be chronic.	It is usually a chronic disease.
2. Frequency:	It is very common.	It is rare or sporadic.
3. Age:	1 day and above.	4-5 months and above. However, immature genetically susceptible chickens may be induced by high protein levels in the diet.
4. Sex:	Both males and females are susceptible.	Mostly males.
5. Gross lesions		
Kidney:	Kidneys are almost always involved and they look grossly abnormal with deposition of white, chalky precipitates.	Kidneys are normal grossly. Kidneys may become abnormal with white urate deposits if the bird gets dehydrated.
Soft tissues:	Visceral organs like liver, myocardium, spleen or serosal surfaces like pleura, pericardium, air sacs, mesentery, etc. are commonly involved.	Soft tissues other than synovium are rarely involved, however, comb, wattles, and trachea have been observed to be involved.
Joints:	Soft tissues around the joints may or may not be involved. Surfaces of muscles, synovial sheaths of tendons and joints are involved in severe cases.	Soft tissues around the joints are always involved, especially feet. Other joints of the legs, wing, spine, and mandible are also commonly involved.
6. Microscopic lesions:	Generally no inflammatory reaction in synovium or visceral surfaces. Kidney has inflammatory reaction around tophus.	Granulomatous inflammation in synovium and other tissues.
7. Pathogenesis:	It is generally due to failure of urate excretion (renal failure).	It is probably due to a metabolic defect in the secretion of urates by the kidney tubules.
8. Causes:	1. Dehydration. 2. Nephrotoxicity: calcium, mycotoxins, (ochratoxins, oosporein, aflatoxins, etc.), certain antibiotics, heavy metals (lead), ethylene glycol, ethoxyquin etc. 3. Infectious agents: nephrotropic IBV and avian nephritis virus (chickens), polyomavirus, APMV-1 (pigeons), Salmonella sp., Yersinia sp., Chlamydia psittaci, Eimeria truncata, microsporidia, cryptosporidia, Aspergillus sp., etc. 4. Vitamin A deficiency 5. Urolithiasis 6. Neoplasia (lymphoma, primary renal tumors) 8. Immune mediated glomerulonephritis 9. Anomalies 10. Others?	a. Genetics. b. High protein in the diet. c. Others?

Ref: Shivaprasad, H. L. An overview of anatomy, physiology and pathology of urinary system in birds, AAV Proceedings, pp. 201-205, 1998

Various causes of drop in egg production (and quality) in chickens:

Viruses:

1) Infectious bronchitis Virus (**IBV**) – exterior and interior quality (albumen) can be affected.
2) Newcastle Disease Virus (**NDV**) – exterior egg quality can be affected.
3) Avian Encephalomyelitis (**AE**) – sudden drop but should come back to normal in a week or two.
4) Avian Influenza (**AI**)
5) Egg Drop Syndrome (**EDS76**)
6) Infectious Laringotracheitis (**ILT**)
7) Tumour Viruses:
   - Marek's Disease virus (**MDV - Herpesvirus**)
   - Avian Leucosis Virus (**ALV - Retrovirus**);
   - Reticuloendotheliosis Virus (**REV- Retrovirus**)
8) Fowl Pox Virus (**FPV**)
9) Avian Rhinotracheitis (**ART/Swollen head syndrome-Avian Metapneumovirus**)
10) Hepatitis Splenomegaly syndrome (Hepatitis E virus)

Bacteria:

1) *Mycoplasma Gallisepticum* (**MG**) + *Escherichia coli* (**E.coli**)→CRD
2) *Mycoplasma synoviae* (**MS**)
3) Salmonellosis (*S.* Pullorum/*S.* Gallinarum, *S.* Enteritiids, *S.* Typhimurium, *S. arizonae*, *etc.*)
4) *Avibacterium paragallinarum* (**Infectious Coryza**)
5) *Pasteurella multocida* (**Fowl Cholera**)
6) *Ornithobacterium rhinotracheale* (**ORT**)
6) *E. coli*
7) Staphylococcosis & Streptococcosis
8) Spirochetes (Ceca - Brachyspira)
9) Others

Nutritional:

1) Lack of Calcium, P and vit. D3 – exterior of the egg (shell) quality can be affected
2) Starvation
3) Lack of water
4) Lack of essential amino acids (Lysine, Methionine, Tryptophan, Leucine and Isoleucine)
5) Lack of vitamins including vit A, etc.
6) Lack of salt
7) Lack of Metabolizable energy in feed.

Parasites:

1) Roundworms
2) Tapeworms
3) Histomonas (just in chickens reared on the floor)
4) Coccidia
5) Mites
6) Others

Toxins:

1) Trichothecenes
2) Aflatoxins
3) Ochratoxins
4) Others; minerals and vitamins

Management

1) Light
2) Vaccination
3) Ammonia exposure
4) Temperature
5) Stray voltage

6) Many others

X. Cardiovascular System:

Anomalies:

1) ASD, VSD
2) Dextraposition of major vessels.
3) Subpulmonic and subaortic stenosis
4) Ventricular hypoplasia
5) Others:

Metabolic:

1. Ascites syndrome (chickens)
2. Round heart disease (dilated cardiomyopathy in turkeys)
3. Aortic (and coronary) ruptures (turkeys)
4. Amylodosis.
5. Urate deposition
6. Atherosclerosis
7. Others

Virus and viral diseases:

1. Marek's disease (lymphoid tumors)
2. Retroviruses (LL; inclusion bodies, REV, Myelocytoma)
3. Goose herpesvirus (myocarditis)
4. Avian Paramyxovirus -1 (END)
5. Orthomyxovirus (HPAI)
6. Goose parvovirus (myocarditis with IN inclusions)
7. Muscovy duck parvovirus
8. Reovirus (myocarditis in turkeys and chickens)
9. Avian Encephalomyelitis virus (Picornavirus)
10. Flavivirus (WNV in ducks and geese)
11. Alphaviruses (WEE, EEE, Highland J)
12. Adenovirus group I, serotype 4 (Angara disease)
13. Duck Viral Enteritis (herpesvirus).
14. Others: Bunyavirus (ostrich)

Bacteria and bacterial diseases:

1. Salmonellosis (*S.pullorum/S.gallinarum, S. typhimurium, S. enteritidis*, etc.)
2. Colibacillosis
3. Staphylococcosis
4. Listeriosis
5. Pasteurellosis (*P. multocida, P. gallinarum*)

6. *Riemerella anatipestifer*
7. *Ornithobacterium rhinotracheale*
8. Mycoplasmosis
9. Chlamydiosis
10. *Erysipelothrix rhusiopathiae*
11. Mycobacteriosis
12. Streptococcosis
13. Enterocccus sp.
14. Others

Mycosis:

1. Aspergillosis
2. Zygomyces
3. Candida sp

Parasites:

1. Toxoplasmosis
2. Leucocytozoonosis
3. Sarcocystosis
4. Hemoprotozoa
5. Schistosoma of billharzia sp. (medial hypertrophy of vessels in waterfowl)
6. Sarconema eurycerca
7. Others

Nutritional:

1. Biotin def (Fatty liver and kidney syndrome, fatty change in myocardium)
2. Vitamin E/Selenium
3. Copper def ? (aorta/coronary artery rupture)
4. Others

Neoplasia:

1. Virus induced neoplasia
2. Rhabdomyoma/sarcoma
3. Hemangioma/sarcoma
4. Fibrosarcoma
5. Metastatic adenocarcinoma (rare)
6. Others

Toxicity:

1. Ionophores
2. Sodium (hydropericardium, ascites)
3. Furazolidone
4. Lathyrism – aortic rupture (BAPN β-aminoproprionitrile)
5. Moniliformin

6. Plants (Cassia, Avacado, Oleander, *etc*.)
7. Heavy metals (lead)
8. Toxic fat syndrome (dioxins, PCB's)
9. Others

Others:

1. Anomalies
2. Amyloidosis
3. Visceral urate deposition (gout)
4. Valvular insufficiency
5. Endocardiosis
6. Cardiomyopathy/Round heart disease of chickens and turkeys.
7. Aortic/coronary artery rupture
8. Perirenal hemorrhage
9. Hemopericardium/myocardial rupture
10. Others:

XI. Musculoskeletal System:

Anomalies:

1. Scoliosis
2. Valgus/Varus
3. Spondylolistheses ("kinky back")
4. Rumplesness
5. Cleft strernum/Sternoschisis
6. Syndactlylia, Polydactylia, Phocomelia, *etc.*
7. Brachygnathia
8. Spina bifida
9. Achondroplasia
10. Torticollis (wry neck)
11. Crooked toes
12. Tibial rotation
13. Dwarfism
14. Others

Metabolic:

1. Inherited muscular dystrophies (UC Davis 300 and others)
2. Focal myopathy in turkeys
3. Inherited muscle diseases in Japanese quail (Type II glycogenosis, myotonic muscular dystrophy).
4. Arthrogryposis
5. Dwarfism (sex-linked) and autosomal (?)
6. Others

Viruses and Viral Diseases:

1. Marek's disease (lymphoid tumors)
2. Retrovirus (Osteopetrosis, Sarcoma. Myelocytoma/myelobastosis, etc.)
3. Avian Paramyxovirus -1 (END/NDV)
4. Orthomyxovirus (HPAI)
5. Muscovy duck parvovirus (ducks, geese)
6. Infectious bursal disease virus
7. Chicken infectious anemia virus
8. EEE, Highland J (turkeys experimental)
9. Others

Bacteria and Bacterial Diseases:

1. Arthritis/synovitis, osteomyelitis (Salmonella sp., *E. coli*, *P. multocida,* Mycoplasmosis, *Staphylococcus aureus, S. hyicus*, Streptococcosis/Enterococcus sp. (*E. cecorum),* Mycobacteriosis, Listeria, *etc*,
2. Gangrenous Myositis - *C. septicum, C. perfringens, S. aureus, etc.*
3. Amyloid arthropathy (*Enterococcus faecalis*, MG, MS, *Salmonella sp. S. aureus*, *E. coli*, *etc*.)
4. *Yersinia pseudotuberculosis*
5. *Erysipelothrix rhusiopathiae*
6. *Pseudomonas aeruginosa*
7. Others

Mycotic Diseases:

1. Aspergillus sp.
2. Candida sp.

Parasitic Diseases: (Myositis)

1. Sarcocystis sp.
2. Leucocytozoonosis.
3. Haemoprotozoa
4. Toxoplasmosis
5. Others

Nutrition:

1. Vitamin E/Selenium (myopathy)
2. Rickets (Ca, P, Vit D3 def or imbalance of Ca:P ratio)
3. Osteoporosis/osteomalacia
4. Hypovitaminosis A (thickening of skull bones)
5. Biotin, choline, manganese, pantothenic acid, niacin (perosis)
6. Manganese/choline deficiency (Slipped tendon)
7. Copper (brittle bones – similar to TD)
8. Electrolytes (TD?)
9. Protein def (Muscle atrophy)
10. Zinc (leg deformities in pheasants)
11. Others

Neoplasia:

1. Lymphoma of virus induced (Marek's, LL, REV, etc.)
2. Rhabdomyoma/sarcoma
3. Osteoma/sarcoma
4. Chondroma/sarcoma
5. Fibroma/sarcoms
6. Myxosarcoma
7. Metastatic adenocarcinoma/sarcoma
8. Hemangiosarcoma
9. Others

Toxicity:

1. Ionophores (Monensin, Lasalocid, Salinomycin, Narsin, *etc*.)
2. *Cassia occidentalis* (Coffee senna)
3. Hypervitaminosis A (intereference with Vit. D3)
4. Vitamin D (soft tissue mineralization - proventriculus)
5. Selenium (beak deformity)
6. Others

Others:

1. Tibial Dyschondroplasia
2. Deep pectoral myopathy
3. Gout (both articular and visceral urate deposition forms)
4. Femoral head necrosis
5. Avulsion of ligaments and tendons
6. Rupture of gastrocnemius tendon
7. Femoral fractures and other bones
8. Degenerative joint diseases
9. Osteochondrosis
10. TS-65 (chondrodystrophy)
11. Spraddle-leg
12. Ossification of tendons and cartilage
13. Bumblefoot
14. Vaccine induced myositis/osteomyelitis
15. Improper toe clipping
16. Dehydration
17. Steatosis
18. Rhabdomyolysis (capture, transport, *etc*.)
19. Pipping muscle degeneration
20. Myodegeneration of Anterior *Latissimus Dorsi* in broiler chickens
21. White striping (Pale streaks in broiler meat), myopathies
22. Muscles tears, hemorrhages
23. Xanthoma (common in bone marrow)
24. Trauma
25. Others

XII. Endocrine System:

Not well studied nor examined routinely in poultry; thyroids, adrenals, islets in pancreas, pituitary, pineal, aortic and carotid bodies

Anomalies:
1. Dystrophic thyroid glands
2. Pancreas atrophy
3. Others:

Metabolic:
1. Autoimmune thyroiditis – Obese strain of chicken used as a model, (Lymphocytic thyroiditis in Fayoumi breed of chicken)
2. Goiter in Brahma chickens – genetics
3. Diabetes – experimental work in chickens
4. Amyloidosis.
5. Others:

Virus and viral diseases:
1.Marek's disease (lymphoid tumors), Retroviruses (LL; inclusion bodies, REV, Myelocytoma)
2. Avian Paramyxovirus -1 (END)
3. Orthomyxovirus (HPAI)
4. WNV in ducks and geese
5. Alphaviruses (WEE, EEE, Highland J)
6. Others

Bacteria and bacterial diseases:
1.Salmonellosis (*S.pullorum/S.gallinarum, S. typhimurium, S. enteritidis, etc*.)
2.Colibacillosis
3. P. multocida
4. Chlamydiosis
5. Erysipelothrix rhusiopathiae
6. Mycobacteriosis
7..Others

Mycosis:
1. Aspergillosis

Parasites:
1. Toxoplasmosis
2. Others

Nutritional:
1. Calcium, phosphorus and vitamin D3 deficiency or imbalance of Ca to P ration - hyperparathyroidism

2. Others

Neoplasia:
1.Virus induced neoplasia
2.Adenoma/carcinoma - rare
3.Others

Toxicity:
1. Rapeseed, Iodine, Propylthiouracil, Sulofonamides – thyriod affected
2.Others

Others:
1. Corpora amylacea in thyroids (mineralized follicles, hemosiderosis, *etc*)
2. Adrenocortical hyperplasia or vacuolations – stress induced
3. Pigments in adrenals (bile, hemosiderin, lipofuscin, mineralization, urates, *etc*.)
4. Cysts
5. Others:

Differential diagnoses of Marek's. LL and RE diseases

Character	MD	LL	RE
Virus	Herpesvirus	Retro (LS group)	Retro (RE group)
Oncogene	*Meq*	Numerous	V-*rel*
Age	Mostly young	> 4 months	> 2 months
Transmisn.	Horizontal	Vertical/Hor	Vertical/Hor
Hosts	Chi (Turk, Qul)	Chi (many)	Many hosts
Bursa	Atrophied/Enlar	Enlarged	Atrophy/Enlarg
Thymus	Atrophy/Tumor	Mild Enlarg	Atrophy/Enlarg
Nerves	Enlarged	Not affected	Enlarged
Tumor	Lymphoma	Lymph/others	Lympho
Cell type	T cells	B cells	B (T) cells

XIII Appendix

1. Hatchability Problems:

1. Fertility problems
    a. Male
        i. Male:female ratio imbalance
        ii. Lameness (feet/legs)
        iii. Decreased male libido
        iv. Old males
        v. Male sterility
        vi. Body weight differences
        vii. Semen collection program (if used)
        viii. Semen quality
    b. Female
        i. Number of hens per nest
        ii. Nest conditions/nest type
        iii. Feeding/drinking space
        iv. Broody behaviour
        v. Artificial insemination program
        vi. Age of the females
    c. Barn conditions
        i. Inadequate lighting
        ii. Air quality/ventilation type
        iii. Litter conditions
        iv. Egg collection frequency and times
        v. Weather changes
        vi. Pen mating
        vii. Social dominance
        viii. Vaccination times during lay
    d. Diseases
    e. Inbred strains (genetic lethals)
    f. Nutritional imbalance/vitamin deficiencies (Vit. E)
    g. Insemination problems
2. Egg quality
    a. Egg size (too small or too large)
    b. Broken or dirty shells
    c. Shell thickness
    d. Pore size
    e. Pore number
    f. Cuticle quality

g. Membrane quality
h. Nutrition
i. Diseases (IBV, NDV, AI, etc)
j. Toxicities
k. Handling

3. Storage
    a. Storage conditions (on farm/hatchery)
    b. Eggs age
    c. Temperatures
    d. Humidity
    e. Eggs washed at very high temperatures
    f. Length of storage
4. Incubator/hatcher
    a. Temperature
    b. Humidity
    c. CO2 imbalances
    d. Hatch window
    e. Egg/vent temperatures
    f. Machine controllers
    g. Pressure gradients
    h. Power failure
    i. Poor ventilation
    j. Sanitation
    k. Multi stage vs. single stage machine
    l. Improper turning
    m. Improper fumigation/disinfection
    n. Egg washing
    o. Dirty eggs
    p. Malposition of the eggs
    q. Disease

References:

(2002). Factors affecting hatchability. In D. D. Bell & W. D. Weaver, Jr. (Eds.), *Commercial chicken meat and egg production* (pp. 727-773). Norwell, Massachusetts, USA: Kluwer Academic Publishers.

"Optimizing Performance During Tough Economic Times" presentation by: Dave Fernandez, Director of Technical Services with Wilmar Poultry Company and Ag Forte. Presented at WPDC (ACPV), Sacramento, CA March 24-27, 2013.

2.General information/History Necessary for Investigating Poultry Diseases/Diagnostic Cases:

Owner's name / Address:
Telephone/cell phone / Fax / E-mail-id

Farm/Ranch name and ID / Flock ID:

Species of Birds: Chicken / Turkey / Game /Duck/Others

Class of birds: Broiler / Layer / Broile. Breeder / Layer. Breeder / Pure line

Breed: Sex: Age: (D/W/M/Y)

Total number of birds, Ranch: House / Brood:

Number of specimens submitted (live/dead):

1. Current Situation

    i) Reason for submission:

    ii) Clinical signs (respiratory, digestive, neurological, ill thrift, *etc*.):

        a) Morbidity (number/%) -

        b) Morbidity pattern-

            a) Since how long the clinical signs observed?

            b) How many houses affected?

    iii) Mortality:
        a) Percent
        b) Pattern (last 7 days)

    iv) Production problem:

        Egg type chicken:

        a) Egg production problems (past 1-4 weeks):

        b) Egg quality problems (internal/ external)

        Meat type chicken:

a) Uniformity of the flock:

b) Body weight:

vi). Any change in feed or water intake: Y / N if yes, please describe:

vi). Any Treatments / Vaccination given (past one week): Y / N

If yes, Treatments:

Vaccines:

vii) Details of past history of similar or other conditions:

vii) Field necropsy findings:

viii) Others:

2. Farm details: Location: Orientation of houses: NS / EW/?

Weather condition:

Type of brooding:

Type of rearing: Cage/Aviary/ Deep litter/ Slats/ others

Type of litter material:

Disposal / change of litter material: Once in

Source of litter material:

Access to wild birds, animals/backyard poultry, birds: Y/N, if yes describe:

Down time/C & D:

Ventilation (type):

3. Feed: Type of feed:

Change of feed (how often/when?):

Number of feeders (in deep litter /slats):

Source of feed:

Feed formula:

Others:

4. Water: Source of water:

   Quality of water:

   Number of waterers (deep litter system):

5. Lighting: Source:

   Number of lights:

   Lighting schedule:

6. Vaccination (details):
7. Production records:
8. Unusual events:
9. Biosecurity measures:

3. TEN COMMANDMENTS ON HISTORY OF THE FLOCK FOR SUBMITTING POULTRY FOR DISEASE DIAGNOSIS

Clients: In order to provide **TIMELY, THOROUGH** and **QUALITY** service please **PROVIDE** the following information.

1. You can submit up to **EIGHT** birds for the same price. Submitting one or two birds representing thousands of birds will not help most of the time.
2. Pick representative birds of the problem in the flock. For example, if the birds are showing respiratory signs submit birds with respiratory signs. If the main problem is increased mortality, please submit a few fresh (not decomposed) dead birds in addition to live birds, if the birds have digestive problems such as diarrhea or neurological signs, or down on legs submit birds with such clinical signs. Submission of a few normal birds is also encouraged for comparison purposes. .
3. Complete the submission form; provide age, sex, species (chickens/turkeys/others), breed, # of birds on the ranch, # of birds in the house, # sick, mortality (per day/week)
4. Describe **CLINCAL SIGNS** such as; looking sick (depressed), not eating or drinking, increased mortality (provide last 5 days mortality), snicking, difficulty breathing, watery eyes, swollen sinuses, watery droppings, head shaking, down on legs, loss of feathers, skin problems, swollen hocks/foot pads, increased condemnation, *etc*, *etc*.
5. Provide information on change of feed, weather changes, management (ventilation, litter, water, down time, cleaning and disinfection, rodent control, biosecurity)
6. How long the problem has been going on?
7. How many houses/broods are on the ranch and how many are affected.
8. Any medications, if so what kind and for how long? Any improvements?
9. Vaccination history if any. Diseases for which vaccinations are done and when?
10. Field necropsy: such as airsacculitis, enteritis, pneumonia, *etc*.

4. Necropsy Procedure of Poultry and Collection of Specimens

("more is being missed through not looking, than through not knowing")

Poultry is a collective term used to designate domesticated birds primarily kept for eggs, meat and feathers such as chickens, turkeys, ducks, geese, *etc*. Game birds such as pheasant, quail and partridge as well as squabs (young pigeon), guinea fowl and ratites (ostrich, rhea and emu) are also considered poultry.

Knowledge about the type of birds, their anatomy and how they are managed helps one to understand the type and kind of diseases different birds are susceptible. The major factor that influences the kind of disease one sees in poultry is management. This is the major difference between the commercial poultry which are raised intensively and in large numbers and back yard poultry which are raised as a hobby but also as a small family enterprise. Chickens which are raised organically (there are various definitions for this but generally free of antibiotics, feeding organically grown feed, access to outside, *etc*.) are becoming very popular throughout the US. Regardless of whatever management practices are used, genetics, nutrition, environment and vaccination play a significant role in the initiation and outcome of a diseases.

Before the start of the necropsy make sure that one is familiar with principles of good laboratory practices (GLP) as well as follow the American Association of Veterinary Laboratory Diagnosticians (AAVLD) and American Veterinary Medical Association (AVMA) approved written protocols. Wear laboratory coat, boots, gloves and safety glasses. If one is dealing with zoonotic diseases such as chlamydia, mycobacteria, highly pathogenic avian influenza perform the necropsy of birds in a certified biosafety cabinet.

Organize the supplies and equipment needed for necropsy and testing which will make necropsy easier, efficient and fun. These include Co2 euthanasia container, knives, shears, scissors, scalpels, rib cutters, jars with 10 % neutral buffered formalin, karnovski fixative for Electron Microscopy if necessary, casettes for small tissues, blood collecting tubes, sterile swabs with wooden sticks (for general culturing), swabs with polyurethane sticks for PCR, plastic tubes for swabs, viral transport media, small plastic bags and glass slides for coccidia check, cytology (blood smears, cytology of tissues, exudates), fecal cups, Bunsen burner, spatula for sterilization, pen and tape for labeling, magnifying glass, camera, syringe, *etc*. Also be prepared for disposal of carcasses (mostly by rendering) by providing cleaning and disinfection equipment and supplies, biohazard bags, barrels, *etc*.

It is important to observe the birds for any clinical signs most important if nervous or locomotor signs but also respiratory signs, *etc*. Mark the birds with neurological signs or down birds on their shanks or head with a black felt pen so that they can be examined in detail Systematic approach and examination of each system at a time will be most beneficial and efficient for achieving excellent results.

1. Review the clinical history thoroughly (see history to be considered for poultry) and consider all likely diagnoses. Live sick birds or freshly dead birds are ideal samples for necropsy. Commercial poultry are usually submitted live, 4 to 8 birds. If day-old chicks/poults, *etc*., are submitted their number can exceed 10. Backyard poultry is generally submitted as a single dead bird. Ask the Vet or the owner to take blood for serology before euthanizing a live bird and submitting it.

2. Examine the externa and observe the clinical signs if the bird is alive. Pay particular attention to abnormalities of the eyes/eyelids, nostrils, comb, snood, wattles, ears, oral cavity, feathers, skin, wings, legs, hocks, foot pads, *etc*. Check carefully for hemorrhages/bruises, fractures, external parasites such as mites, lice and fleas.

3. If the bird/s alive, the bird/s may be euthanized by any of three methods approved by AVMA.
   a. Administration of CO2 gas in an appropriate closed container.
   b. Disarticulate the head at the atlanto-occipital joint.
   c. Intravenous injection of barbiturate or other approved product.

4. Moisten the feathers with water containing detergent. If ornithosis or psittacosis is suspected, the bird should be soaked in 5% Lysol solution and a laminar flow hood should be utilized for the necropsy. If large birds like turkeys are suspected of chlamydiosis and are necropsied in a large PM room wear approved N 95 face mask fitted for you, secure the room, alert the other coworkers/employees and follow proper disposal procedures; incinerate the carcasses, disinfect cardboard boxes, autoclave plastic, waste, *etc*.

5. Place the birds on their dorsum with feet facing you, make an incision of the femoral vein as soon as the bird/s euthanized. Collect blood in tubes and place them in a rack in an inclination so that serum can separate easily. In small chicks, poults and ducklings collect blood from the neck after cervical dislocation or soon after euthanasia.

6. Incise the loose skin between the medial surface of each thigh and the abdomen. Reflect the legs laterally and disarticulate the hip joints. In broiler chickens and others observe proximal femur for FHN. Incise the skin on the medial aspect of each leg and reflect it to expose the muscles and stifle joint.

7. Connect the lateral skin incisions with a transverse skin incision across the middle of the abdomen. Reflect the skin of the breast anteriorly and, the skin of the abdomen posteriorly.

8. Make a longitudinal incision through the pectoral muscles on each side of the keel and over the costochondral junctions. The anterior end of each incision should intersect the thoracic inlet at the dorso-ventral midpoint. With heavy scissors cut through the coracoid and clavicle bones.

9. With sterile scissors make a transverse incision through the posterior part of the abdominal muscles. On each side continue the incision anteriorly through the costochondral junctions. Remove the ventral abdominal wall and breast as one piece, observing the air sacs as they are torn during removal.

10. Without touching them, examine the viscera and air sacs in situ. If air sacs are cloudy they can be cultured for bacteria including mycoplasma and fungus if necessary. Air sacs should be collected in cassettes to facilitate processing.

11. Using sterile instruments remove any organs and take any swabs desired for culturing. The spleen can be exposed aseptically by freeing the left margin of the gizzard and reflecting that organ to the bird's right side. All unnecessary manipulations and delays prior to culture increase the probability of contamination. Take intestinal cultures last.

12. Examine the pancreas. Transect the esophagus at the anterior border of the proventriculus. Reflect the entire gastrointestinal tract posteriorly by cutting the mesenteric attachments and then remove it after transecting the rectum. Examine the bursa

13. Remove and examine the liver with gall bladder and spleen.

14. With shears or scissors, cut through one lateral commissure of the mouth and examine the oral cavity. Note any ulcers, hemorrhages or exudate.

15. Continue at the cut commissure and make a longitudinal incision through the skin of the neck to the thoracic inlet. Reflect the skin laterally and examine the paired vagus nerves and the thymus if present.

16. Make a longitudinal incision in the esophagus and crop. Note the contents and odor especially in the crop.

17. Make a longitudinal incision in the larynx and trachea and examine. Examine syrinx also, some times aspergillus lesions are present only in the syrinx.

18. With heavy scissors, remove the upper beak by a transverse cut as near the eyes as possible. This will allow inspection of the nasal cavity and will expose the open anterior end of the infraorbital sinuses. Insert one blade of a sterile scissors into the infraorbital sinus. Make a longitudinal lateral incision through the wall of each sinus and examined them.

19. Examine the gonads. In the female, remove the ovary and oviduct and open the oviduct longitudinally.

20. Examine the ureters and kidneys in situ. If indicated you can remove them for closer examination.

21. Remove and examine the heart. If you suspect aortic rupture in turkeys (blood in the abdominal cavity), dissect the aorta starting at the origin near the heart and continuing distally till you can find the rupture. Rupture is most common at the branch of coeliac artery.

22. Examine the lungs by reflecting them medially from their attachment to the rib cage. For histopathology collect lungs at the entrance of the primary bronchus for best results.

23. With knife or scissors make a longitudinal incision through the proventriculus, ventriculus, small intestine, ceca, colon, and cloaca. Examine for lesions and parasites.

24. Examine brachial plexuses, sciatic nerves and vagus for any enlargements or loss of cross striation. The brachial plexus is most easily observed anterior to the first rib. The sciatic nerves are exposed by careful separation of the adductor and semimembranous and semitendinoses muscles. The intrapelvic portion of the sciatic nerves can be exposed by removal of the overlying portion of the kidneys by blunt dissection. Vagus can be examined on the lateral sides of the neck (it is easier to examine the left vagus)

25. Using a sharp knife open each tibiotarsal joint (coxofemoral joint, stifle and foot pad if necessary) and examine the joint fluid for signs of exudate.

26. Use the sharp knife or scalpel to make a longitudinal cut through the anterior or medial aspect of the head of the tibia to expose the growth plate of immature birds for signs of TD, rickets, osteomyelitis.

27. Disarticulate the femoral head for any evidence of femoral head necrosis. With an osteotome split one femur longitudinally and examine the bone marrow.

28. To examine the brain, disarticulate the head and skin it. Remove the calvarium with strong scissors cutting the skull starting at the atlantooccipital joint and continuing on and around till the cut is complete at the opposite side of the atlantooccipital joint.

29. Other organs such as thyroids (at the thoracic inlet), parathyroids, adrenals, eyes, gland of Harder, ears, spinal cord with vertebrae intact should be collected for histopathology depending on the clinical signs and pathology.

Samples to be collected for various diseases that affect different systems: Consider the species of birds, their age and the system affected while collecting samples. In general in commercial poultry multiple systems are affected in any given case. Therefore, consider obtaining blood samples for serology, culturing organs for bacteria and collect tissues for histopathology any organ that has lesion/s and save tissues for further tests.

In general the following tests are available:
Serology: AI, APMV-1, APMV-2, APMV-3, IBV, IBDV, AE, ILTV, CIAV, HEV, Reovirus, MG, MS, MM, *B. avium*, Salmonella sp.(Pullorum, Typhimurium, arizonae).
Biotechnology: AI, APMV-1, IBV, IBV sequencing, ILTV, IBDV, vvIBDV, WNV, MG, MS. Others: ABV, BFDV, PBFDV, Psittacine herpes and adenovirus (External labs.)
Virus isolation: chicken embryo inoculation, cell culture, (HA, HI, AGID, EM- ID).
Bacteriology: Aerobic, anaerobic, campylobacter, mycology, coliforms, botulism toxin, *etc.* Antimicrobial tests, Gram stain. small rRNA testing, *etc*.
Parasitology: visual observation, direct smear, fecal floatation, McMaster.
FA: Chlamydia, ILTV
Histopathology: all tissues. H and E and special stains available.
IHC: WNV, APMV-1, IBV, ILT, ABV, vvIBDV, chlamydia, toxoplasma, sarcocystis falcatula, Trichomonas, Clostridia sp..
Electron microscopy: Negative stain (direct EM), thin section EM, immune EM, and scanning EM.
Toxicology: Heavy metals, selenium, vitamins (A and E), ionophore screen, mycotoxins, salt screen, trace element screen, anticoagulant screen, herbicide screen, cholinesterase, insecticides/pesticides, domoic acid, metaldehyde, avitrol, plant identification, zinc/aluminum phosphide, etc.

Tests to consider for various systems:
Respiratory System:
Serology: MG, MS, *Bordetella avium*, AI, APMV-1, APMV-2, APMV-3, IBV, ILT, TRT, in addition for MM in turkeys.
Bacteriology: culture for aerobic bacteria; sinus, trachea, air sacs and lungs.
For fungus: syrinx, air sac, lungs.
Virology: trachea, lungs, cecal tonsils (for IBV)
PCR: Trachea/lung, cecal tonsils.

Digestive System:
Serology: APMV-1, AI, HEV (turkeys), IBDV,
Bacteriology: culture ceca (pool) for salmonella, (AEEC), intestine for clostridia if lesions are present.
Intestine: make smears on glass slides for coccidia and other parasites
Transmission electron microscopy (negative stain): pool of small intestine (and ceca) in viral transport media.

Note: collect sections of intestine in formalin as soon as the live birds are euthanized especially for detecting attaching and effacing E. coli (AEEC).

Nervous System:
Serology: APMV-1, AI, AE, Marek's
Bacteriology: culture brain for aerobic and fungus (if lesion present).
For botulism liver and cecal contents are suitable as well as sera
Virology: brain in viral transport media
Toxicology: brain for cholinesterase inhibition, sodium levels

Immune System:
Serology: IBDV, CIAV, APMV-1, AI, HEV (in turkeys)
Virology: Bursa of Fabricius.
PCR: Bursa of Fabricius.

Musculoskeletal system:
Serology: Reovirus,
Bacteriology: culture synovium/joint, keel bursa for aerobic bacteria, mycoplasma
Virology: swab from joint, tendon,
PCR: joint (& trachea) swab for MG and MS.
Ionophore toxicity: collect adductor and intercostal muscles. Heart is very rarely involved in young poultry, but sometimes in adults.

Toxicity or nutritional:
Feed.
Liver, kidney: for heavy metals. Liver also for vitamins (A, E), selenium, insecticides/pesticides, rodenticides and certain aflatoxins.
Brain: cholinesterase, sodium, OP's HC's
Crop/gizzard contents: strychnine, etc.

5. A brief protocol for necropsy of pet, exotic, pigeons, and wild birds

A. Protect yourself from zoonotic diseases such as Chlamydia, WNV, Mycobacteria, Aspergillus, Salmonella, *etc*.
B. Follow good laboratory practices
C. Always perform necropsies in BSL II hoods, especially psittacines and pigeons
D. Be aware of occasional legal (start chain of custody) and/or insurance cases.

1. Read the history. If it is incomplete, talk to the owner and obtain details.
2. Develop a list of differential diagnoses based on history.
3. If the bird/s is live observe the bird/s for clinical signs such as respiratory, diarrhea, neurological, weakness, *etc*. For euthanasia use only methods approved by AVMA.
4. Weigh the bird, record the weight.
5. Obtain blood for serology, and hematology and serum chemistry if necessary.
6. If blood is available make a blood smear especially from pigeons, wild birds, *etc*. Do Wright's/Giemsa stain, examine for hemoprotozoa, differential count, *etc.*
7. Rinse the bird in a suitable disinfectant.
8. Observe the exterior: conjunctiva/eyes, feathers, skin, nostrils, vent, uropygial gland, toes, keel, *etc*. Look for tumors, fractures (use x-ray if available), bruising, bleeding, *etc*.
9. Record ID (leg band #, color, *etc*). Record the starting time of necropsy if necessary.
10. Determine breed, age and sex. If information is not available, talk to the owner regarding the breed and age (age is difficult to determine if wild caught).
11. Observe for signs of dehydration (eyes, skin, muscle).
12. Determine nutritional condition (pectoral muscle atrophy, keel score).
13. Determine the postmortem condition.
14. Determine obesity/fat content, *etc*.
15. Record the nature and amount of contents if any in crop, proventriculus, gizzard, intestine.
16. Record all lesions accurately, if necessary weigh organs like liver, heart, spleen, *etc*.
17. Photograph lesions. Use a scale/ruler when ever possible or if necessary.
18. Photograph the whole bird with accession # clearly visible if it is a legal or insurance case.
19. Disposal of carcasses and remains: should be done according to the protocols; in a biohazard bag for autoclave or incineration especially psittacines.

Laboratory procedures:

a. i) Bacteriology – culture any lesion for aerobic bacteria on Blood Agar/MacConkey agar plates. Culture liver, lung/trachea, and intestine on BA/Mac. agar plates. Also, culture intestine for salmonella. Culture for Mycoplasma, clostridia, campylobacter if necessary. Save cecal contents and liver for botulism assay if necessary.
ii) Mycology – culture for fungus if necessary.

b. i) Make smears from liver, spleen, air sac/conjunctiva/kidney for Chlamydia by FA.

ii) Make smears from liver and spleen for Geminez stain (Chlamydia)
iii) Do cytology of tumors, exudates, granulomas, *etc.*, if necessary.

c. Save:
i) Liver, spleen, kidney, lung, heart, brain, intestine in viral transport media for virology. Keep them separate or pool such as liver, lung, heart if necessary.
ii) Submit intestine for direct (negative stain) electron microscopy if necessary.
iii) Liver and kidney for toxicology (others – crop/proventriculus, gizzard contents and fat, brain).

d. Check for mites, lice, round worms, tapeworms, protozoa, *etc.*

e. For PCR; Kidney for West Nile virus, Liver for Psitt Beak and Feather Dis., Polyomavirus, Psittacine Herpesvirus, Adenovirus, etc.

f. Oropharyngeal and cloacal swabs for AI and END/NDV PCR.

g. Take the tissues for histopathology (see the list below)

List of tissues to be collected for histopathology

(Note: Take any tissue that looks abnormal/has a lesion. Be aware! There are anatomical differences between various species (>22,000 subspecies) of birds and ages.

Integument

1. Skin (with feathers)
2. Eye lids (with palpebral/bulbar conjunctiva)

GI tract

1. Tongue/oral mucosa
2. Esophagus
3. Crop
4. Proventriculus
5. Ventriculus (gizzard)
6. Duodenum (with pancreas)
7. Jejunum
8. Ileum/cecum
9. Colon, rectum/cloaca
10. Liver (with gall bladder if necessary)
11. Pancreas

Cardiovascular

1. Heart (with the major vessels)
   Measurements if necessary: (Weight)
   1. L ventricle wall
   2. R ventricle wall
   3. Septum
   4. Measure the volume of ventricles
   (also can measure the valve circumference)
2. Vessels:
   1. Major vessels

2. Aorta (major and abdominal) and carotid,

Respiratory
1. Sinuses/turbinates
2. Larynx
3. Trachea (mid/distal and bronchi with lung)
4. Syrinx (sometimes the only organ affected with aspergillosis)
5. Lung
6. Air sacs

Lymphoid organs
1. Thymus
2. Spleen
3. Bursa (if present)

Endocrine/Other glands
1. Thyroids/parathyroids
2. Pancreas (splenic lobe)
3. Adrenals
4. Pineal *
5. Gland of Hardar
6. Lachrymal gland*
7. Pituitary*
8. Uropygial gland (if present)

Repro/Renal
1. Testes/ovary
2. Oviduct/vas deferens
3. Kidneys

Nervous/Special Senses
1. Eye/s
2. Brain (cerebrum, cerebellum, brain stem)
3. Cervical/thoraci/lumbar/sacral or entire spinal cord with vertebrae – glycogen body
4. Brachial plexus/sciatic nerves
5. Vagosympathetic trunk*
6. Ears

Musculoskeletal
1. Pectoral/breast muscles
2. Thigh muscles
3. Joint/tendon
4. Bone (femur) could be pneumatic
5. Tibiotarsus (bone marrow)

* Optional.

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Table 1: Oncogenes originally identified through their presence in transforming retroviruses

Oncogene	Protein	Source of virus	Tumour
abl	Kinase	Mouse, cat	Pre-B-cell leukaemia
akt	Kinase	Mouse	T-cell lymphoma
crk	**Kinase activator**	**Chicken**	**Sarcoma**
erb-A	**TH-R**	**Chicken**	**Erythroleukaemia**
erb-B	**EGF-R**	**Chicken**	**Erythroleukaemia**
ets	**TF**	**Chicken**	**Myeloid leukaemia**
fes/fps	**Kinase**	**Chicken/cat**	***SARCOMA***
fgr	Kinase	Cat	Sarcoma
fms	Kinase	Cat	Sarcoma
fos	TF	Mouse	Osteosarcoma
jun	**TF**	**Chicken**	**Fibrosarcoma**
kit	Kinase	Cat	Sarcoma
mil/raf	**Kinase**	**Chicken/mouse**	**Sarcoma**
mos	Kinase	Mouse	Sarcoma
myb	**TF**	**Chicken**	**Myeloid leukaemia**
myc	**TF**	**Chicken**	**Myelocytoma, lymphoma, carcinon**
H-ras	G-protein	Rat	Sarcoma
K-ras	G-protein	Rat	Sarcoma
rel	TF	Turkey	Reticuloendotheliosis
ros	**Kinase**	**Chicken**	**Sarcoma**
sea	**Kinase**	**Chicken**	**Sarcoma, leukaemia**
sis	PDGF	Monkey	Sarcoma
ski	**TF**	**Chicken**	**Carcinoma**
src	**Kinase**	**Chicken**	**Sarcoma**
yes	**Kinase**	**Chicken**	**Sarcoma**

Abbreviations: EGF-R, epidermal growth factor; PDGF, platelet-derived growth factor; TH-R, thyroid hormone receptor; TF, nuclear transcription factor. Chicken genes are shown in **bold**.

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H. L. Shivaprasad – Biography

Is a Professor of Avian Pathology with the California Animal Health and Food Safety Laboratory System (CAHFS), Tulare branch, University of California, Davis since 1989. He obtained his BVSc from Bangalore Veterinary College, India in 1969, MVSc in Poultry Genetics from UPAU, Pantanagar, India in 1971, PhD from The Ohio State University in 1977 and residency training in Veterinary Pathology from Purdue University 1978-1980. He was a faculty member in Genetics in Bangalore Veterinary College (> 1 year), in Veterinary Pathology at University of Illinois (5 years) and in Avian Pathology at Cornell University (4 years) before joining CAHFS. He is board certified by the American College of Poultry Veterinarians. He has been involved in avian diagnostics, teaching and research for more than 35 years. His primary research interests are to identify novel etiologies and diseases of both infectious and noninfectious nature and study their pathogenesis in avian species. He has published extensively in journals, books and proceedings and has presented numerous papers in national and international conferences. He is a member of many professional organizations, serves on the editorial board of one journal, associate editor of Avian Pathology J and is an ad-hoc reviewer of a number of other journals. He was the senior author of the best paper published in the J of Veterinary Pathology in the year 2011. The paper was recognized for its scholarship, significance and illustrations. He was also the recipient of Lasher-Botorff award in 2015 awarded by the American Association of Avian Pathologists in his recognition as an eminent avian pathologist and for his contribution to the poultry health programs in North America He has traveled to more than 30 countries on invitation primarily for teaching.