Getting More from Forages

Targeted feeding strategies:

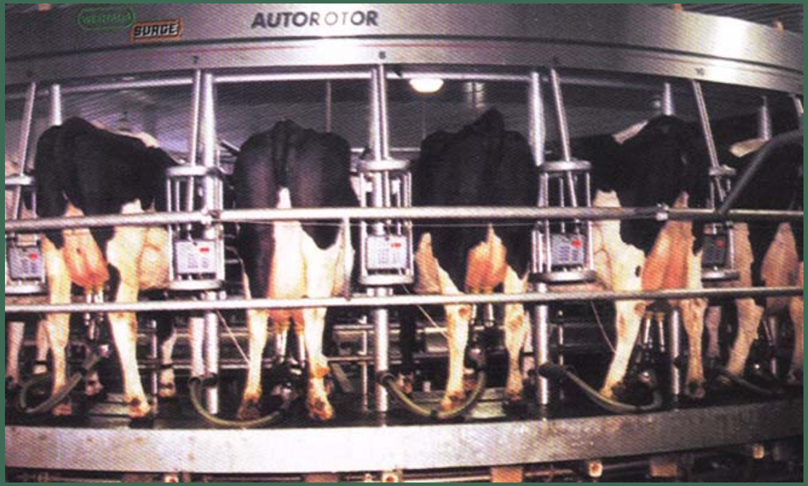
Accounting for quality

Accounting for Protein Degradation in the Rumen

Glen Broderick

Dairy Cows Need Lots of High Quality Protein to Make Milk

1000 gm Feed Protein



Yield 300 gm Milk Protein

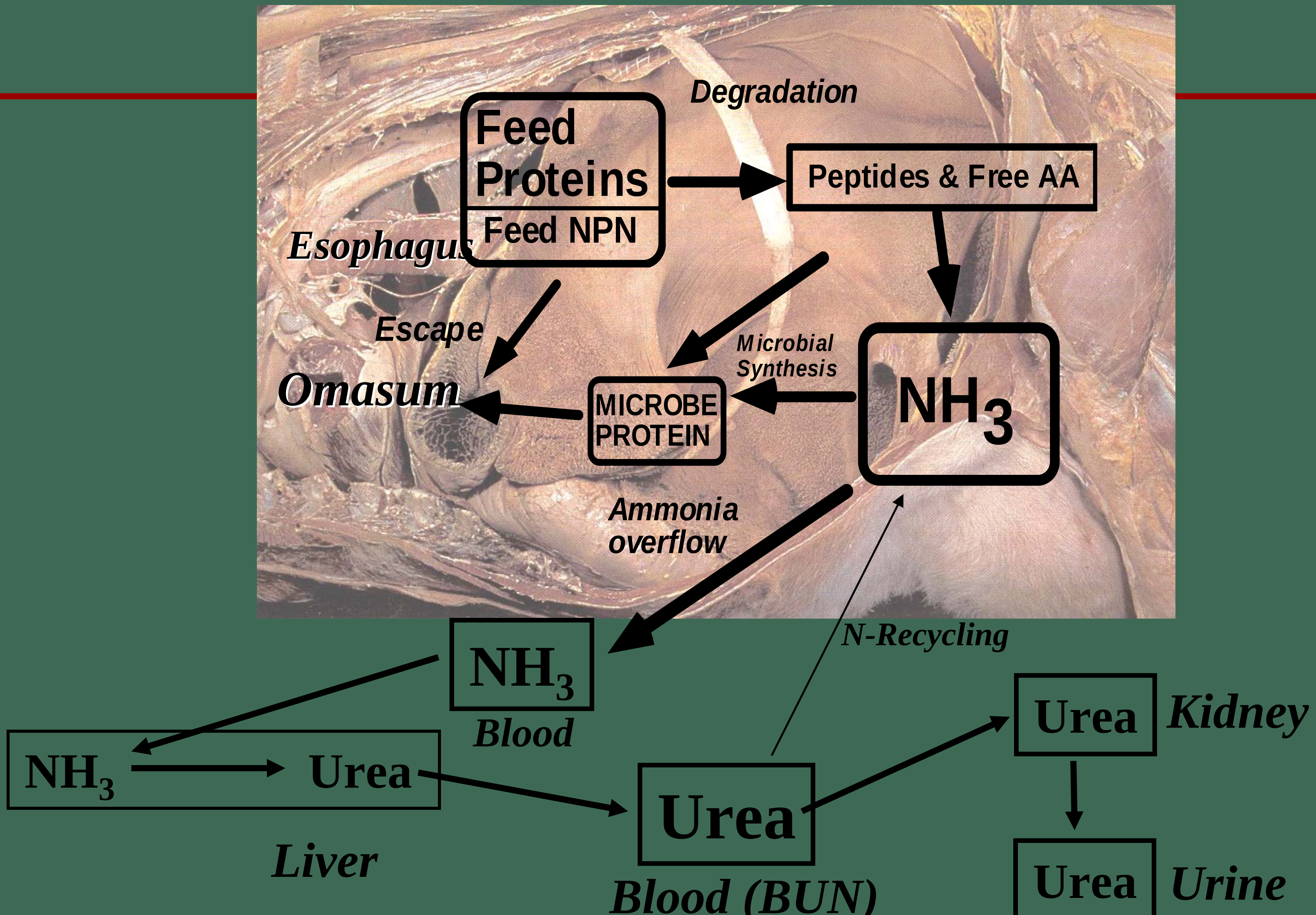
Average U.S. Dairy Cow Excretes >120 kg of N/year--

(M.P. Russelle; 2004)

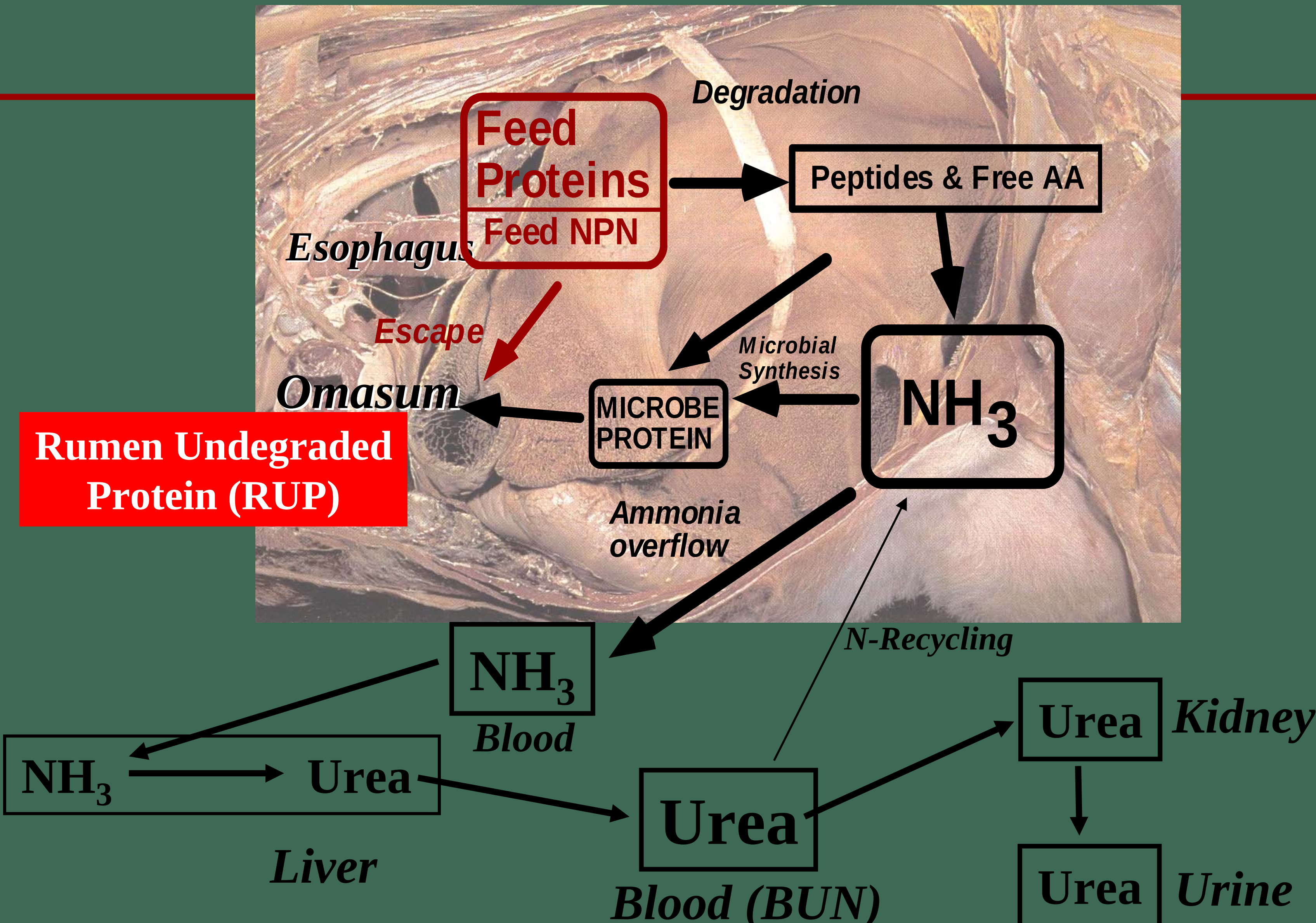
--in 20,000 kg of Manure

How Should Protein Degradation be Altered to Optimize N Efficiency?

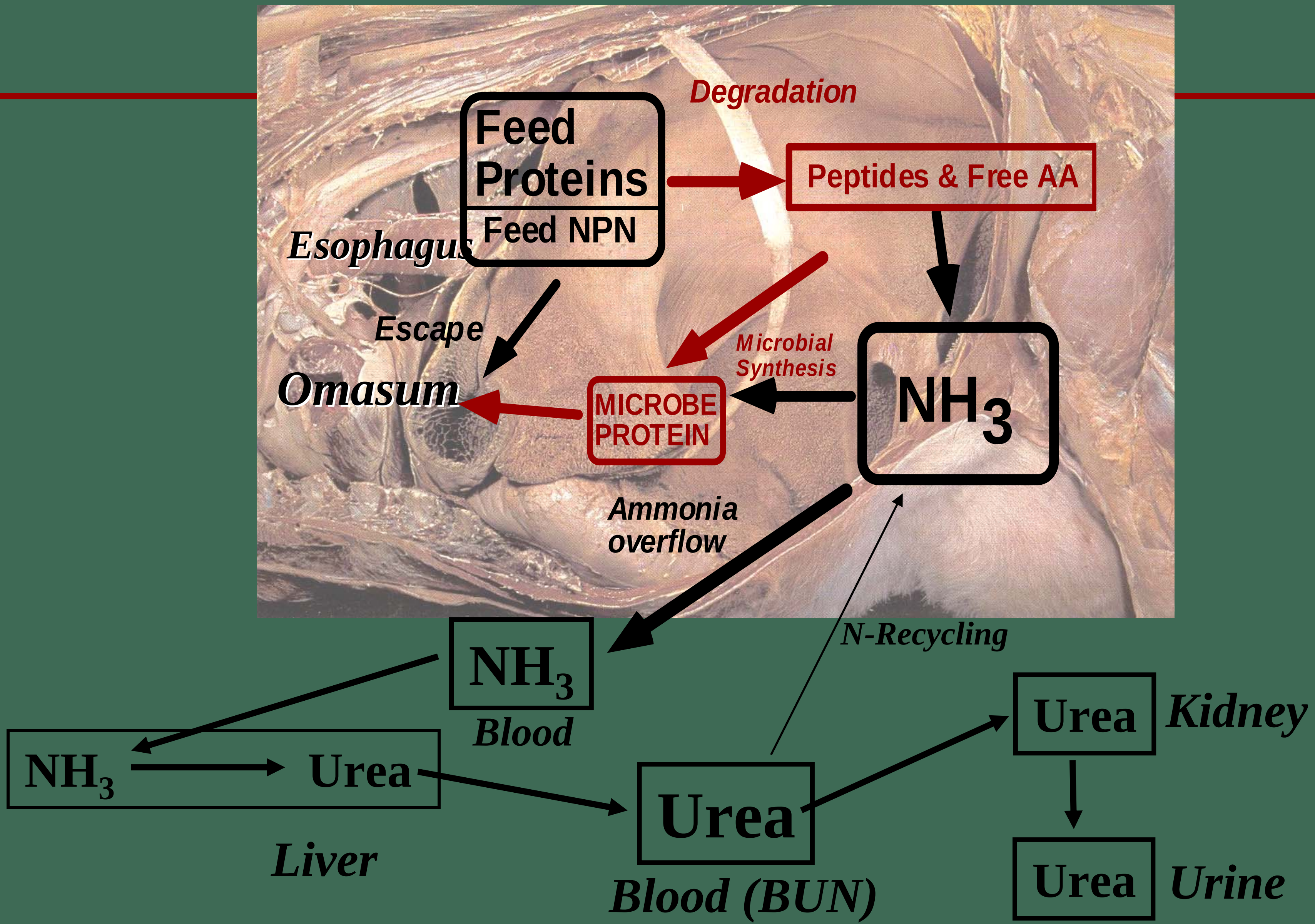
Nitrogen Metabolism in the Rumen



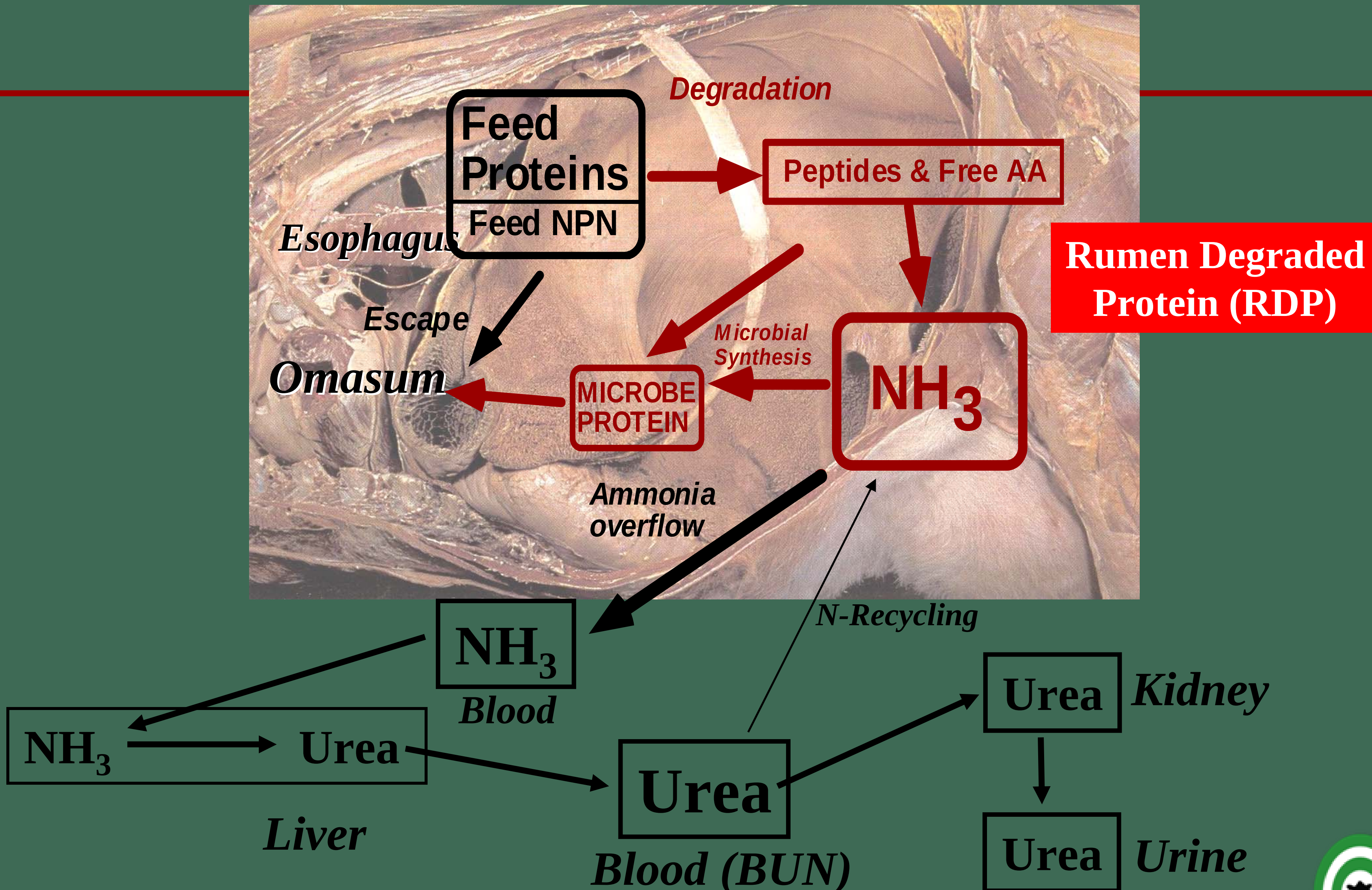
Nitrogen Metabolism in the Rumen



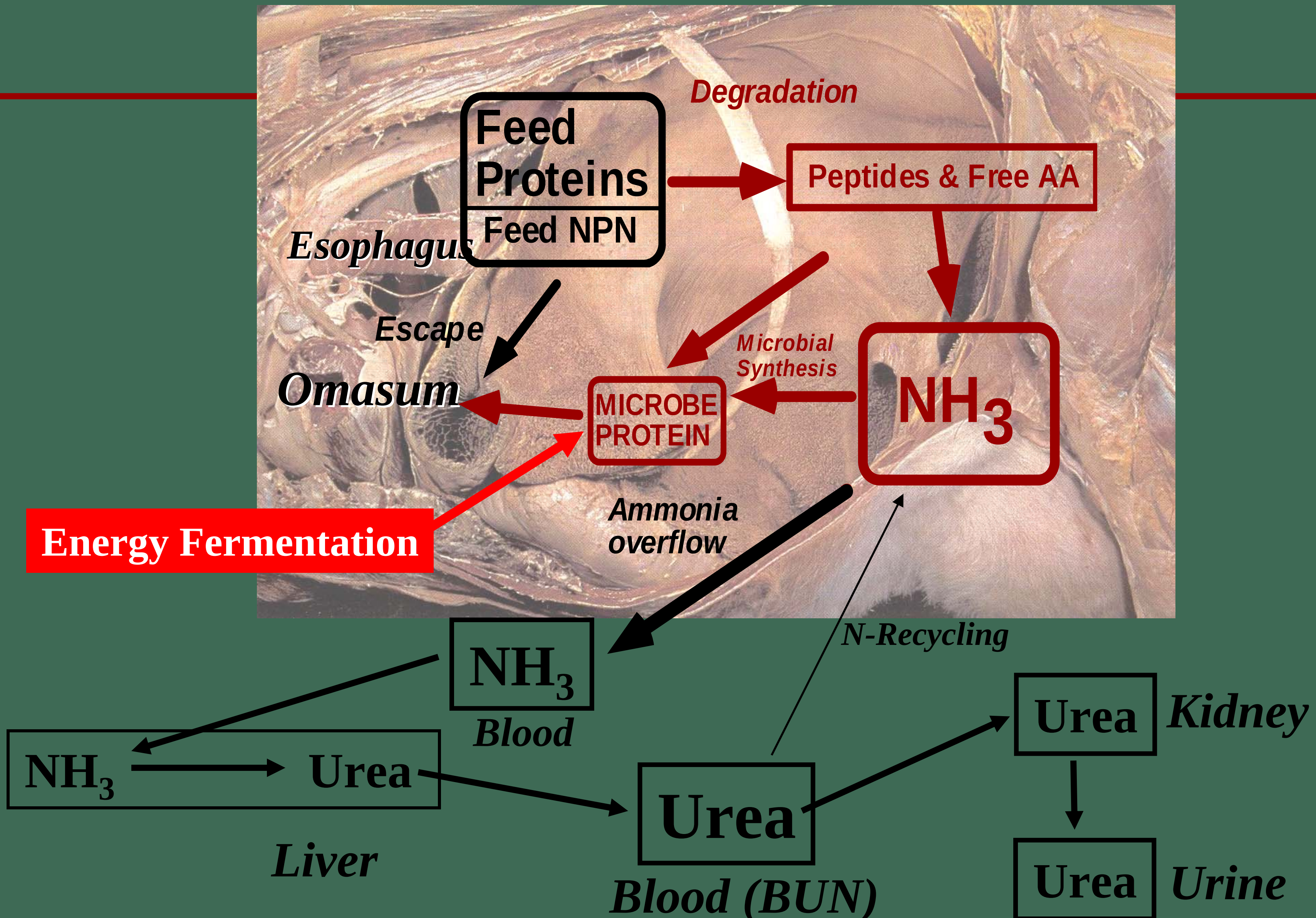
Nitrogen Metabolism in the Rumen



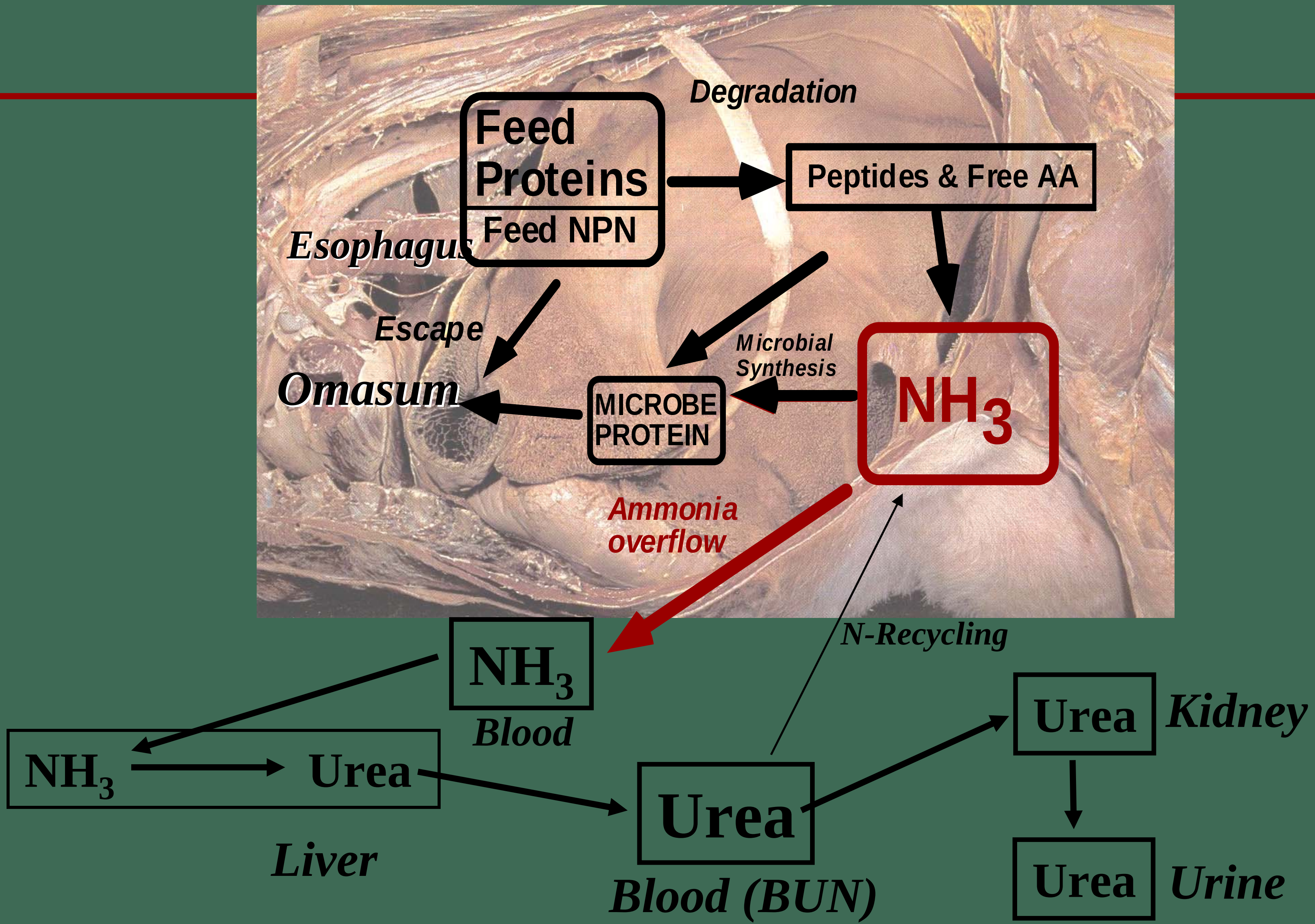
Nitrogen Metabolism in the Rumen



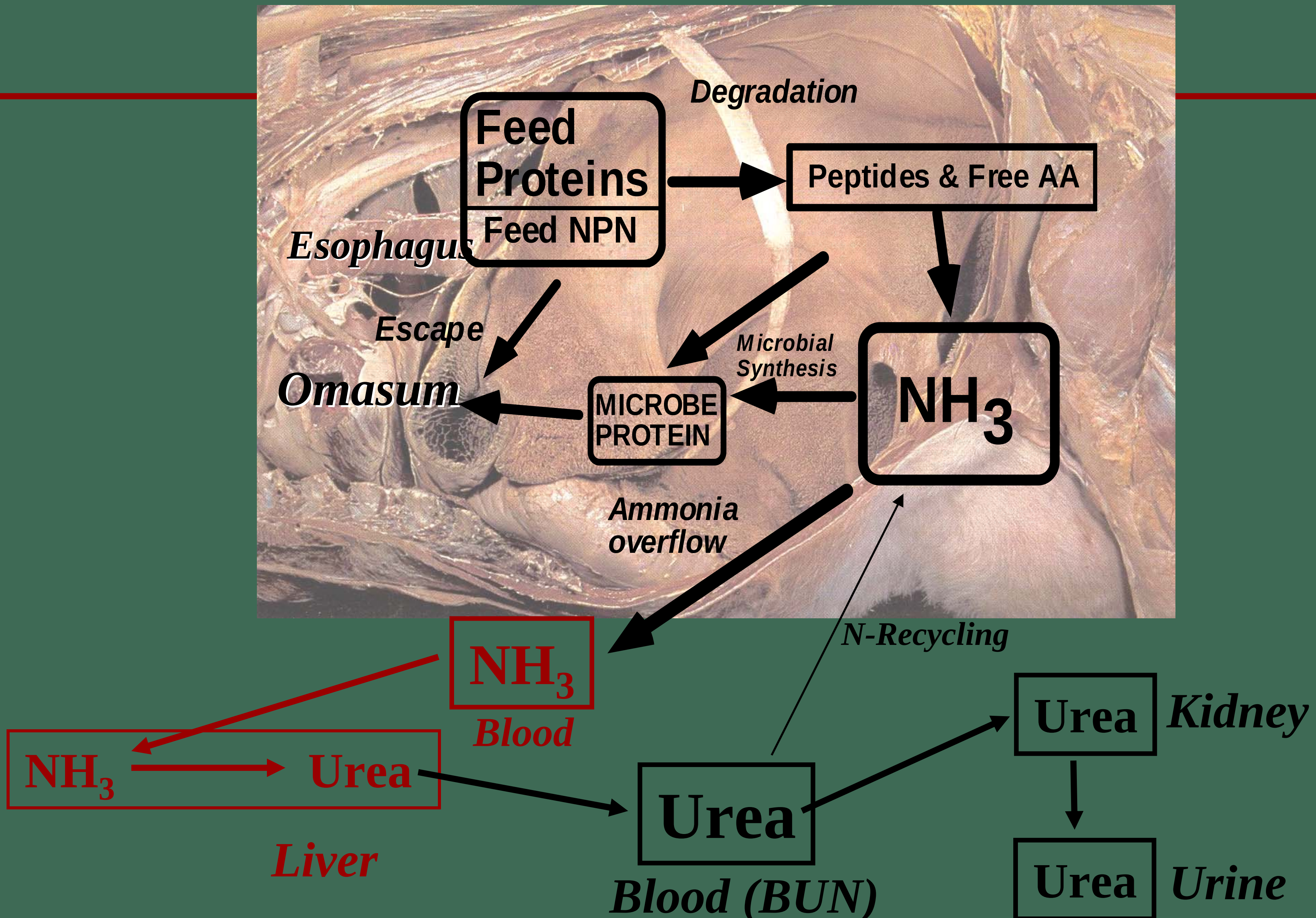
Nitrogen Metabolism in the Rumen



Nitrogen Metabolism in the Rumen



Nitrogen Metabolism in the Rumen



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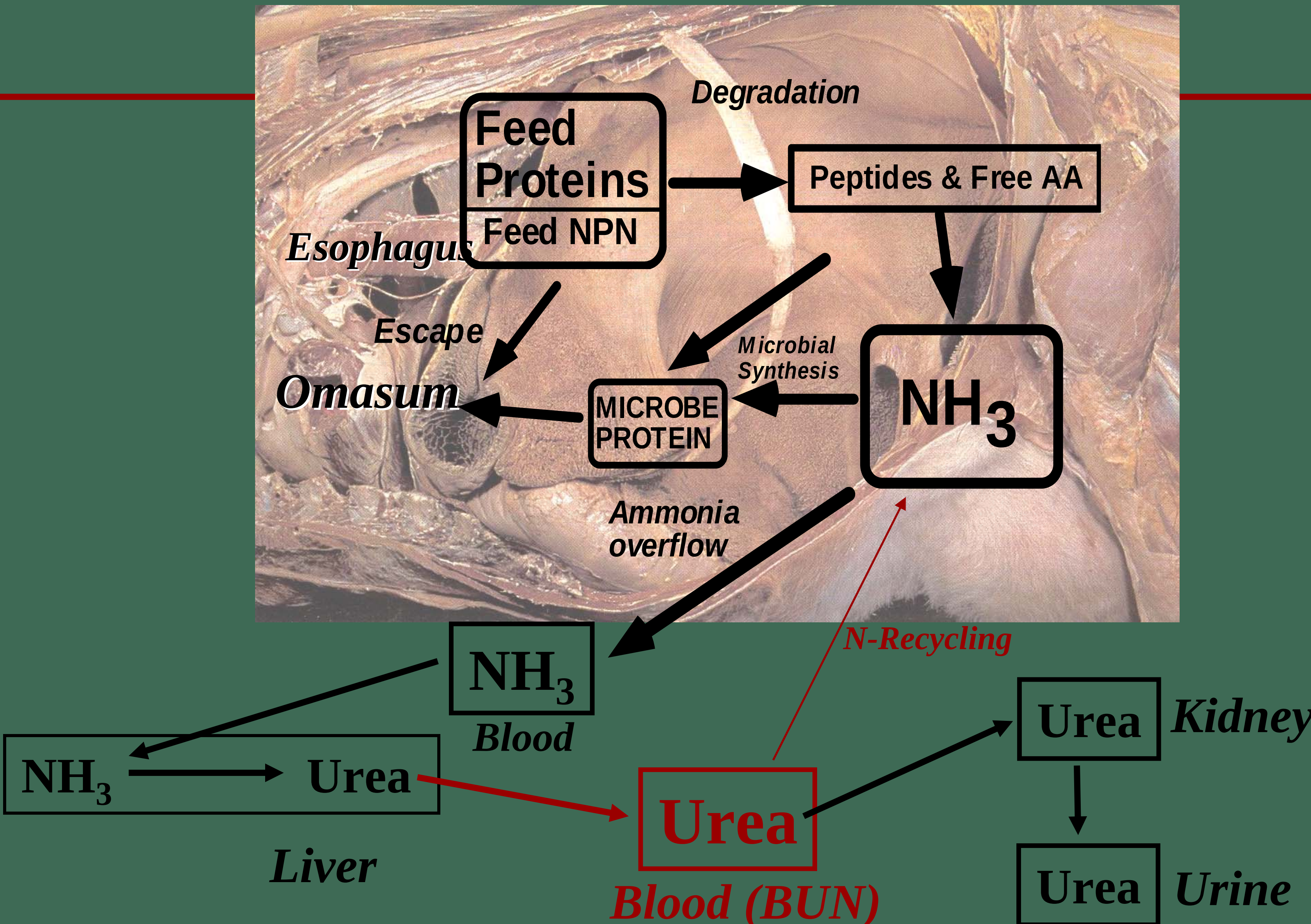
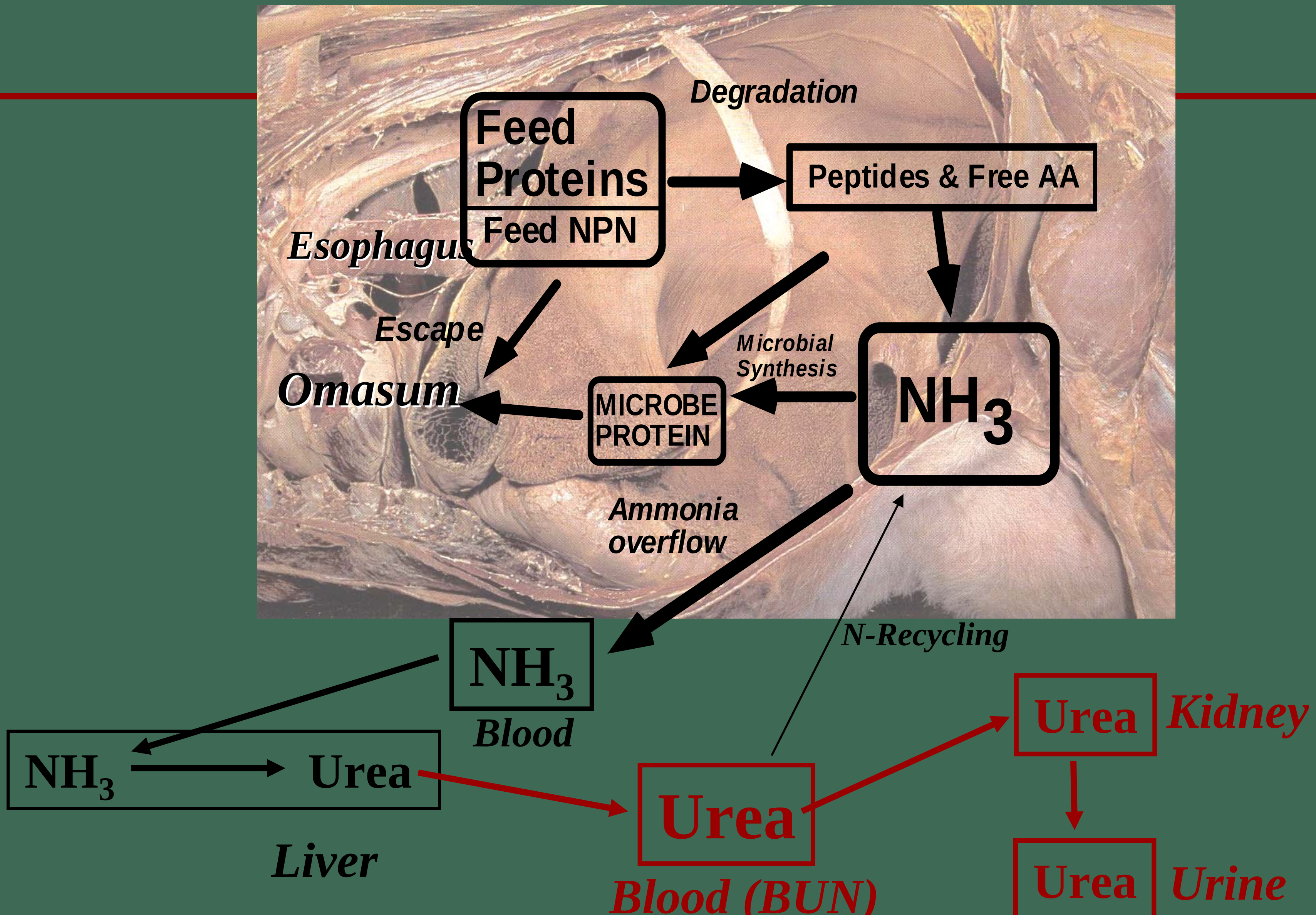


Nitrogen Metabolism in the Rumen



Proper Balance of Rumen Protein Degradation & Escape will:

1. Optimize Microbial Protein Formation
2. Supply the Animal with Additional Protein of the Correct Amino Acid Pattern

How do Proteins Differ in Rumen Degradation?

Differences in RUP Content of Forages & Concentrates--In Situ Assay (NRC, 2001)

RUP source	Crude protein (% of DM)	RUP[1] (% of total N)
Forages		
Alfalfa hay (40-46% NDF)	20.8	19
Grass hay (<55% NDF)	18.0	21
Alfalfa silage (40-46% NDF)	21.9	18
Corn silage	8.8	35
Red clover silage	*18.5*	*30*
Concentrates		
Solvent soybean meal	53.8	43
Expeller soybean meal	46.3	69
Fish Meal	68.5	66
Corn grain	9.4	47
Corn Distillers (DDGS)	29.7	51

[1]Rumen-undegraded protein computed assuming DM intake = 4% of BW

Does Rumen Protein Degradation Make Any Difference to the Cow?

Effect of Condensed Tannins in Silage on Dairy Production (Hymes-Fecht et al., 2005)

			Birdsfoot trefoil [CT]		
Item	Alfalfa	Red clover	Low	Medium	High
	---------------------(% of DM)---------------------				
Forage CP	22.0	18.1	21.7	20.4	20.1
Diet					
Leg. Forage	59	51	61	60	61
Corn Silage	16	16	15	15	15
HMSC	22	24	21	21	21
Solv. SBM	3	9	3	3	3
CP	18	18	17	17	17
NDF	29	29	26	27	27

Effect of Condensed Tannins in Silage on Dairy Production (Hymes-Fecht et al., 2005)

			Birdsfoot trefoil [CT]			
Item	Alfalfa	Red clover	Low	Medium	High	P > F
DMI, kg/d	24.4	25.6	25.2	23.3	24.5	0.37
Milk, kg/d	30.2[c]	31.1[c]	32.9[b]	34.6[a]	34.3[a]	< 0.01
Fat, kg/d	1.13[c]	1.17[bc]	1.20[bc]	1.32[a]	1.24[ab]	< 0.01
Protein, kg/d	0.94[b]	0.96[b]	1.04[a]	1.09[a]	1.07[a]	< 0.01
Rumen NH_3, m*M*	8.8[a]	5.9[c]	7.5[b]	7.9[ab]	8.1[ab]	< 0.01
MUN, mg/dl	10.8[a]	11.0[a]	10.9[a]	9.3[b]	9.2[b]	< 0.01

CT = Condensed Tannins; Diets = 60% Forage DM & ~17% CP; [a-d]($P < 0.05$)

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Milk, kg/d	30.2[c]	31.1[c]	32.9[b]	34.6[a]	34.3[a]	< 0.01
Fat, kg/d	1.13[c]	1.17[bc]	1.20[bc]	1.32[a]	1.24[ab]	< 0.01
Protein, kg/d	0.94[b]	0.96[b]	1.04[a]	1.09[a]	1.07[a]	< 0.01
Rumen NH_3, mM	8.8[a]	5.9[c]	7.5[b]	7.9[ab]	8.1[ab]	< 0.01
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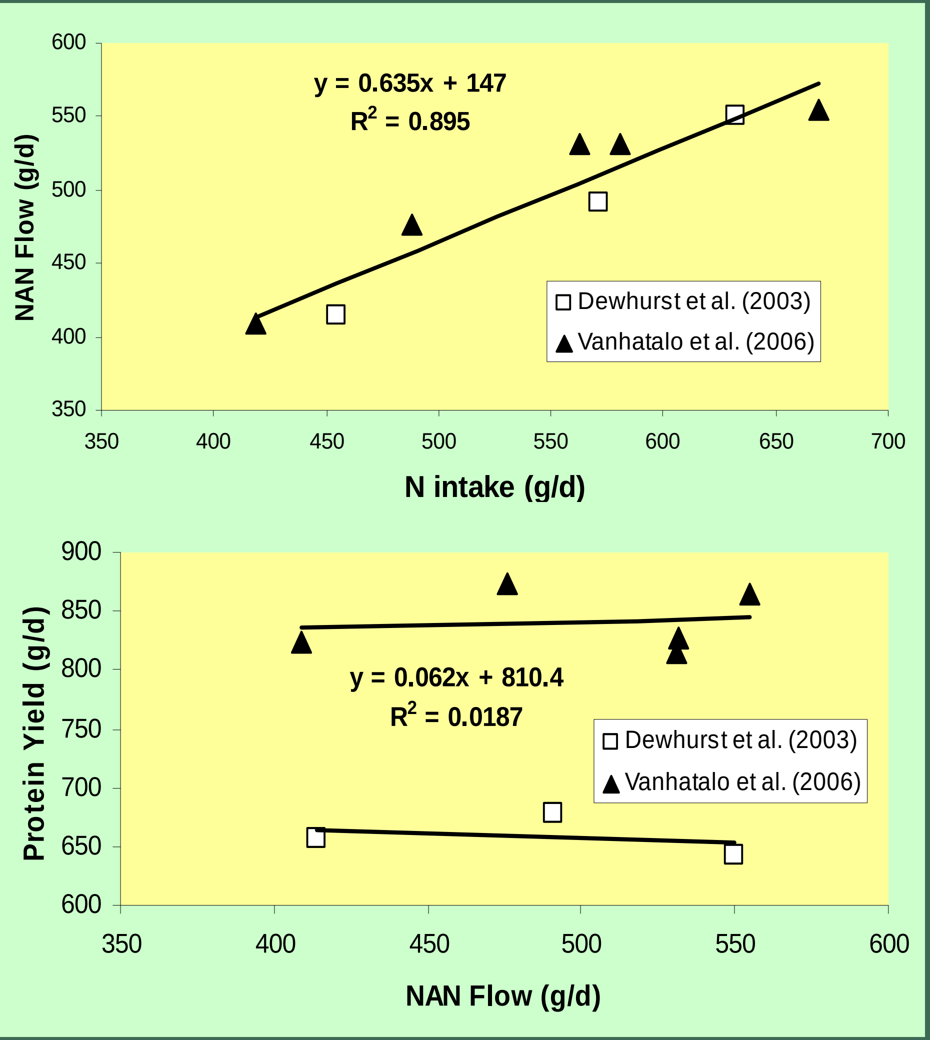
CT = Condensed Tannins; Diets = ~60% Forage DM & ~17% CP; [a-c]($P < 0.05$)

Replacing Grass Silage with Red Clover Increased NAN Outflow but Not Protein Yield



Increasing N Intake by Replacing Grass with Red Clover increased Rumen NAN Outflow

Increased Protein Flow did Not Increase Milk Protein Yield

Utilization of RUP from Red Clover is Impaired

Effect of Replacing Solvent Soybean Meal with RUP (Santos et al., JDS 81:3182, 1998)

RUP source	Cows	Milk yield (kg/d) Solv. SBM	RUP	Prob.
Treated SBM	641	34.2	34.9	**0.03**
Fish Meal	662	31.3	32.1	**0.01**
Animal By-Products	725	34.1	33.8	0.34
Brewers & Distillers	334	31.5	31.8	0.34
Corn Gluten Meal	297	33.2	32.4	0.12
		FM	CGM	
FM vs. CGM	156	29.1	28.0	**0.02**

CP Supplement & Production in Dairy Cows

(Brito & Broderick, 2007)

	CP Supplement				
Item	Urea	SSBM	CSM	CM	*Prob.*
	------------------(kg/d)------------------				
DM intake	22.1[c]	24.2[b]	24.7[ab]	24.9[a]	< 0.01
Milk	32.9[b]	40.0[a]	40.5[a]	41.1[a]	< 0.01
Protein	0.92[c]	1.23[ab]	1.18[b]	1.27[a]	< 0.01
Fat	1.01[c]	1.22[ab]	1.18[b]	1.29[a]	< 0.01

(Alfalfa & Corn Silages, High Moisture corn, 16.5% CP)

SSBM = Solvent Soybean Meal; CSM = Cottonseed Meal; CM = Canola Meal; [a-c]($P < 0.05$)

CP Supplement & Production in Dairy Cows

(Brito & Broderick, 2007)

Item	CP Supplement				Prob.
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CP Supplement & Production in Dairy Cows

(Brito & Broderick, 2007)

	CP Supplement				
Item	Urea	SSBM	CSM	CM	*Prob.*
	------------------(kg/d)------------------				
DM intake	22.1[c]	24.2[b]	24.7[ab]	24.9[a]	< 0.01
Milk	32.9[b]	40.0[a]	40.5[a]	41.1[a]	< 0.01
True protein	0.92[c]	1.23[ab]	1.18[b]	1.27[a]	< 0.01
Fat	1.01[c]	1.22[ab]	1.18[b]	1.29[a]	< 0.01

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SSBM = Solvent Soybean Meal; CSM = Cottonseed Meal; CM = Canola Meal; [a-c]($P < 0.05$)

CP Supplement & Protein Flow from the Rumen (Brito et al., 2007)

	Diets[1]				
Item	Urea	SSBM	CSM	CM	*Prob.*
Microbial eff. (g NAN/kg of OMTDR)	26.3[b]	29.0[a]	29.7[a]	29.5[a]	<0.01
	----------------g/d-------------------				
Microbial protein	2344[b]	2706[a]	2706[a]	2775[a]	0.04
Escaped protein (RUP)	538[c]	987[b]	1348[a]	1150[ab]	<0.01
Total protein	2882[c]	3693[b]	4054[a]	3925[ab]	<0.01

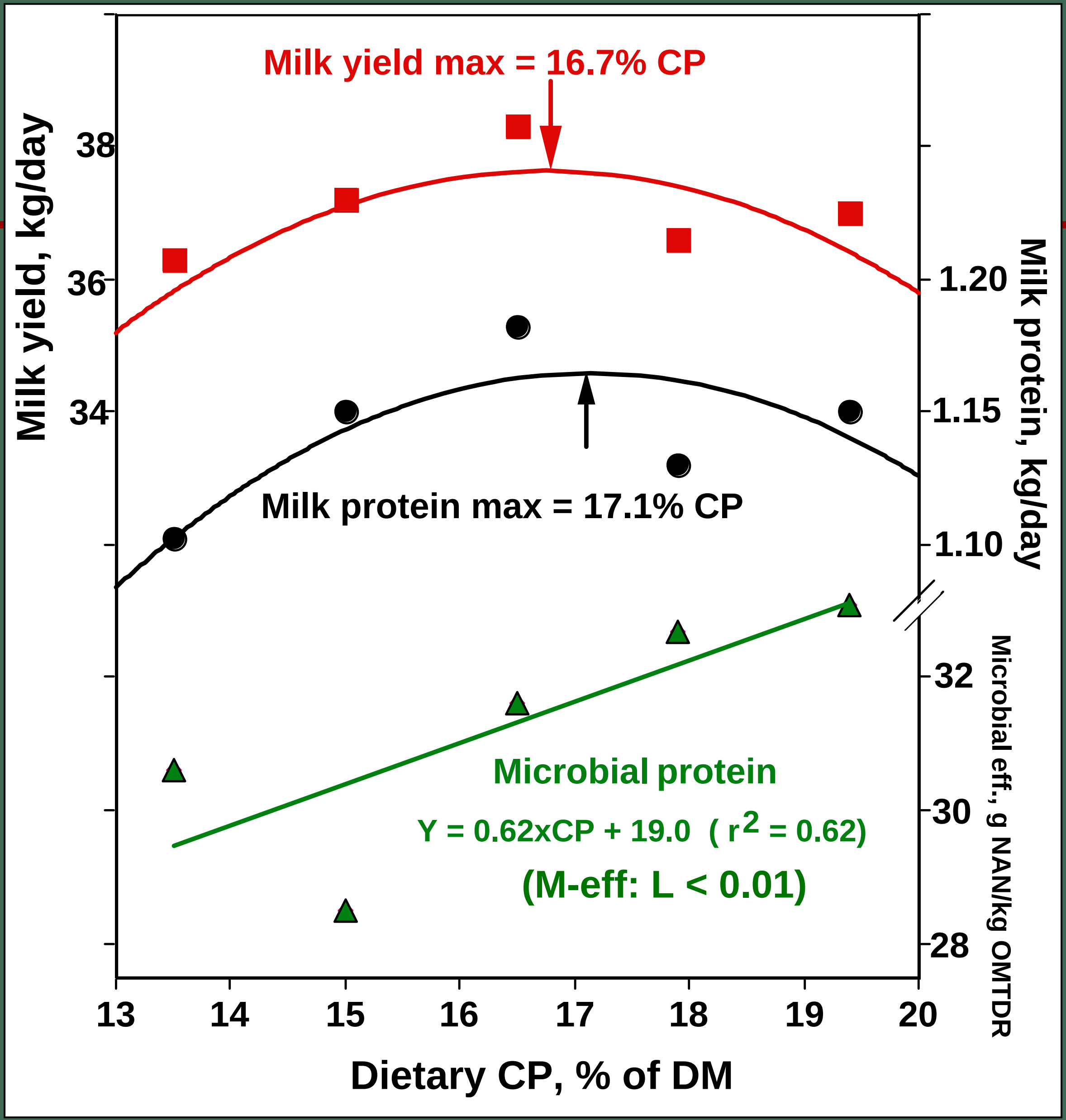
[1]SSBM = solvent soybean meal; CSM = cottonseed meal; CM = canola meal
[a-c]($P < 0.05$)

Protein Content of the Essential Amino Acids Lys & Met (NRC, 2001)

Item	Cow's Milk	Bacterial Protein	Solvent SBM	Cottonseed meal	Canola meal
	------------------------(% of EAA)------------------------				
LYS	15.0	16.7	13.9	9.7	13.2
MET	5.4	5.4	3.2	3.7	4.4
Lys:Met	2.8	3.1	4.3	2.6	3.0

Effect of CP (Solvent SBM) on Yield & Microbial Protein

(Olmos & Broderick, 2006)



Studies on Rumen-Protected Essential Amino Acids

1. **Rumen-Protected Methionine (RP-Met) fed as Mepron (Evonik-Degussa); & SmartAmine or MetaSmart (HMBi) (Adisseo).**
2. **Rumen-Protected Lysine Now Sold by Balchem.**

Mepron

SmartAmine

MetaSmart

Can We Reduce CP by Using Rumen-Protected Methionine? (Trial 2)

CP/Mepron	DMI	Milk	FCM	Fat	Protein
	---------------------(kg/day)---------------------				
17.0%/0	25.2	41.5	46.5	1.49	1.30
17.0%/15 g/d	25.7	41.8	47.8	1.55	1.34
15.7%/0	23.9	39.5	43.8	1.38	1.26
15.7%/15 g/d	24.7	40.6	46.0	1.48	1.30

Can We Reduce CP by Using Rumen-Protected Methionine? (Trial 2)

CP/Mepron	DMI	Milk	FCM	Fat	Protein
	----------------------	(kg/day)	----------------------		
17.0%/0	**25.2**	**41.5**	**46.5**	**1.49**	**1.30**
17.0%/15 g/d	25.7	41.8	47.8	1.55	1.34
15.7%/0	23.9	39.5	43.8	1.38	1.26
15.7%/15 g/d	**24.7**	**40.6**	**46.0**	**1.48**	**1.30**
Probability	***0.01***	***0.06***	***0.38***	***0.50***	***0.57***

How Reliable are In Situ Estimates of Rumen Undegraded Protein?

In Situ Bags

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

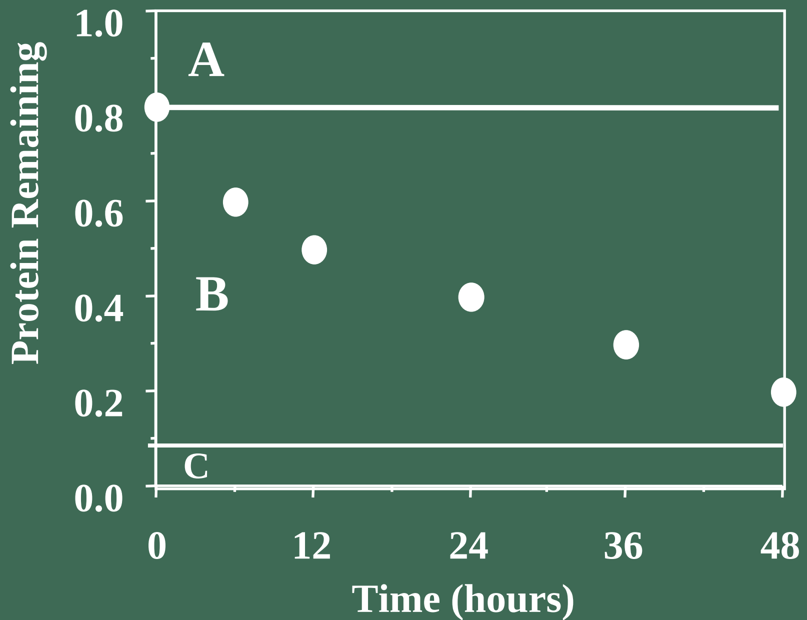
Inserting Bags into the Rumen

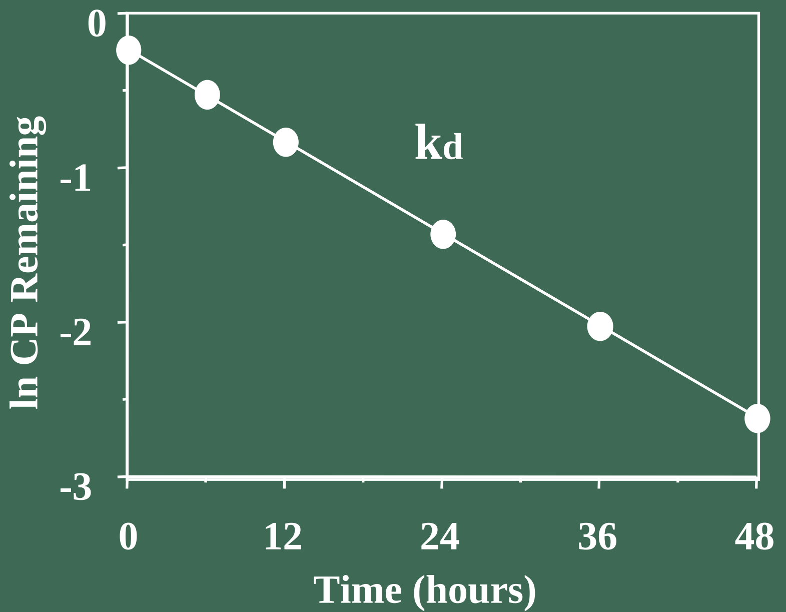
Bag Sealer

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Washing Bags

Data Analysis for In Situ Model





$$\text{Degradation} = A + B \times \left(\frac{k_d}{k_p + k_d}\right)$$

$$\text{Escape} = B \times \left(\frac{k_p}{k_p + k_d}\right) + C$$

In Situ Protein Degradation Model (NRC)

Degraded Protein = A + B $[k_d / (k_d + k_p)]$

Escaped Protein = B $[k_p / (k_d + k_p)]$ + C

- **A = Soluble Protein & NPN (t = 0)**
- **B = Degradable Protein**
- **C = Undegraded Protein (Kinetic; ADIN)**
- **k_d = Degradation Rate (/h)**
- **k_p = Rumen Passage Rate (/h)**

In Situ Protein Degradation (NRC Model)

(Goh & Broderick, 2002)

Item	Solvent SBM	Expeller SBM	Blood Meal	Corn Gluten
NRC N-Fractions, % of total N				
Fraction A	19.7[ab]	21.1[a]	9.4[b]	10.7[ab]
Fraction B	79.4[a]	73.7[a]	34.3[b]	75.1[ab]
Fraction C	0.8[d]	5.2[c]	56.3[a]	14.2[b]
Degradation rate (k_d), /h	0.10[a]	0.07[b]	0.10[a]	0.03[c]
Rumen escape, % (k_p = 0.06/h)	31[d]	41[c]	69[a]	64[b]
In vivo escape, % (Reynal et al., 2003)	27	50	60	73

[a-d]Means in rows with different superscripts differ (*P* < 0.05). **Significant effect of protein (*P* < 0.01).

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In Vitro Degradation Rates of Soluble Proteins

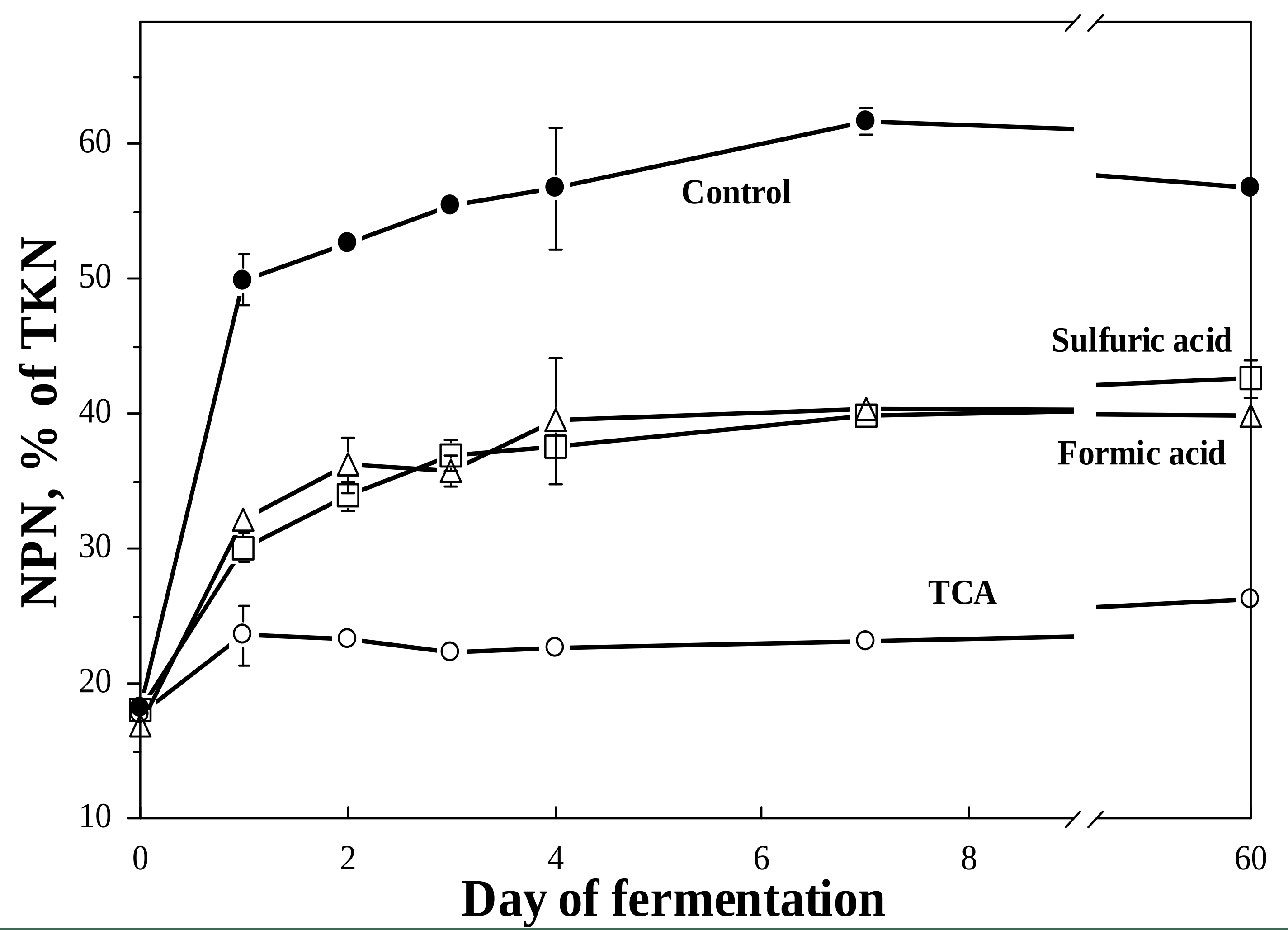
(Hedqvist & Uden, 2006)

Soluble protein	Soluble Protein, % of TN	kd /h	RUP[1]
Distillers' grains	5	0.62[b]	0.21[b]
			0.27[b]
			0.29[b]
			0.46[cd]
			0.56[d]
			0.54[d]

0.16/h

Formation of NPN in Alfalfa Silage

(Vagnoni et al., 1997)



Alfalfa Average (of Total N; 19 trials):
NPN = 54%
Ammonia-N = 7%
FAA-N = 40%
Unidentified N = 7%

Concentration of Soluble Non-Ammonia N (SNAN) in the Rumen (Choi et al., 2003)

Total SNAN (Dietary SNAN = 6.5% of RUP-NAN)

Peptide NAN

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Protein NAN

FAA NAN

Contribution of Soluble ProteinS, Peptides & Amino Acids to Protein Escape (Reynal et al., 2007)

Item	CP Supplement				*Contrast*[1]
	Urea	SSBM	LSBM	CGM	
Dietary NAN (% of TNAN)	21	31	36	30	U, S, L
Sol. AA-N (% TNAN)	16	12	9	16	
Sol. AA-N (% of RUP)	74	37	26	52	U

(Alfalfa & Corn Silages, Ground corn, 15-20% CP)

SSBM = Solvent Soybean Meal; LSBM = Lignosulfonate SBM; CGM = Corn Gluten Meal;
[1]Contrasts: U = urea vs. SSBM; S = SSBM vs. LSBM; L = LSBM vs. CGM

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In Situ Forage Protein Degradation Not Well Related to Milk Protein Yield (Rinne et al., 2009)

Protein Yield Underestimated

Milk Protein Yield
(Observed - Predicted)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Protein Yield Overestimated

Summary

1. Excessive Degradation Wastes Protein.
2. RUP Supplies 1/3 of Metabolizable Protein.
3. Increasing RUP Improves Production.
4. Amino Acid Pattern of RUP is Critical.
5. Supplementing RP-Met Improves Efficiency
6. In Situ Method (NRC) Over-Estimates RUP (Forage Proteins are Over-Valued).

Conclusion

More Research is Needed to Develop Rapid & Reliable Assays for Estimating Ruminal Degradation of Forage Proteins.