blood vitamins and minerals help in assessing nutritional status?

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Veterinarians use the DAMN IT acronym to help recall all the potential causes

D = Degenerative or Developmental

A = Anomalous or Autoimmune

M = Metabolic, Mechanical, or Mental

N = Nutritional or Neoplastic

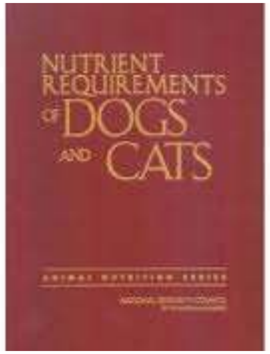
I = Inflammatory, Infectious, Ischemic, Immune-mediated, Inherited, Iatrogenic, or Idiopathic

T = Traumatic or Toxic

Abnormality attribution - Nutrition

- Physical examination
  - Body/muscle condition
  - Skeletal/Dental
  - Integument condition
  - Ascites/edema
  - Eyes – cataracts, blindne
- Medical history
  - Disease condition
  - Excessive losses
  - Food intake

Abnormality attribution Nutrition



Diet history - Nutrient Intake Asses

All foods & amounts

Nutrient contents (manufacturer, datab

Nutrient allowances (NRC, FEDIAF)

Incomplete diet history, usual finding

Large dogs, ~ 10 % ME "treats" (Leavitt et al 2025)

Small dogs, 16 (0-100) % ME "treats" (Freeman et al 2003)

Abnormality attribution - Nutrition

- Clinical laboratory evaluation
  - Hematology
  - Biochemistry

    blood, plasma, serum, and urine

- Nutrients – Clinical Biochemistry
  - Potassium, sodium, chloride, phosphorus
  - Calcium, magnesium (total and ionized)
  - Iodine (thyroid hormone)

Clinical Pathology

Creatinine	1.5	mg/dL	0.9-2.0
Sodium	148	mEq/L	148-154
Potassium	4.2	mEq/L	3.1-4.6
Chloride	115	mEq/L	112-123
Bicarbonate	16	mEq/L	13-23
Anion Gap	21	mEq/L	13-26
Albumin	3.4	g/dL	2.8-3.7
Total Protein	6.9	g/dL	6.1-8.1
Globulin	3.5	g/dL	2.5-5.2
Calcium	10.9 H	mg/dL	8.6-10.4
Phosphorus	4.0	mg/dL	2.3-5.0
Magnesium	2.3	mg/dL	1.7-2.6
Cholesterol	198	mg/dL	80-258
Total Bilirubin	0.1	mg/dL	0.1 - 0.2
ALT	46	U/L	28 - 84
ALP	17	U/L	13 - 50
GGT	<3	U/L	0-3
CK	86	U/L	65 - 574

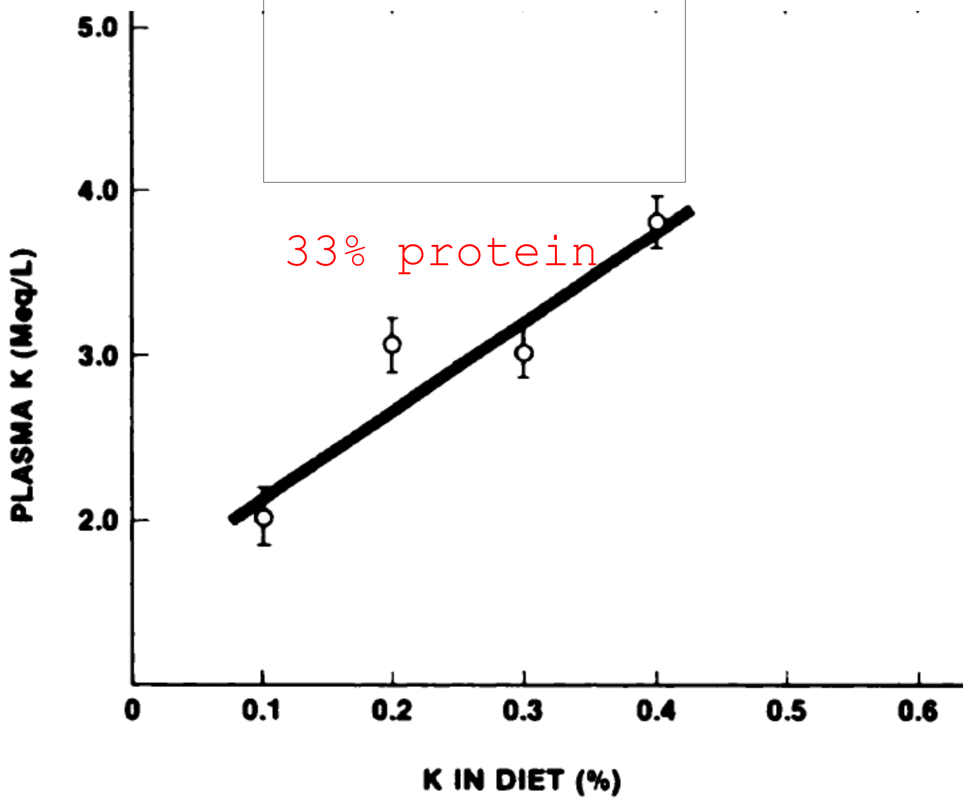
Blood Nutrient Examples

Potassium – Plasma

Potassium status:

- No inactive body storage pool
- Plasma concentration reflects size of body potassium pool
- Correlated with potassium intake

Hills et al 1982 Potassium Requirement of Kittens as Affected by Dietary Protein



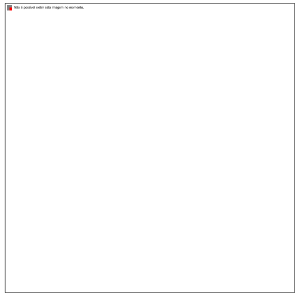
✓Good marker of potassium status

Sodium - Plasma

Sodium – Plasma

Sodium status:

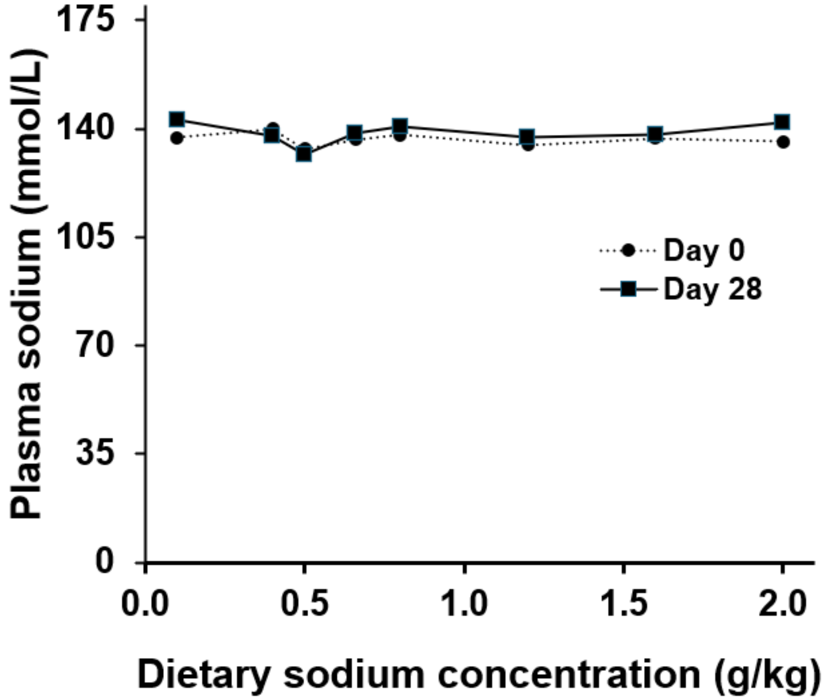
- Adult cats, chronic (e. g., 28 days)



- Intake not correlated with plasma sodium
- Plasma sodium stable

X Poor marker of sodium status

- Requirement being met?

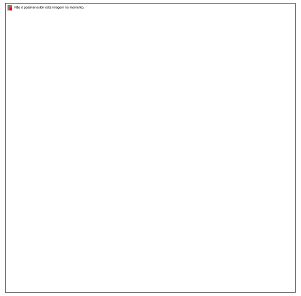


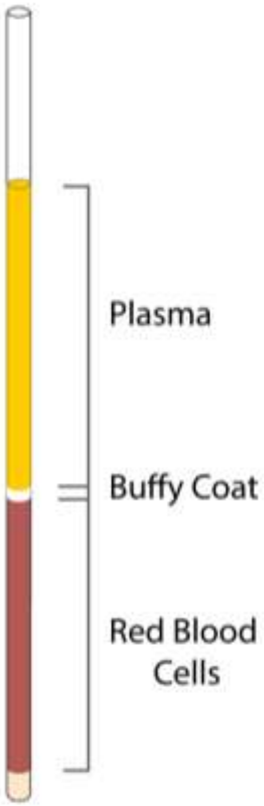
Yu & Morris 1999 Sodium Requirement of Adult Cats for Maintenance Based on Plasma Aldosterone Concentration

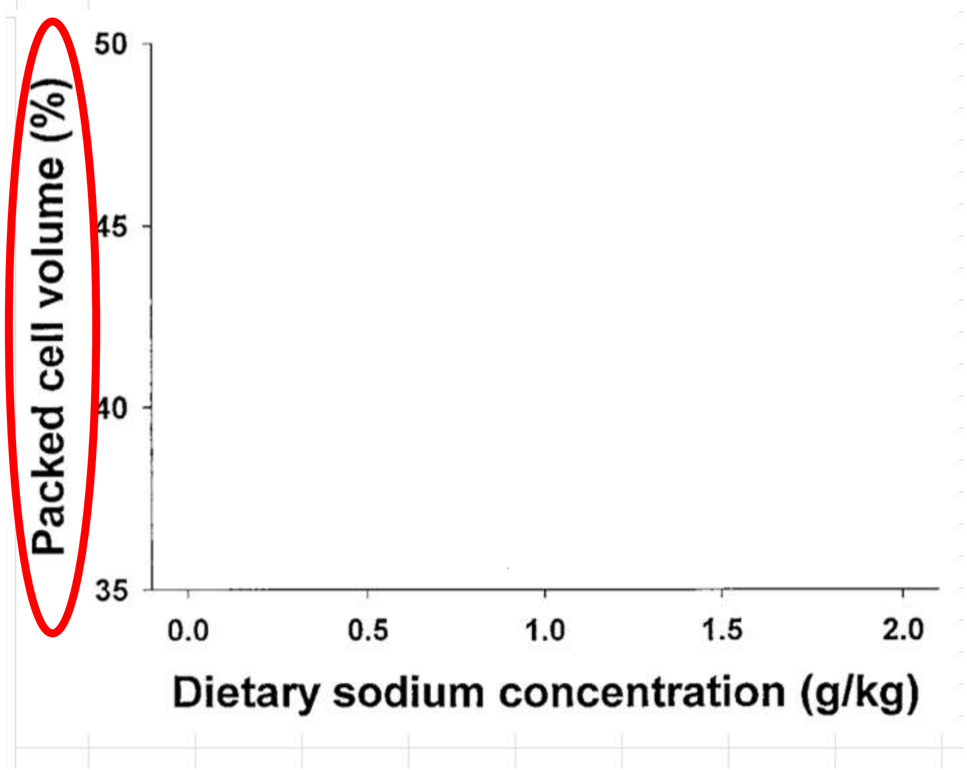
“Definition of a nutrient requirement requires that it be based on one or more physiological responses …”

Yu & Morris 1999 Sodium Requirement of Adult Cats for Maintenance Based on Plasma Aldosterone Concentration

Sodium – Extracellular Fluid Volum

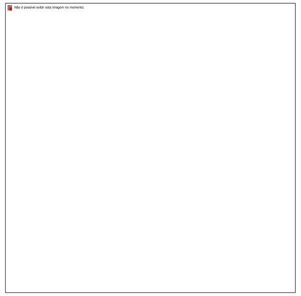


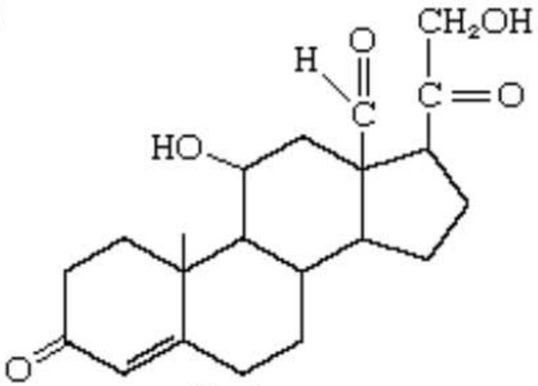




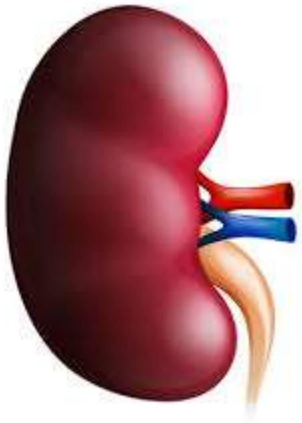
Yu & Morris 1999 Sodium Requirement of Adult Cats for Maintenance Based on Plasma Aldosterone Concentration

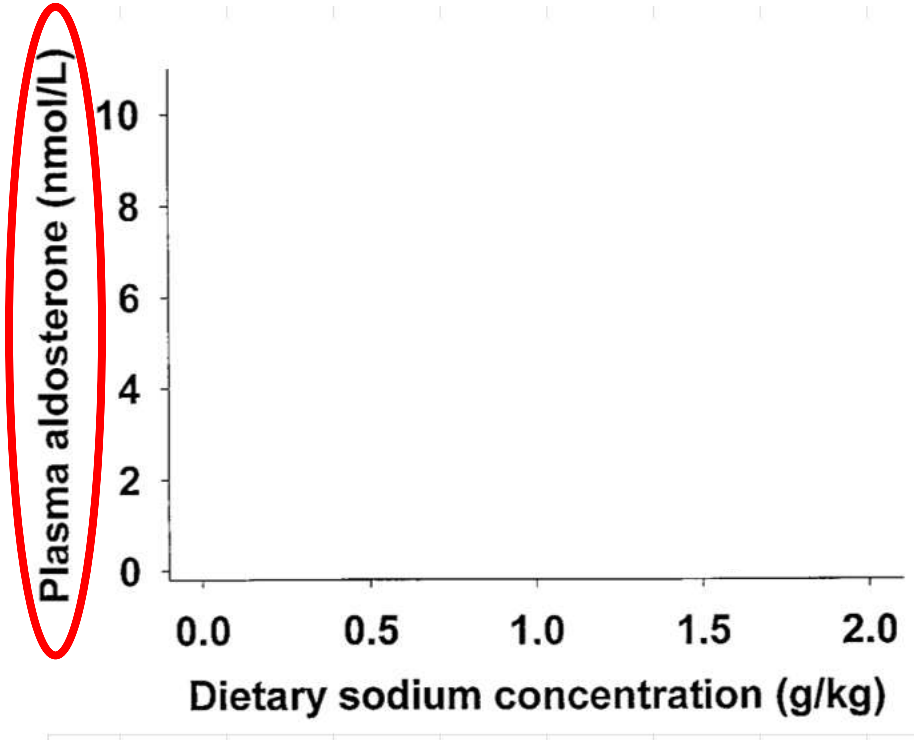
Sodium – Plasma Aldosterone





aldosterone



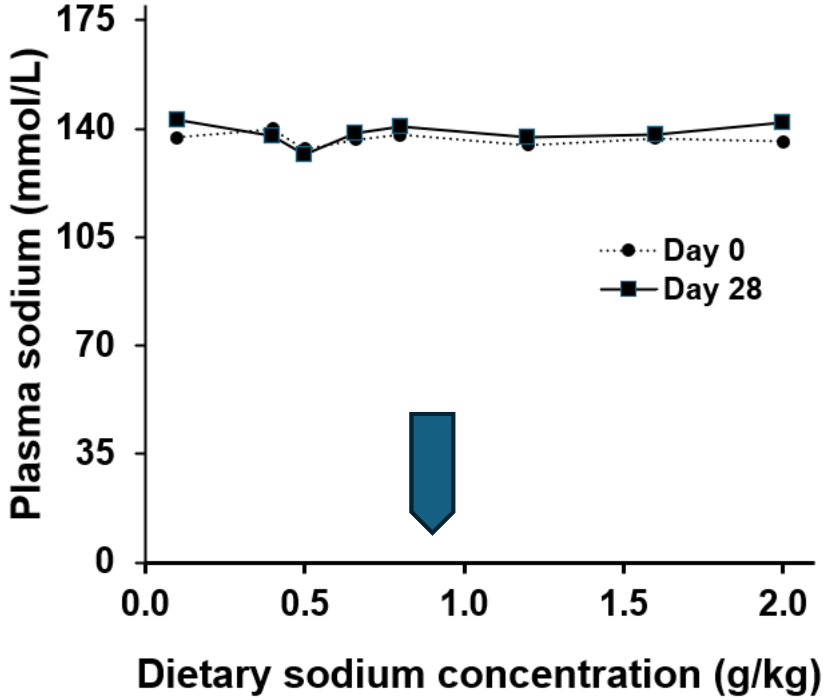


Yu & Morris 1999 Sodium Requirement of Adult Cats for Maintenance Based on Plasma Aldosterone Concentration

Sodium - Plasma

Sodium status:

- Adult cats, chronic (e. g., 28 days)



- Intake not correlated with plasma sodium
- Plasma sodium stable

Yu & Morris 1999 Sodium Requirement of Adult Cats for Maintenance Based on Plasma Aldosterone Concentration

Phosphorus - Plasma

Phosphorus – Plasma phosphorus, low

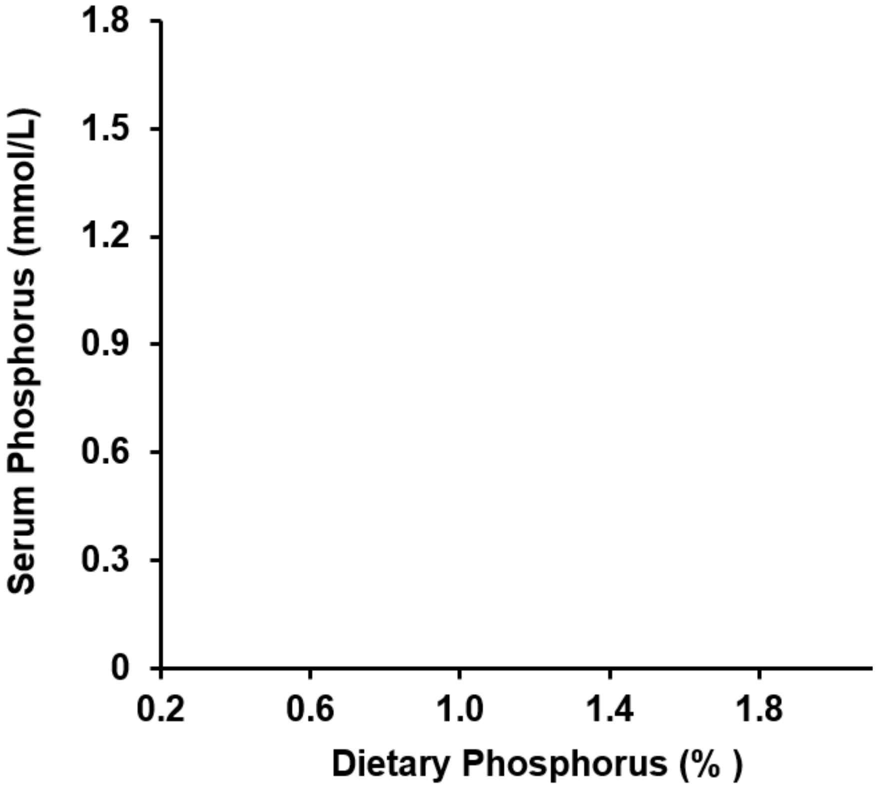
Phosphorus Deficiency (adult cats):

- **Hemolytic anemia**
- **Apathy**
- **Metabolic acidosis**

- **Abnormal mobility, tarsal joint**
- **Flexion of the hind legs**

Kienzle et al 1998 Phosphorus requirements of adult cats

Phosphorus – Plasma



Phosphorus status:

- Adult cats, chronic intake (e. g., 18 days)
- Intake not correlated with plasma phosphorus

X Poor marker of phosphorus status

- Urine phosphorus, positive correlation

X Plasma poor marker of phosphorus excess

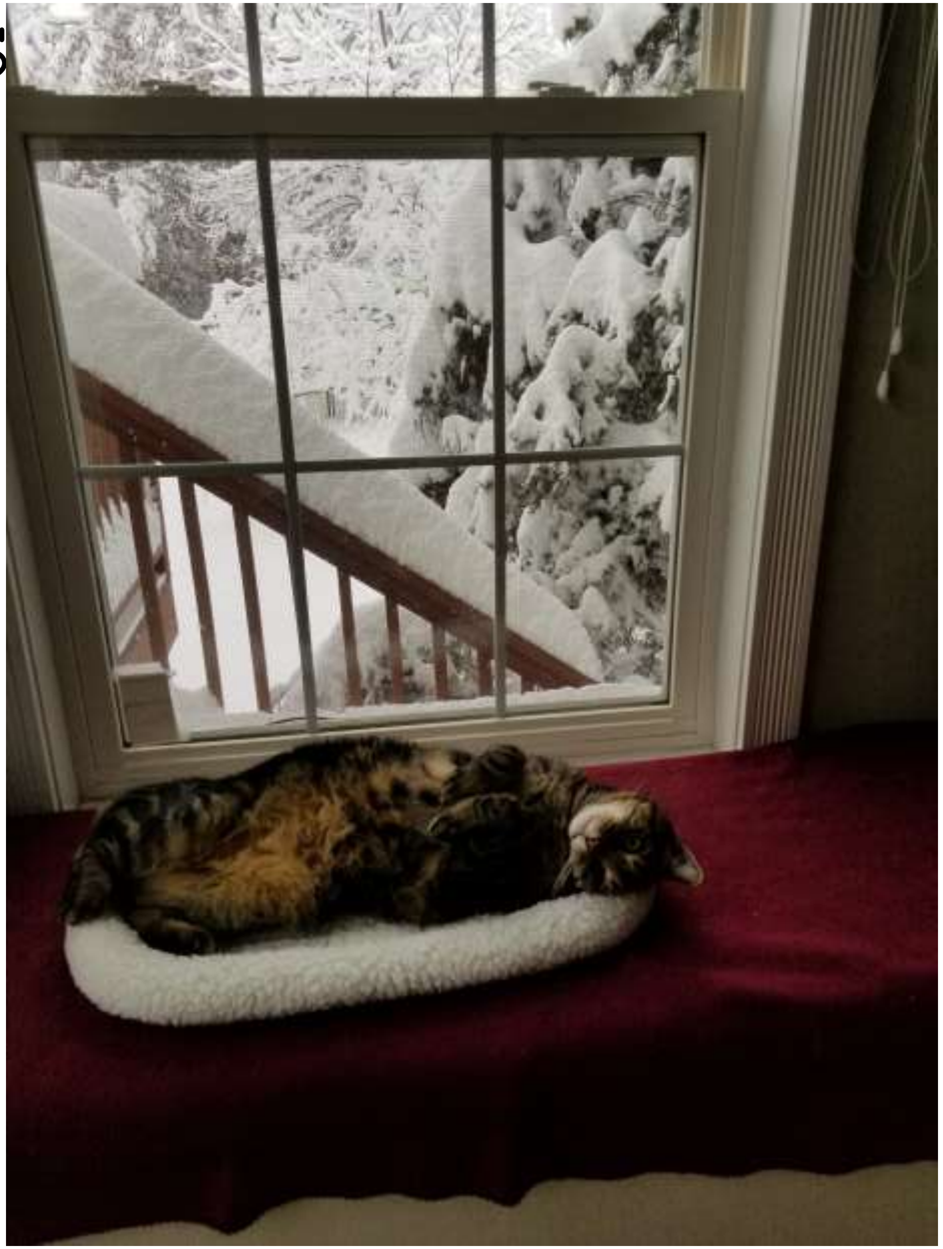
High phosphorus intake can cause cats <u>kidney damage</u> …

✓ Dobenecker et al 2018 (Ca/NaHPO4)

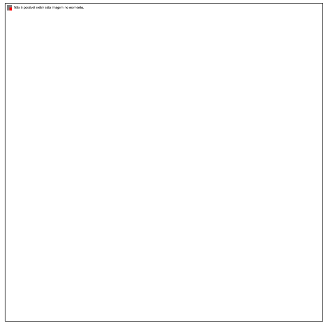
✓ Alexander et al 2018 (NaHPO4)

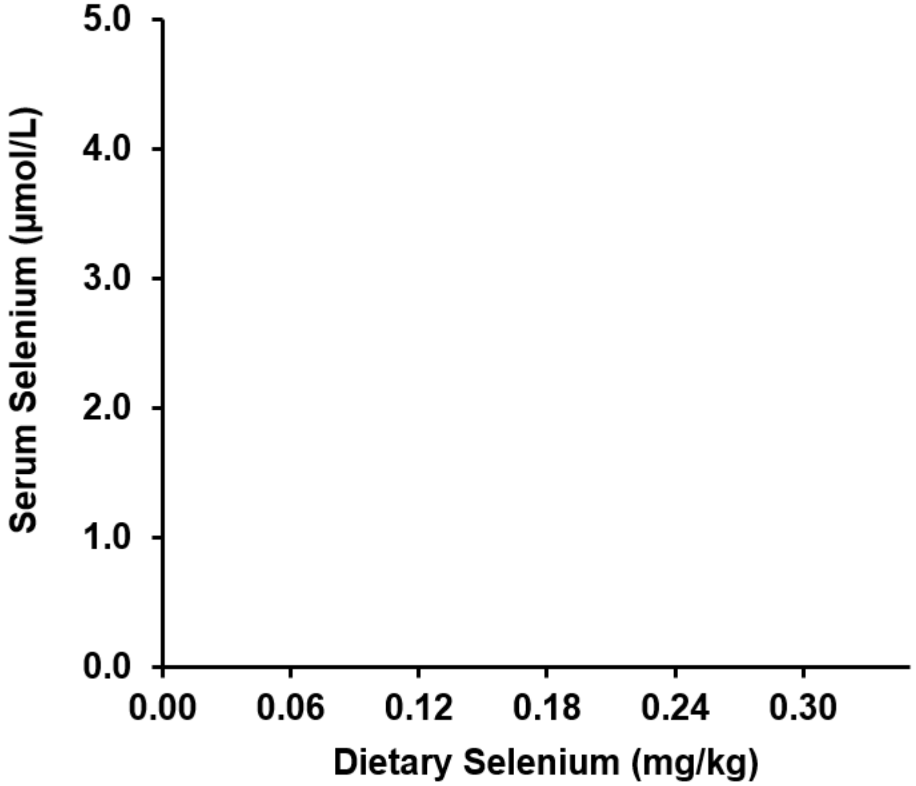
Paßlack et al 2016 Impact of Increasing Dietary Calcium Levels on Calcium Excretion and Vitamin D Metabolites in the Blood of Healthy Adult Cats

Selenium - Plas



Selenium – Plasma





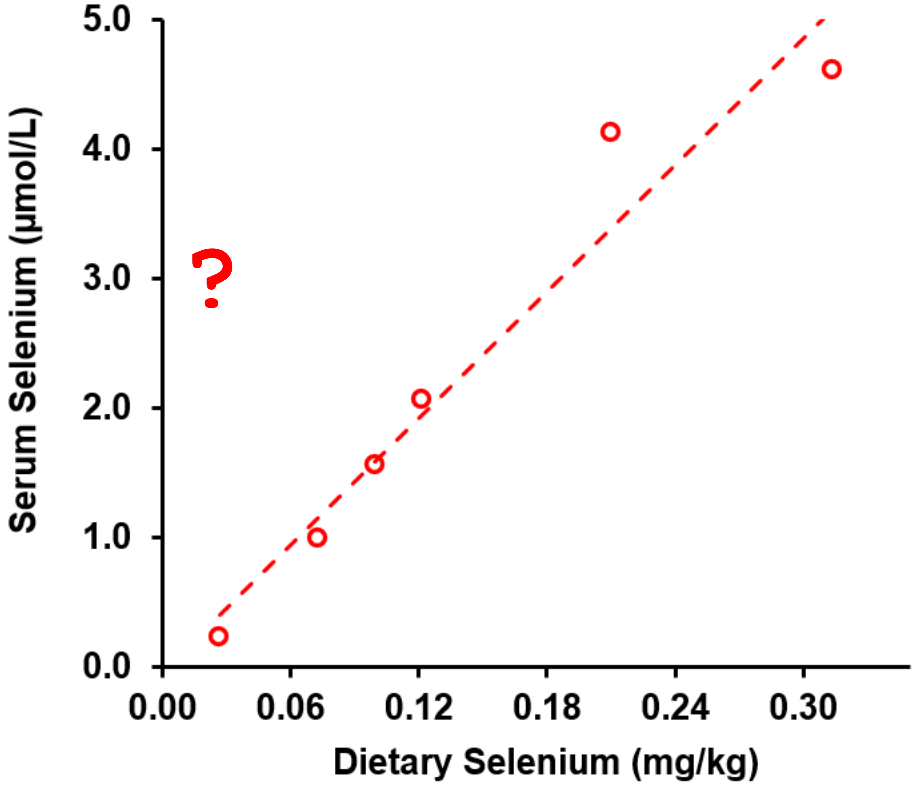
Selenium status:

- Kittens, chronic (8 weeks)
- Pre-depleted of selenium (5 wks)
- Intake correlated with serum selenium
- Selenium in serum proteins

✓ Good marker of selenium status?

Wedekind et al 2003 Determination of the selenium requirement in kittens

Selenium - Plasma



Adequate serum concentration?

- ✓ **Reference interval**
- ✓ **Blood physiological response variable**

Wedekind et al 2003 Determination of the selenium requirement in kittens

Selenium – Plasma Reference Intervals

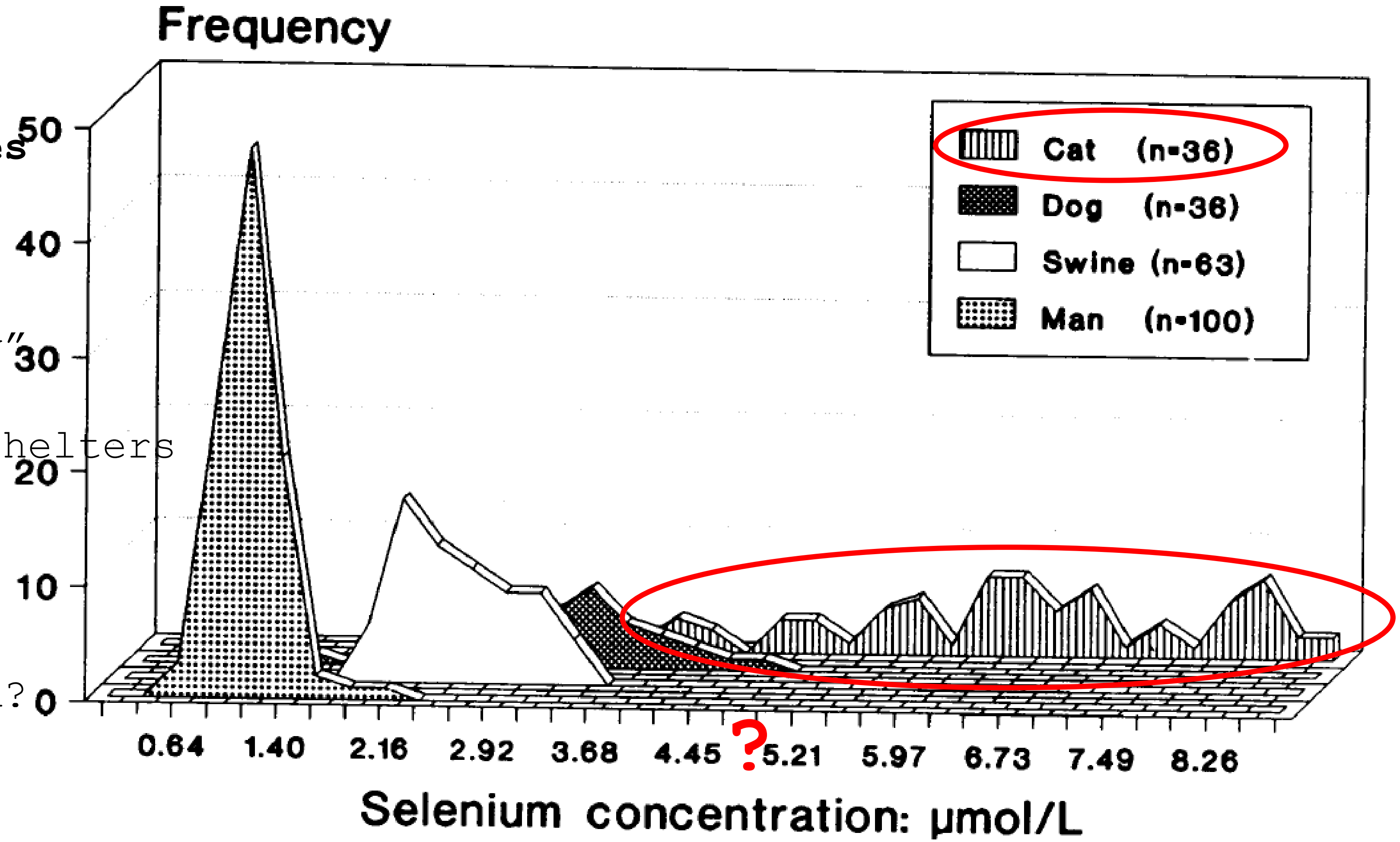
Forrer et al 1991 Comparative determination of selenium in the serum of various animal species

Species differences

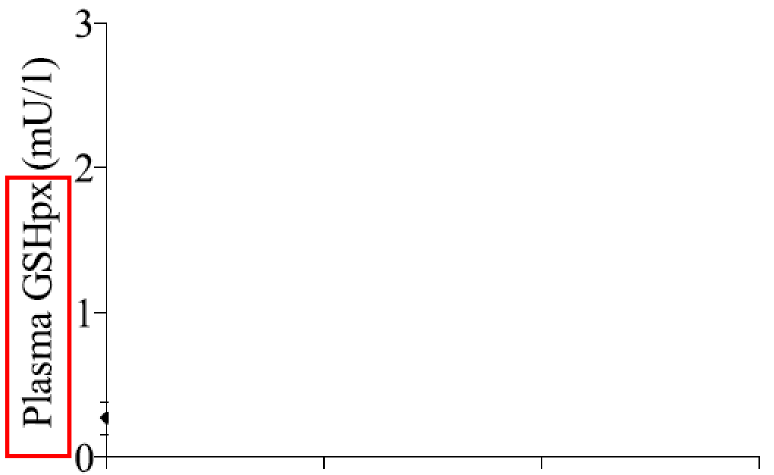
Cats
Adults
"Clinically heathy"
Commercial diets
Privately owned, shelters

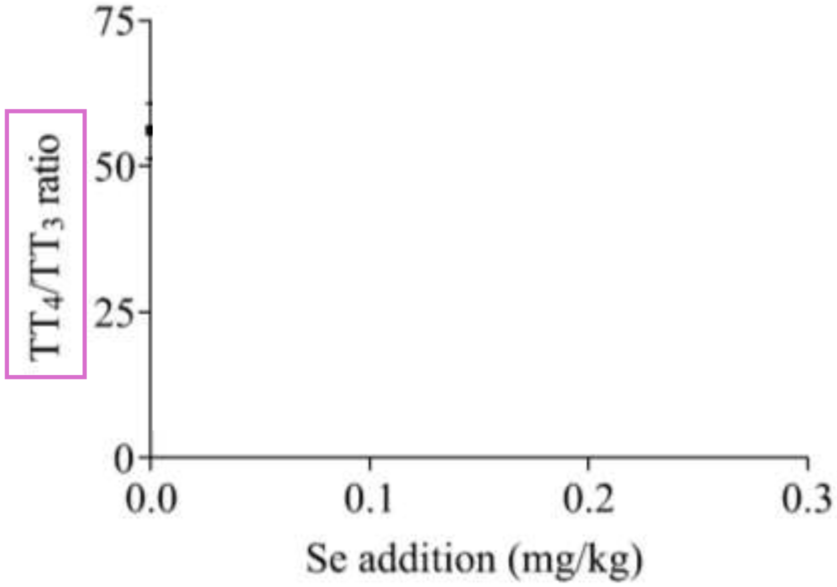
Greatest
Most varied

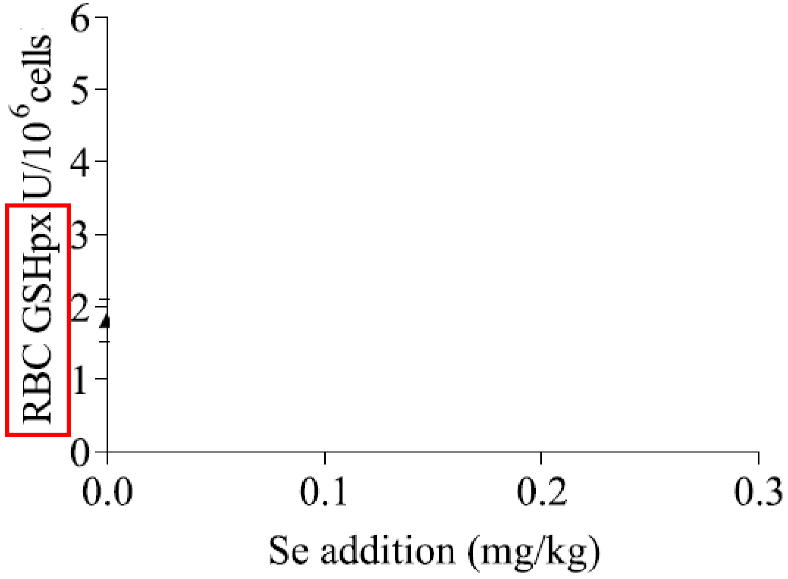
Meat and fish food?



Selenium – Physiological response

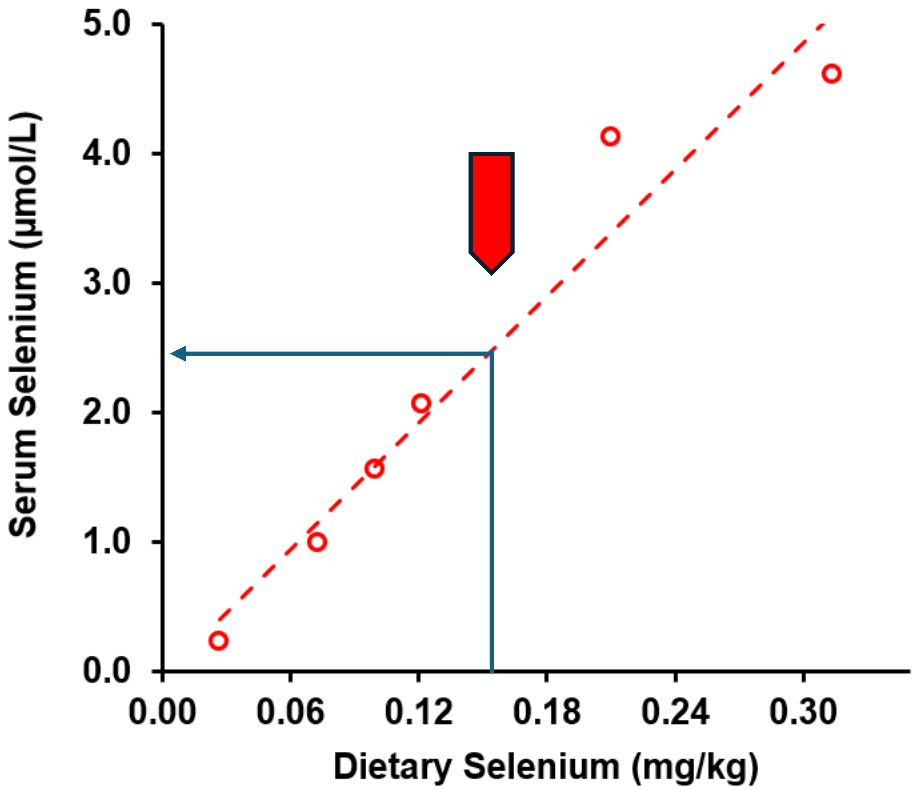






Wedekind et al 2003 Determination of the selenium requirement in kittens

Selenium - Plasma



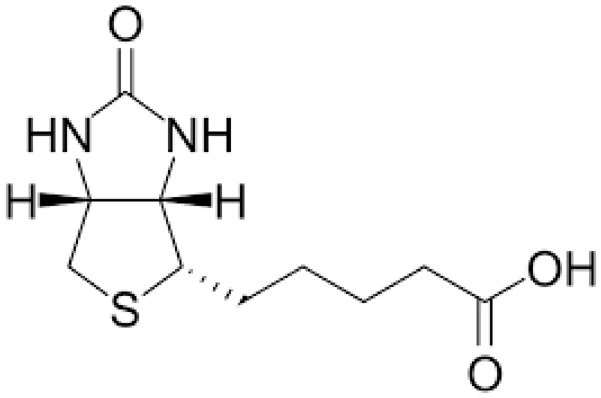
Highest dietary break-point
Selenium in plasma @ break-point

~ 2.5 µmol/L

Wedekind et al 2003 Determination of the selenium requirement in kittens

Plasma, blood - Vitamins

Plasma, blood – Vitamin



Organic compounds, in minute amounts

- mg/kg diet – e.g., Niacin (B3), Vitami
- µg/kg diet – e.g., Cobalamin (B12), Bi (B7)

Different source forms (not always measured)

- Vitamin K – e.g., phylloquinone, mena
- Vitamin A – e. g., retinoids, carotin

Blood only a small pool, body reserves vary

Metabolites of vitamins often measured

Essential or Conditionally Essential (species variation)

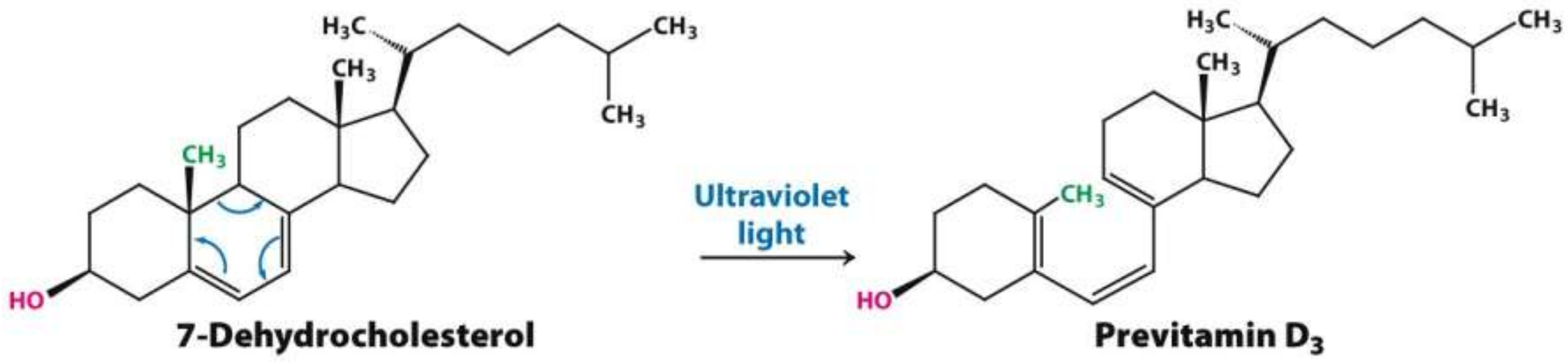
- B-vitamins – adult ruminants

Vitamin D

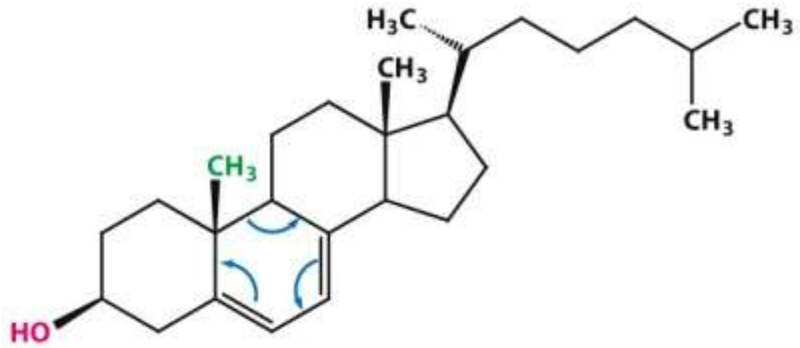
Species-dependent
conditionally essential

Haddad et al 1993 Human Plasma Transport of Vitamin D after Its Endogenous Synthes

Vitamin D – Skin synthesis

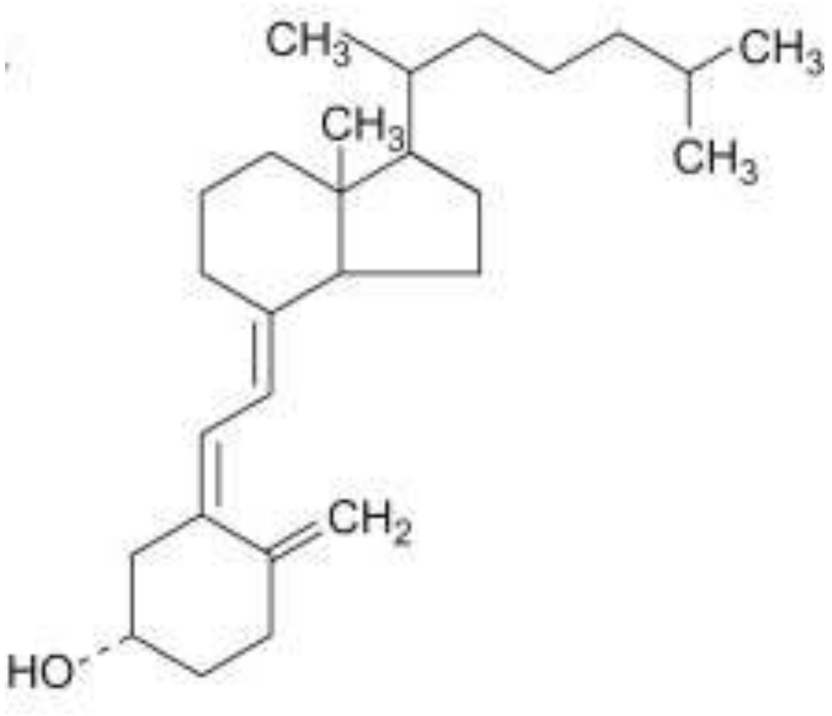


Vitamin D synthesis: ~~Skin~~ of Cats, Dogs



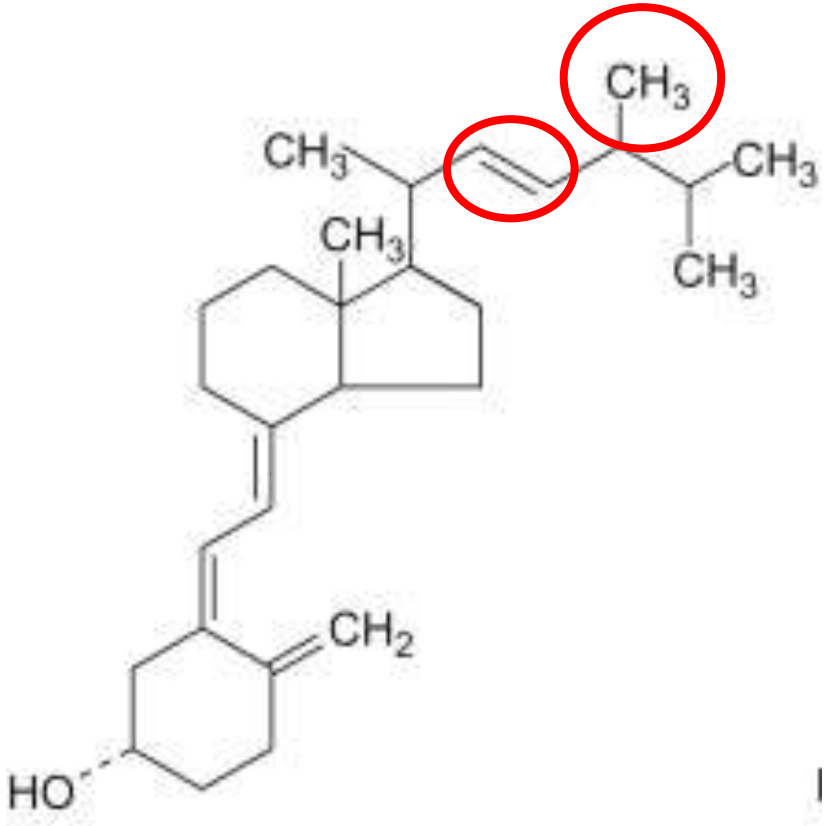
7-Dehydrocholesterol

Vitamin D sources



Cholecalciferol

(vitamin D3)
Skin & Animal origin

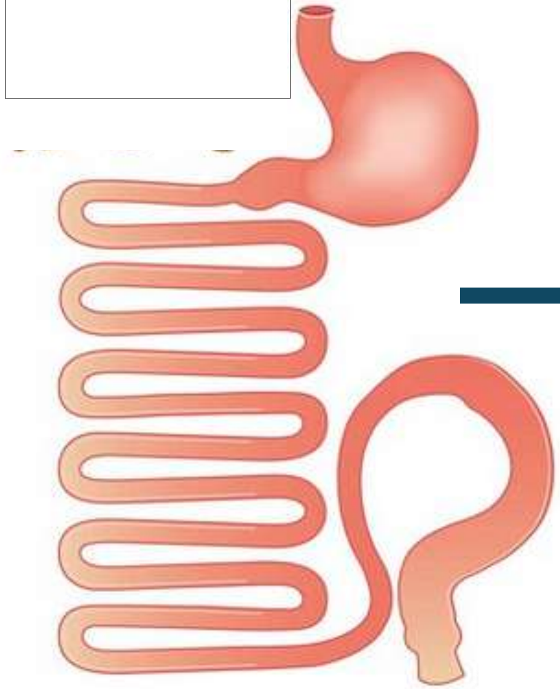


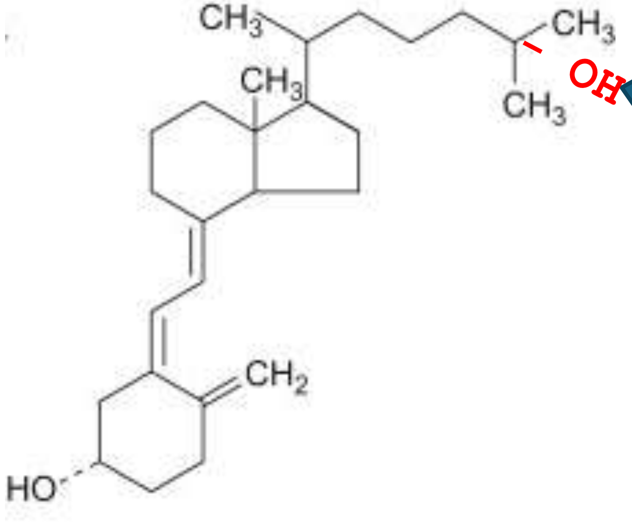
Ergocalciferol

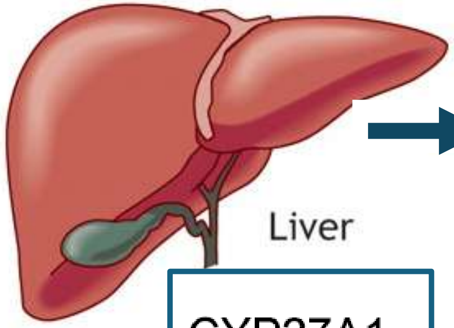
(vitamin D2)
Plant origin

Vitamin D metabolism

Vitamin D through supplements or food







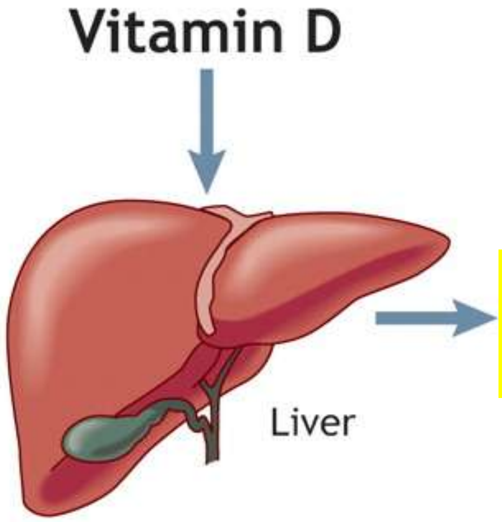
Lipoproteins
VDBP
albumin

CYP27A1
CYP2R1
CYP2J2/3
CYP3A4
CYP2D25
CYP2C11

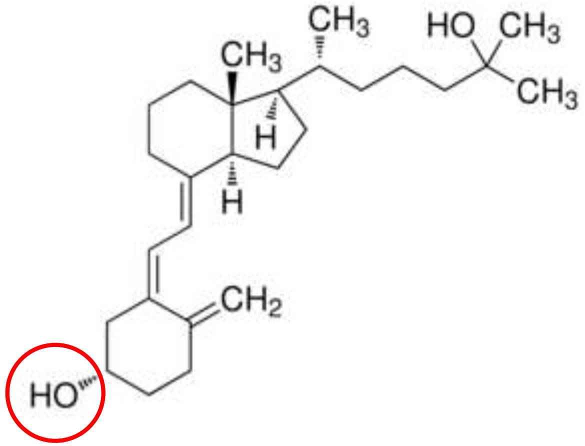
25-hydroxvitamin D

25-hydroxylases

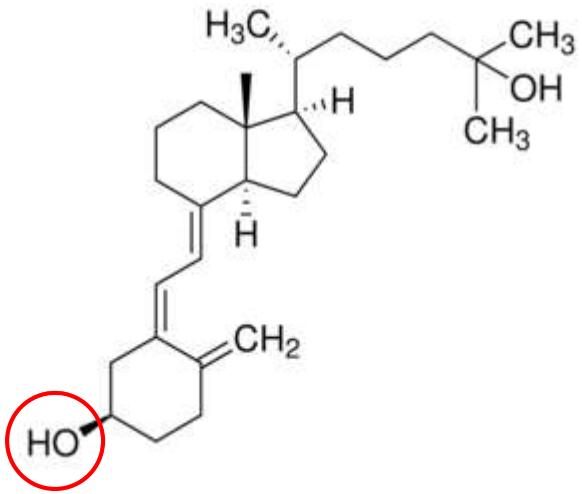
Vitamin D status – Plasma metabolites
Species difference



"Calcidiol"
25-hydroxyvitamin D



β-epimer



α-epimer

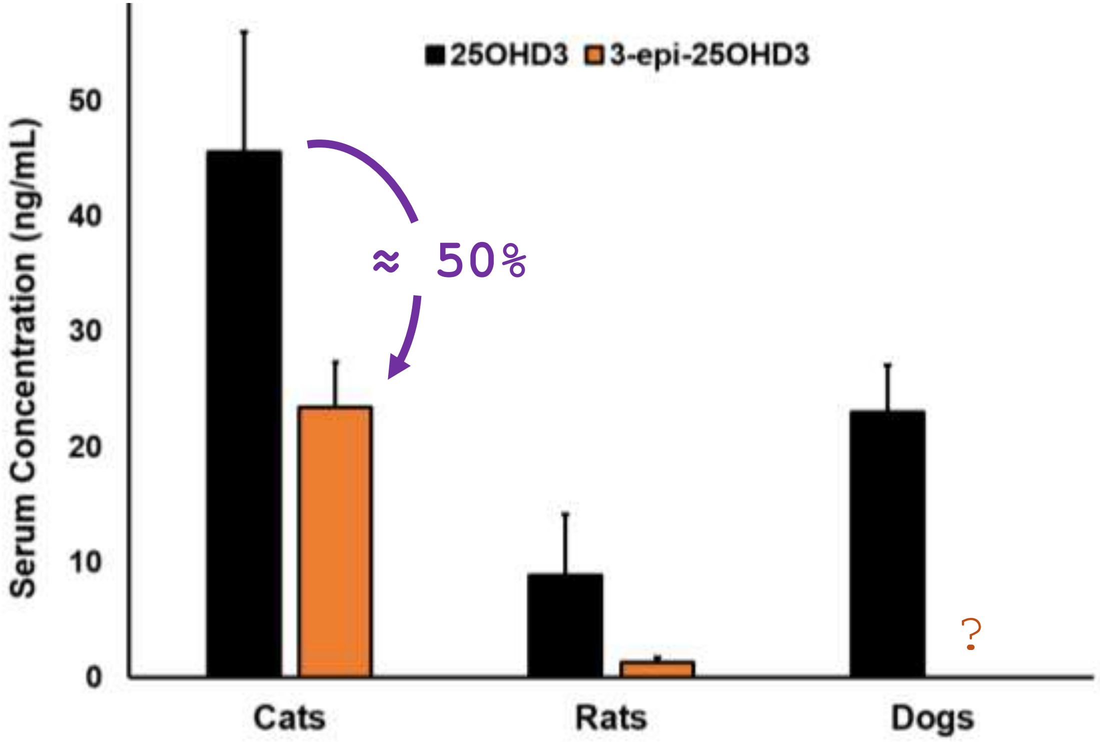
Original Article

Previously undescribed vitamin D C-3 epimer occurs in substantial amounts in the blood of cats

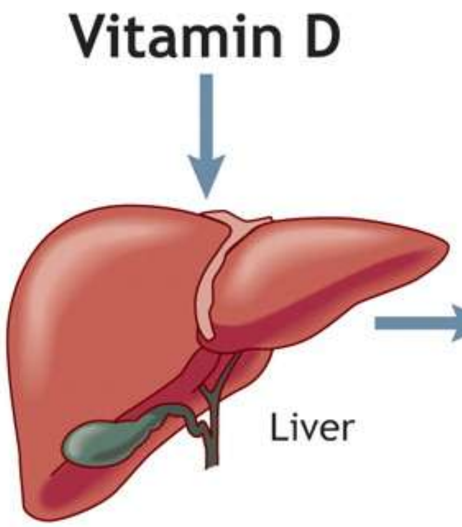
Megan C Sprinkle[1], Sarah E Hooper[2] and Robert C Backus[1]

Journal of Feline Medicine and Surgery
1–8

DOI: 10.1177/1098612X17693523
journals.sagepub.com/home/jfms
This paper was handled and processed by the American Editorial Office (AAFP) for publication in *JFMS*
SAGE



Vitamin D
Plasma Metabolites
Species differences



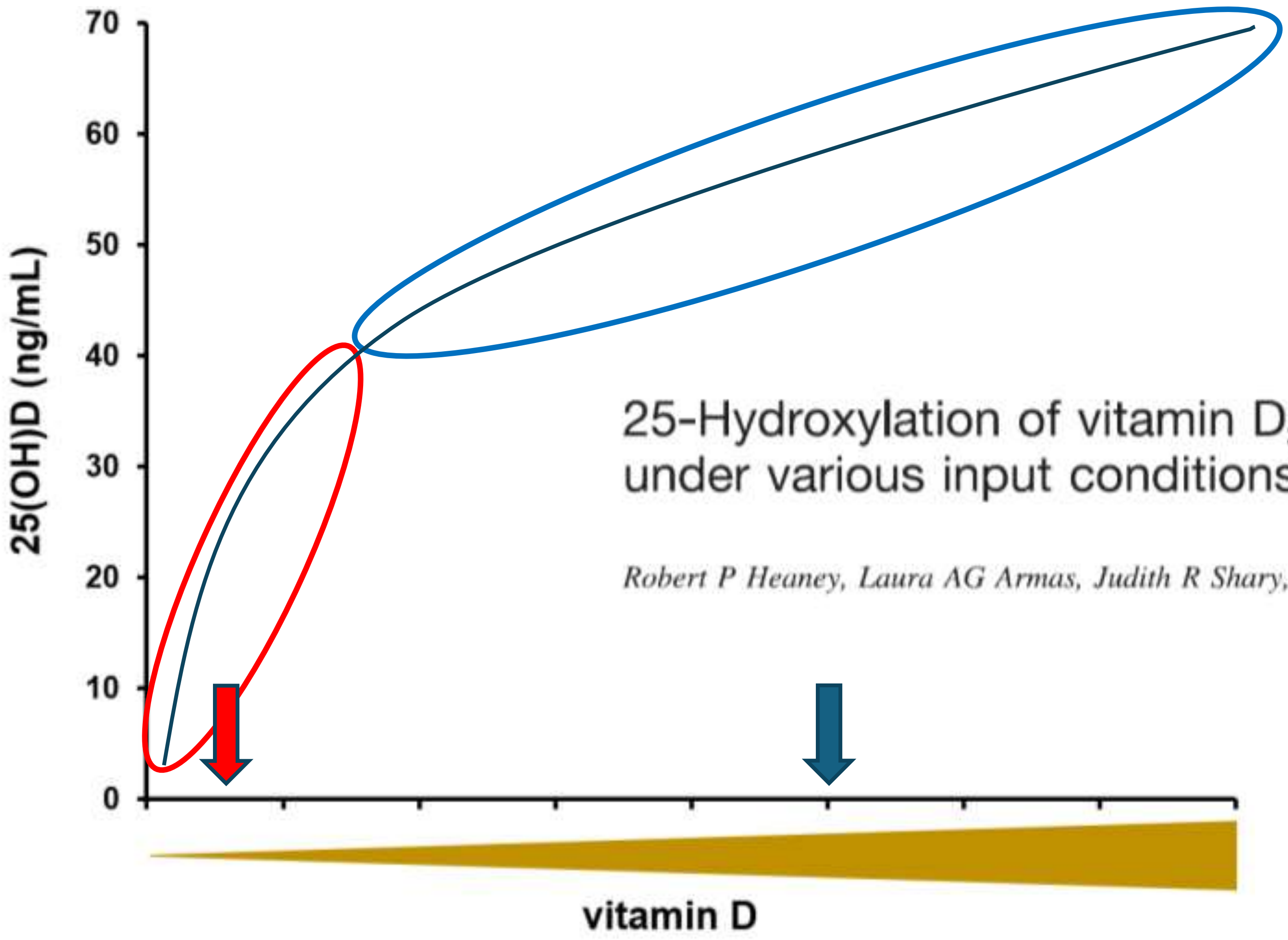
"Calcidiol"
25-hydroxyvitamin D

CYP27B1

"Calcitriol"
1α,25-dihydroxyvitamin D

Calcidiol << **Calcitri**

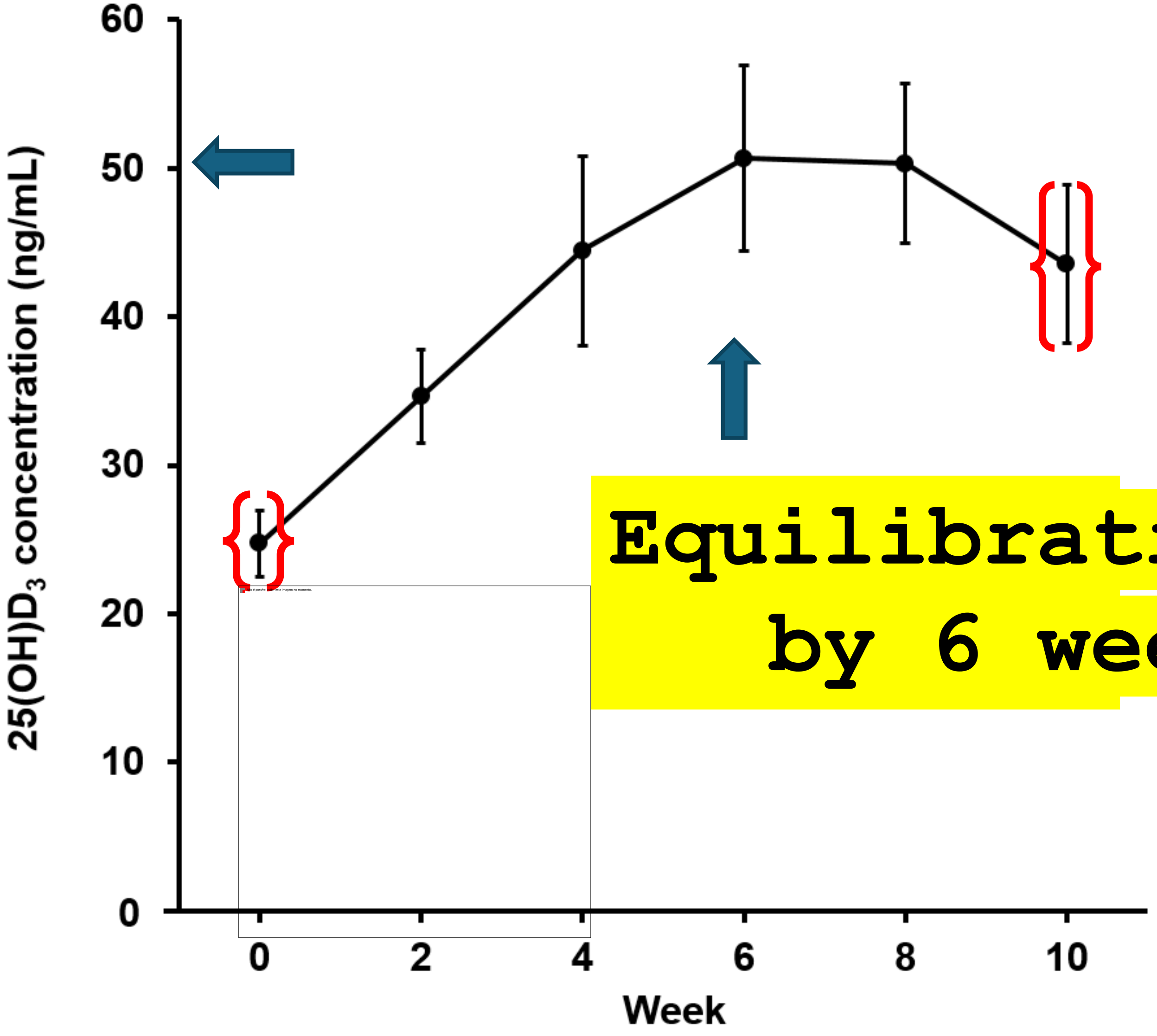
Vitamin D – Plasma, 25-hydroxyvitamin D
Problem – Limited dynamic range with Vitamin D intake



25-Hydroxylation of vitamin D_3: relation to circulating vitamin D_3 under various input conditions[1–3]

Robert P Heaney, Laura AG Armas, Judith R Shary, Norman H Bell, Neil Binkley, and Bruce W Hollis

Problem – Plasma, 25-hydroxyvitamin D: Long equi



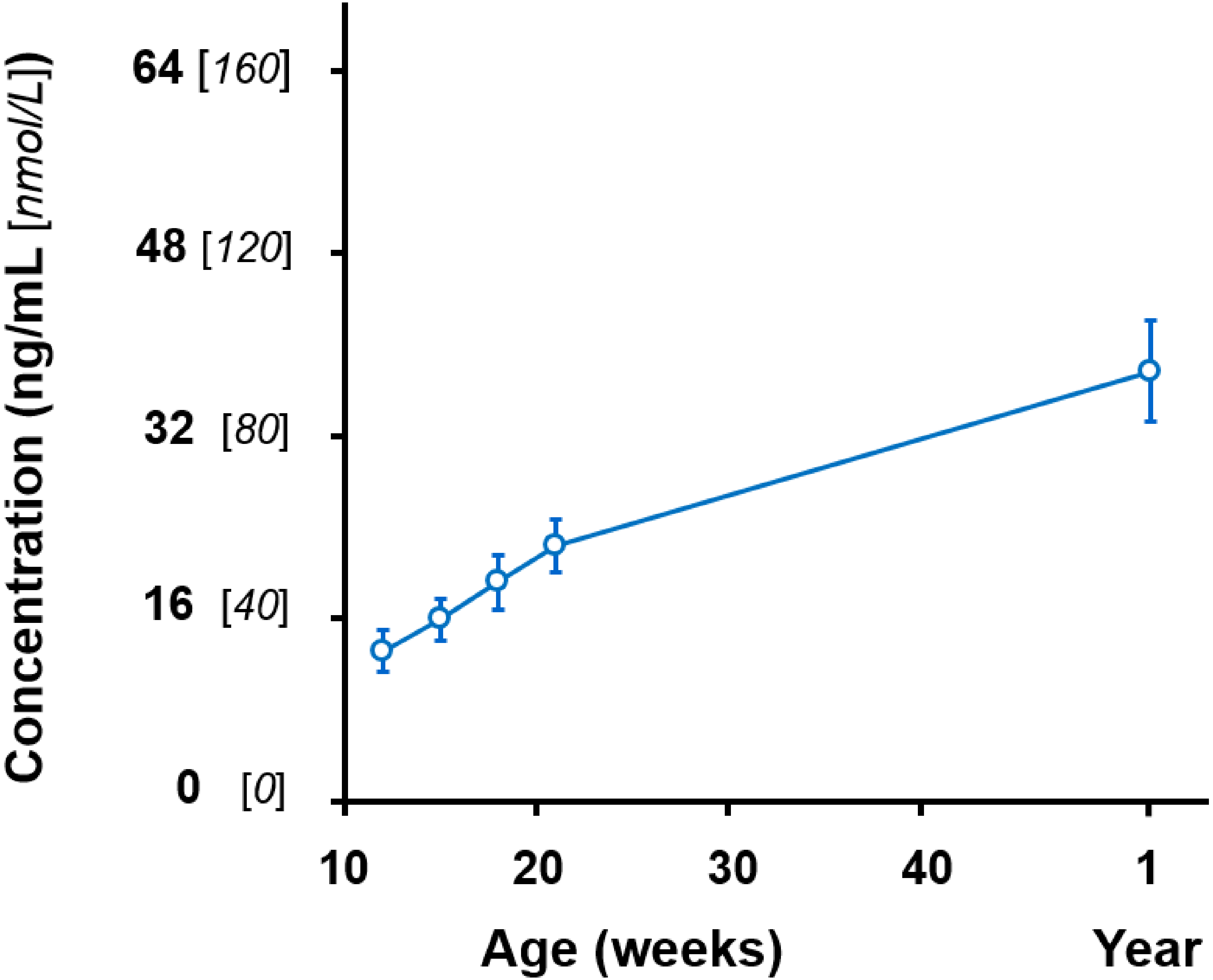
High variance, cause?

1. Same diet
2. Similar genetics
3. Not food intake correlated

Equilibration by 6 weeks

Backus & Foster 2021
Investigation of the effects of dietary supplementation with 25-hydroxyvitamin D3 and vitamin D3 on indicators of vitamin D status in healthy dogs

Problem – Plasma, 25-hydroxyvitamin D: M



Backus & Ueda 2024 Age-dependent changes in plasma 25-hydroxyvitamin D in kittens

Tryfonidou et al 2003 Hormonal - IGF-1, vitamin d - regulation of calcium homeostasis in two breeds of dogs during growth at different rates

Problem – Plasma 25-hydroxyvitamin D: Assay interference by Vitamin D metabolites

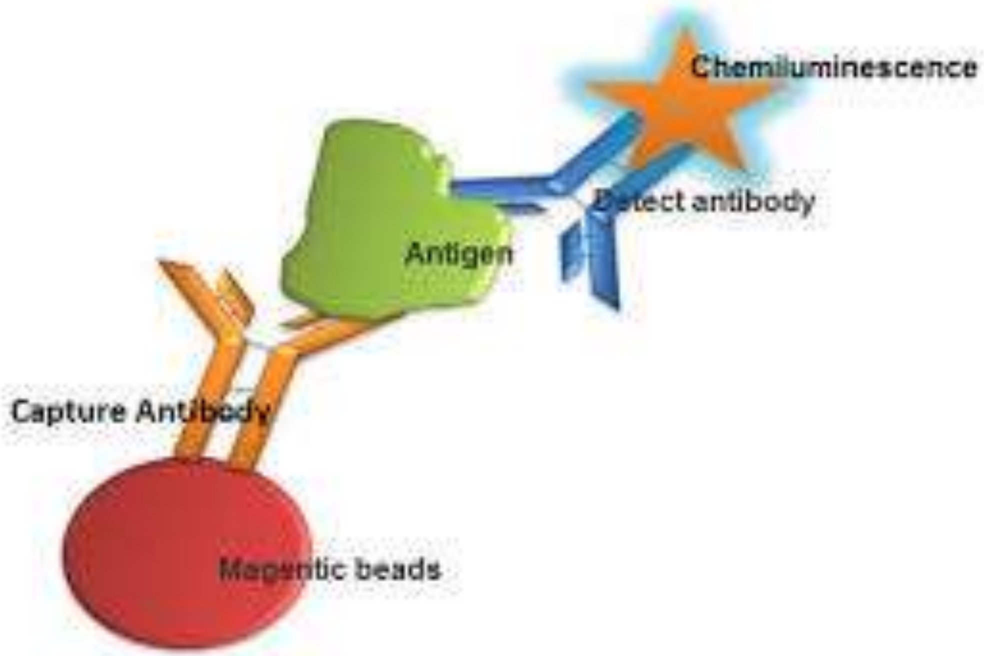
Immunoassays

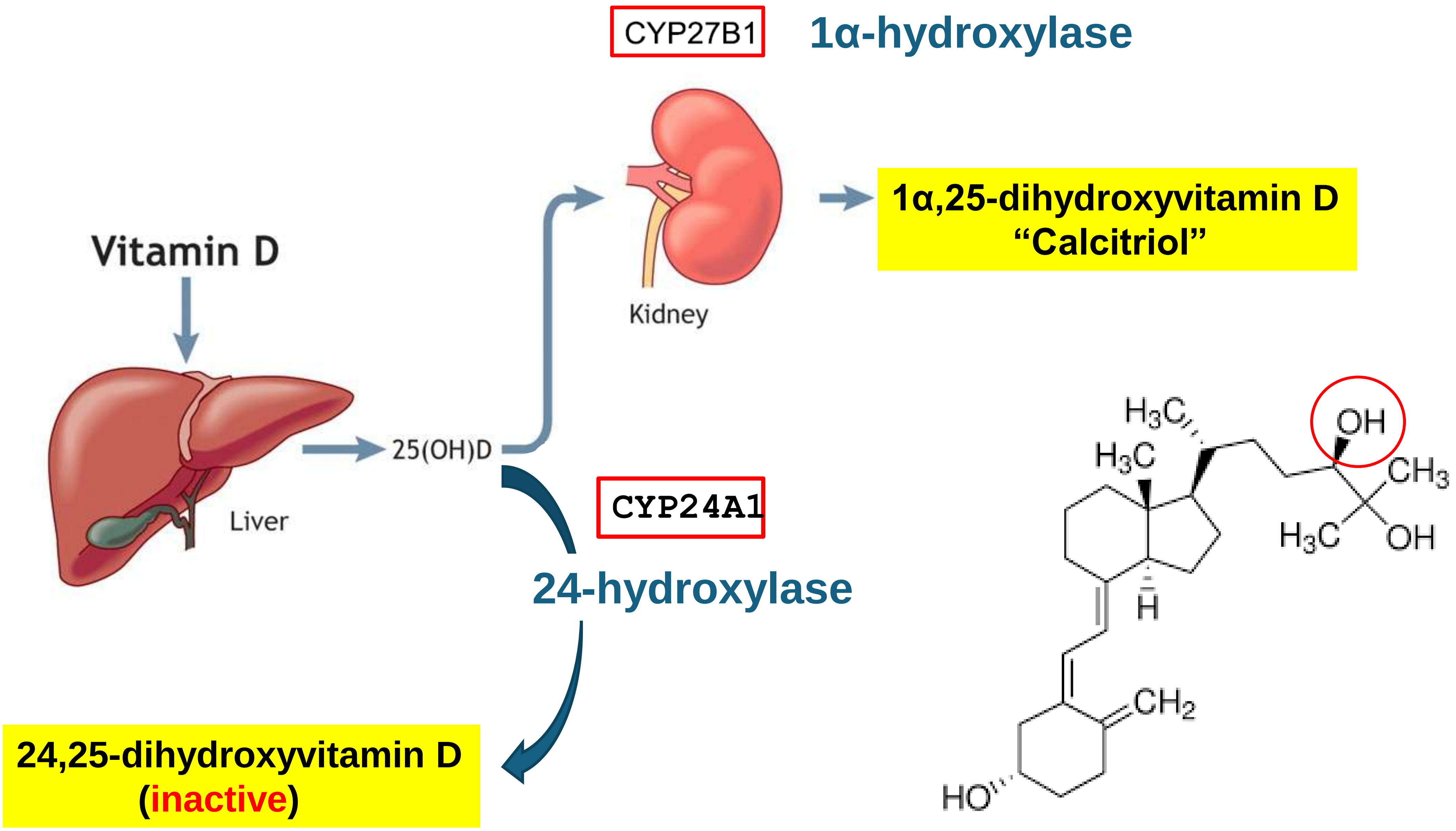
Radioimmunoassay, "**RIA**"

Chemiluminescent immunoassay, "**CLIA**"

Interferences

Cross-reactivities




CYP27B1
1α-hydroxylase
Vitamin D
Kidney
1α,25-dihydroxyvitamin D
“Calcitriol”
Liver
25(OH)D
CYP24A1
24-hydroxylase
24,25-dihydroxyvitamin D
(inactive)
H3C
OH
CH3
H3C
OH
H
CH2
HO

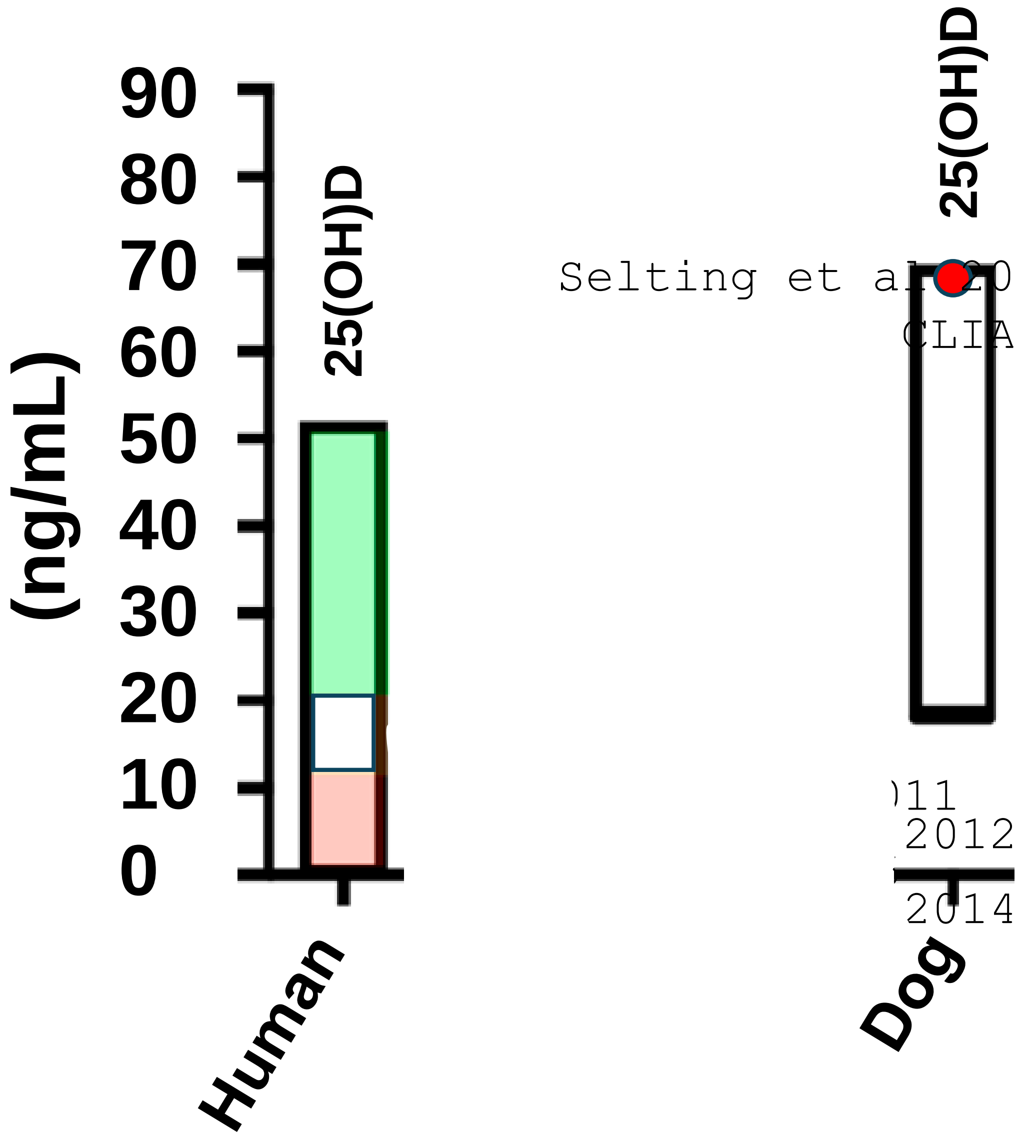
CLIA: Cross-reactivities (Diasorin Liasion®)

Guidelines	Evaluated according to CLSI EP7-A2
Sample concentration	spiking up to 100 ng/mL of the potential cross-reactant
Assays	cross-reactivity normalized to 25 OH Vitamin D3
Molecule	**Cross-reactivity %**
25 OH Vitamin D2	100.0
25 OH Vitamin D3	100.0
Vitamin D2	1.9
Vitamin D3	1.9
1,25 $(OH)_2$ Vitamin D2	6.7
1,25 $(OH)_2$ Vitamin D3	9.3
3-epi-25 OH Vitamin D3	1.3

Calcitriol

24,25-dihydroxyvitamin D
---------------?---------------

Plasma, 24,25-dihydroxyvitamin D concentrations



CLIA 25-hydroxyvitam
Reference Int
ng/mL
44 - 169
50 - 150

7
021

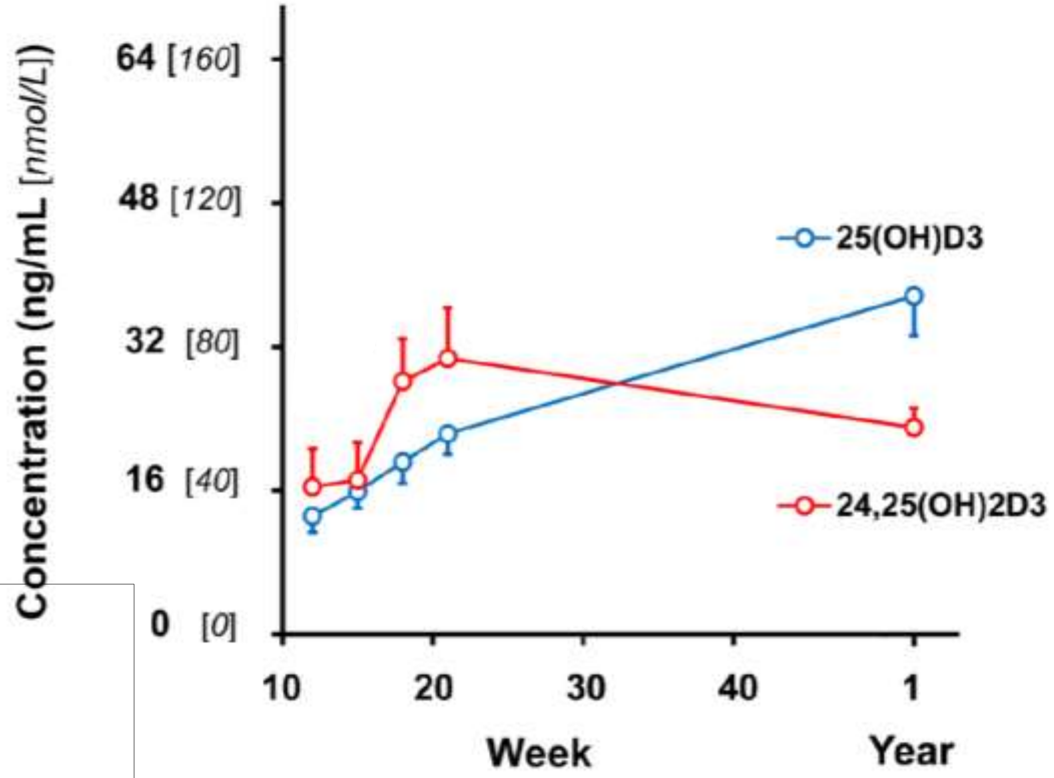
6

Values reported for “**25-hydroxyvitamin D**”

Immunoassays >> chromatography

(RIA, CLIA)
(HPLC, LC-MS/MS)

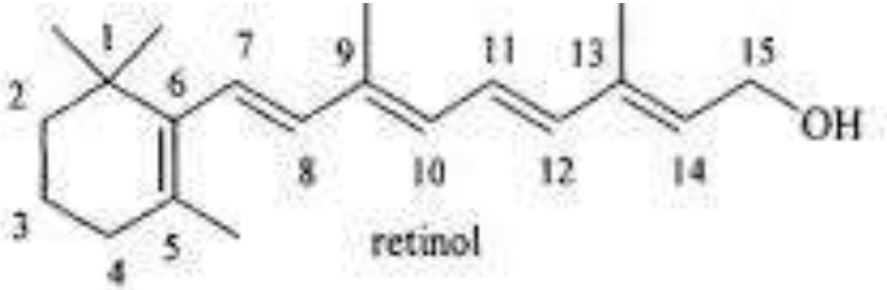
Problem – Plasma 25-hydroxyvitamin D, assay error



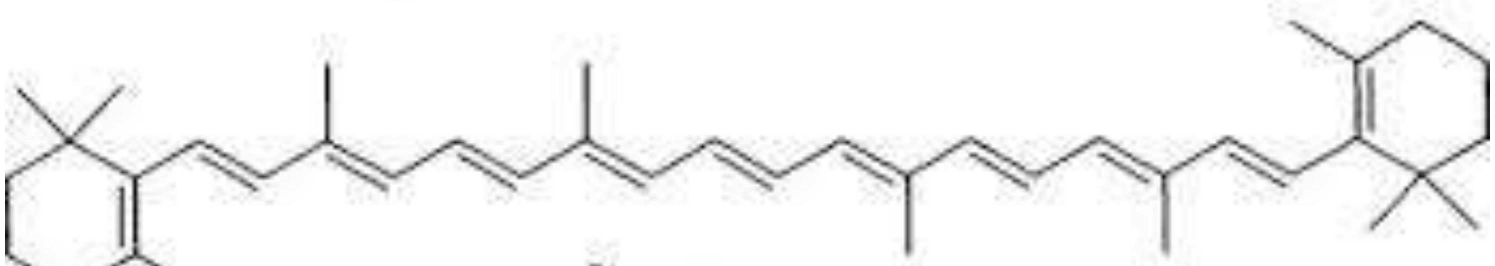
Backus & Ueda 2024 Age-dependent changes in plasma 25-hydroxyvitamin D in kittens

blood parameters with age

Vitamin A - Plasma



retinol



β-carotene

Vitamin A - Plasma

Liver Vitamin A storage

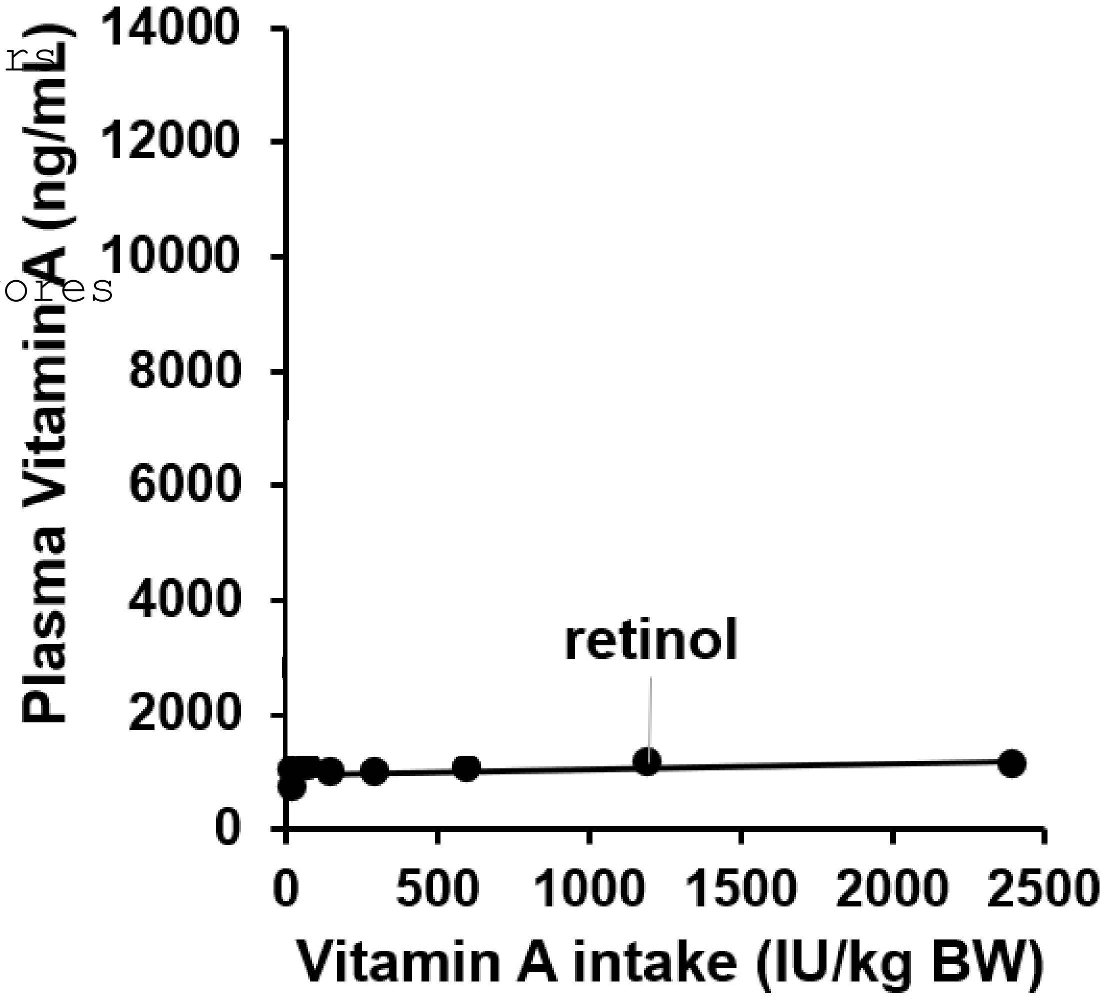
Retinol fatty acids esters

Retinol Binding Protein

Plasma retinol "homeostasis"

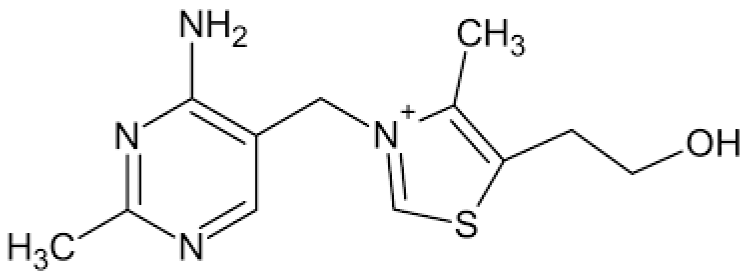
Species differences

Retinol esters in carnivores



Schweigert & Bok 2000
Vitamin A in blood plasma and urine of dogs is affected by dietary level of vitamin A

Thiamin blood/plasma



Erythrocytes contained approximately 80% of the thiamin present in whole blood

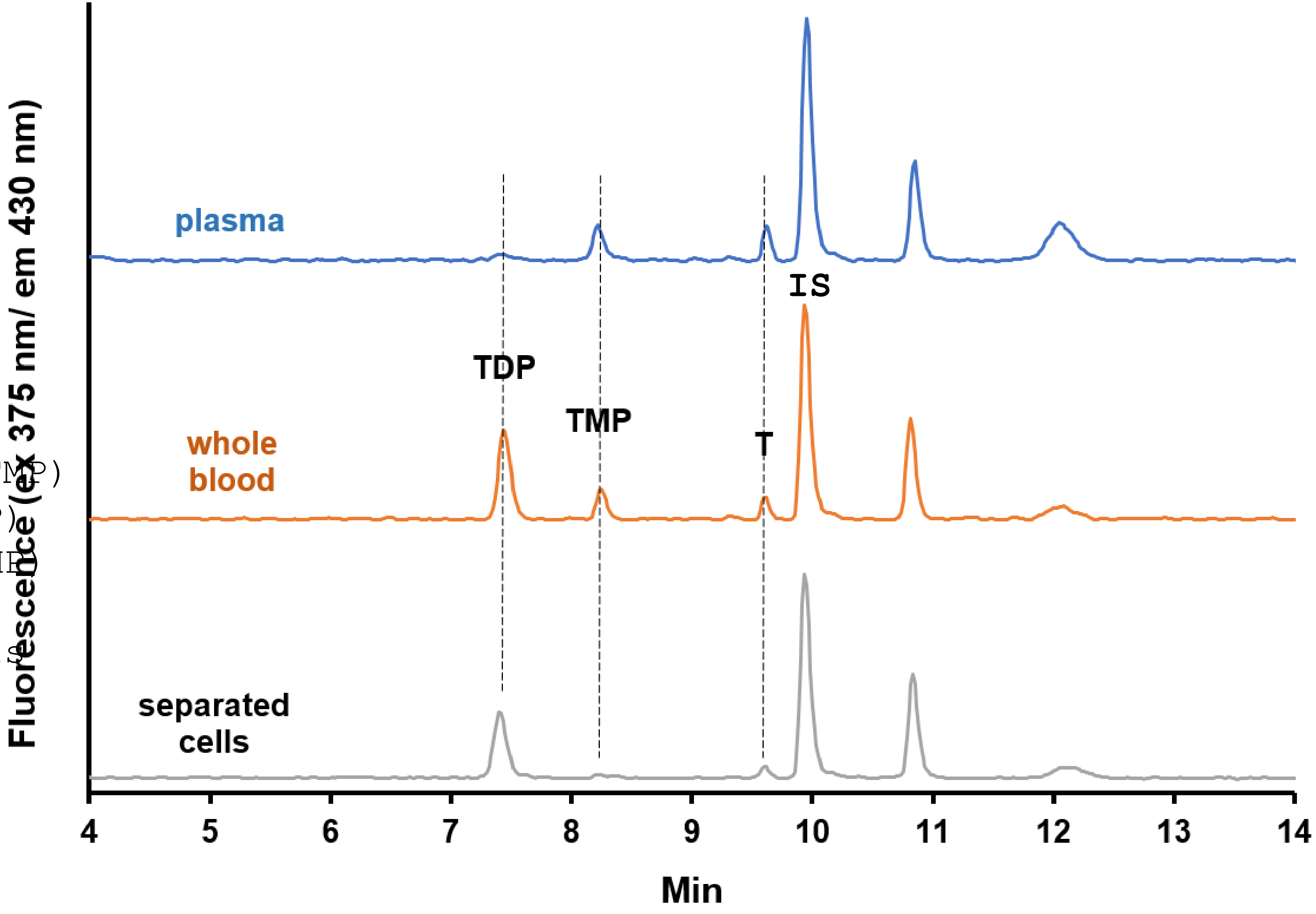
blood/plasma

Figure 1 Cats with cervical ventroflexion

Karpozilou et al 2025 Cervical ventroflexion in cats - 86 cases 2003–2024

Thiamin (T)
T monophosphate (TMP)
T diphosphate (TDP)
T triphosphate (TMP)

Reference intervals
Other methods



Zhang et al 2017 Simple HPLC Method with Internal Standard for Evaluation of Vitamin B1 Status By Use of Whole Blood

Conclusions – Mineral & vitamin status assessment through blood analyses

Yes, but limited by …

- ✓ Nutrient (e.g., potassium vs. sodium)
- ✓ Assay methodology (specificity, sensitivity)
- ✓ Body Pool size and turnover rate (water vs. fat soluble vitamins)
- ✓ Metabolite or carrier (species variation)
- ✓ Reference interval availability (known healthy subjects)
- ✓ Objective
  - Deficiency, Excess, Optimization (e. g., copper)
  - Acuteness (e. g., magnesium)
  - Disease causation/intervention investigation