Detecting sensor drift in rumen pH data

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Overview

- How boluses work
- How boluses fail
- Some physics to explain failure
- An algorithm to automate the rumen pH failure detection

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Rumen pH Bolus

- Retained in Reticulo-rumen
- Raw data (pH & T) downloaded to handset
- Handset Uploads to internet
- Bolus lasts over 100 days before sensor fails
- Accurate +/- 0.1 pH per 30 days
- Used >3 per group

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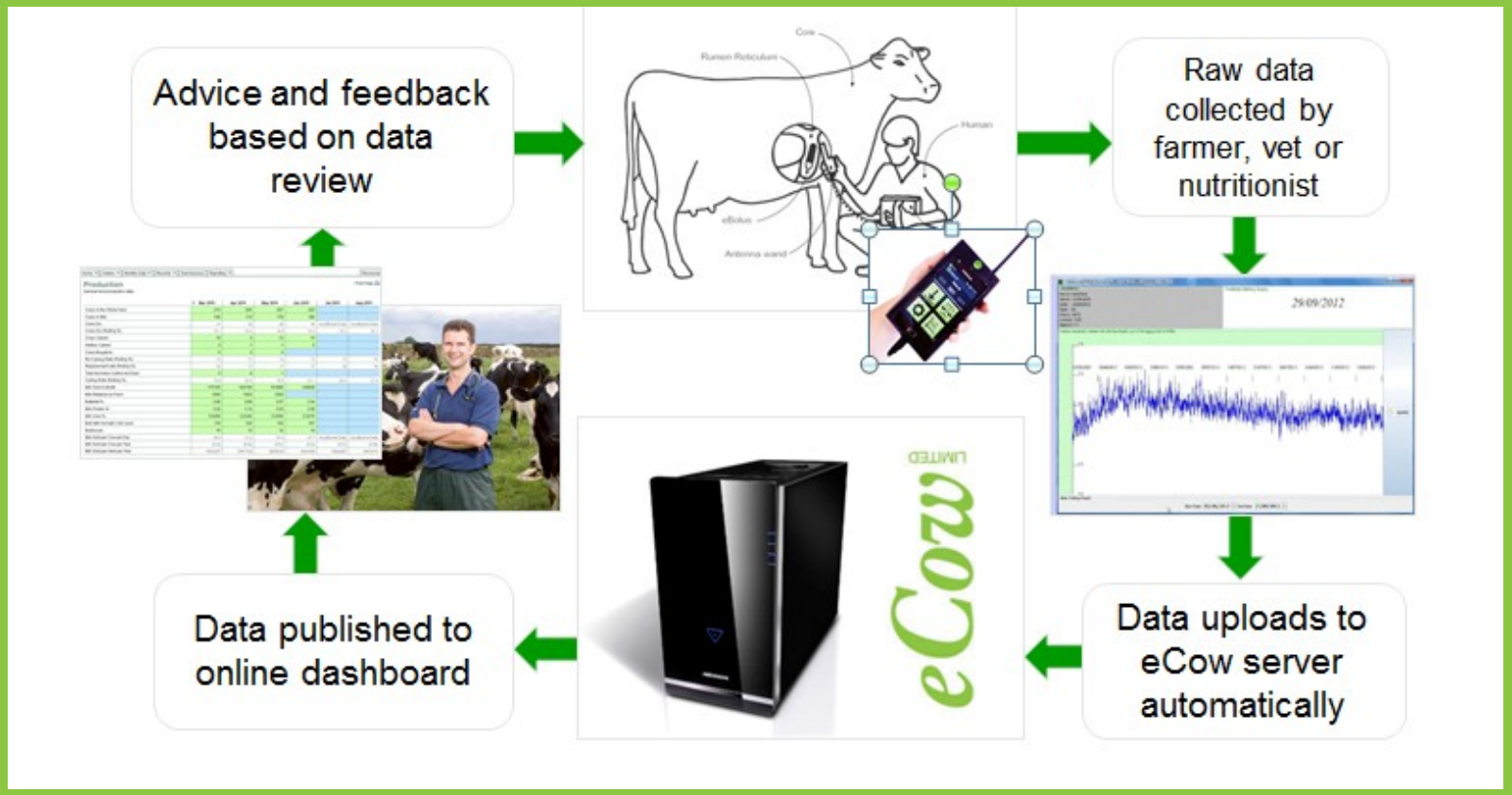
Rumen pH data flow



- eCow now has thousands of daily pH profiles on our server

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Cloud data service benefits

Data can be aggregated and analysed

Drift can be detected

Data can be compared and contrasted

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The reticulum is as remote as Mars

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Sudden bolus failure is now rare

Battery exhaustion

- usually due to excess radio downloads

Electronics failure

- usually due to water ingress

Software lockup

- now possible to reset

Radio attenuation

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Can we trust the data ?

Boluses removed from fistulated cows reveal

a. less than 0.1 pH difference from buffer

OR

b. major deviations (0.5 pH or worse)

Data inspection revealed a pattern of failure in boluses over 90 days

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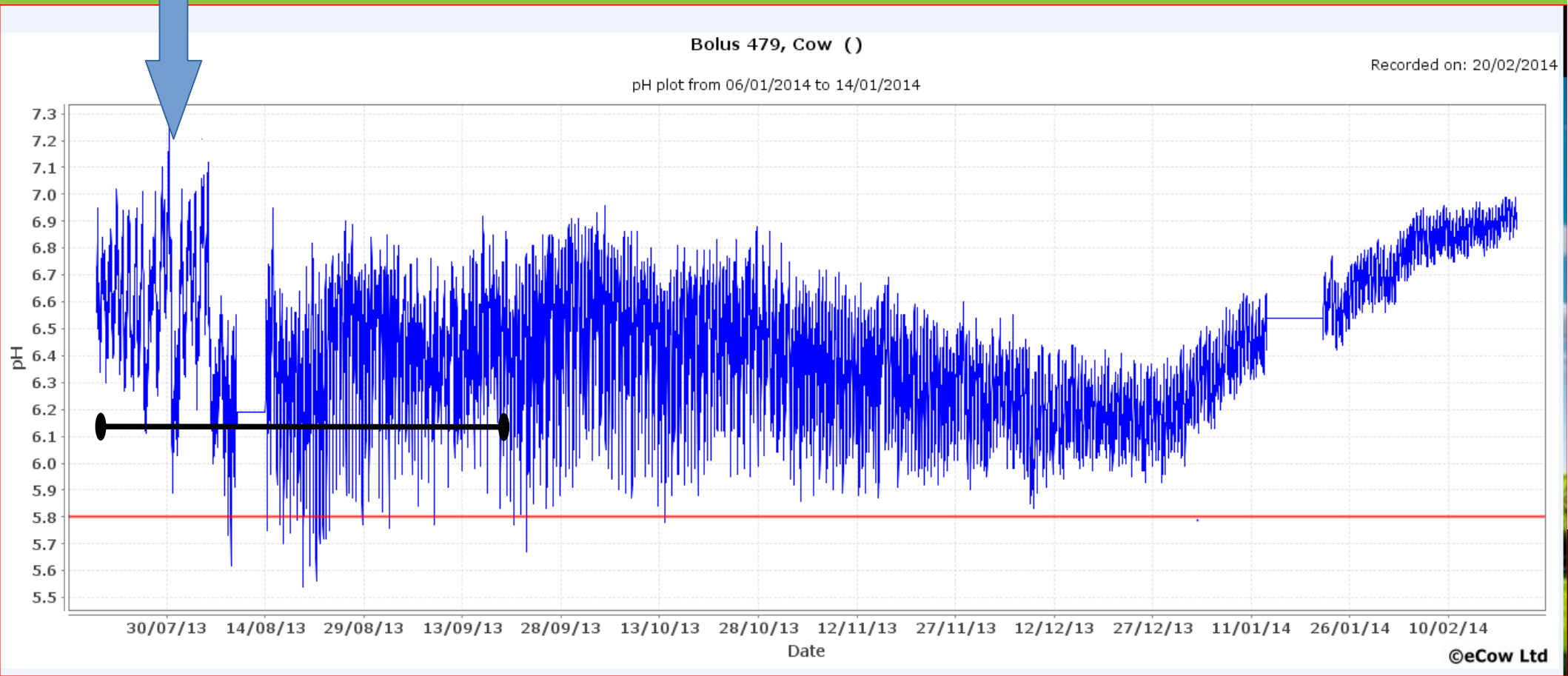
Data from a bolus over 180 days

Ante Partum



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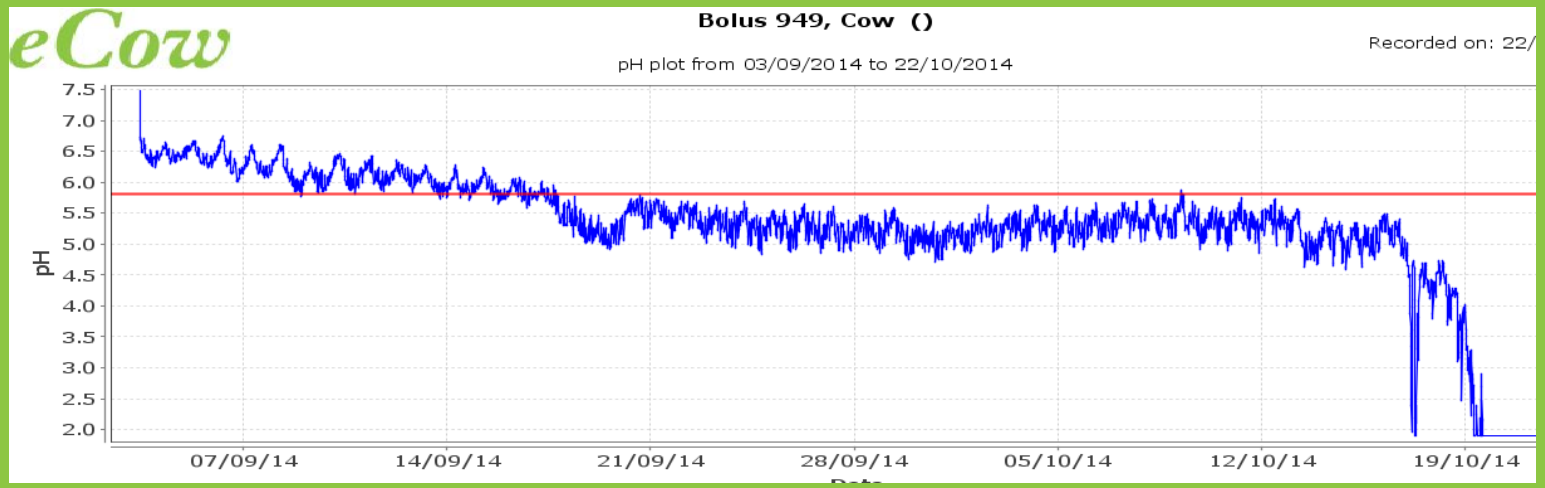
This is the pH bulb being cracked



The values are below physiological range, this cow was eating sand

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Observations

Normal pH daily range is 1 and 0.5

Mean daily pH is anywhere from 5.3 to 6.7

Rarely as high as 7 pH

– cow would be starving

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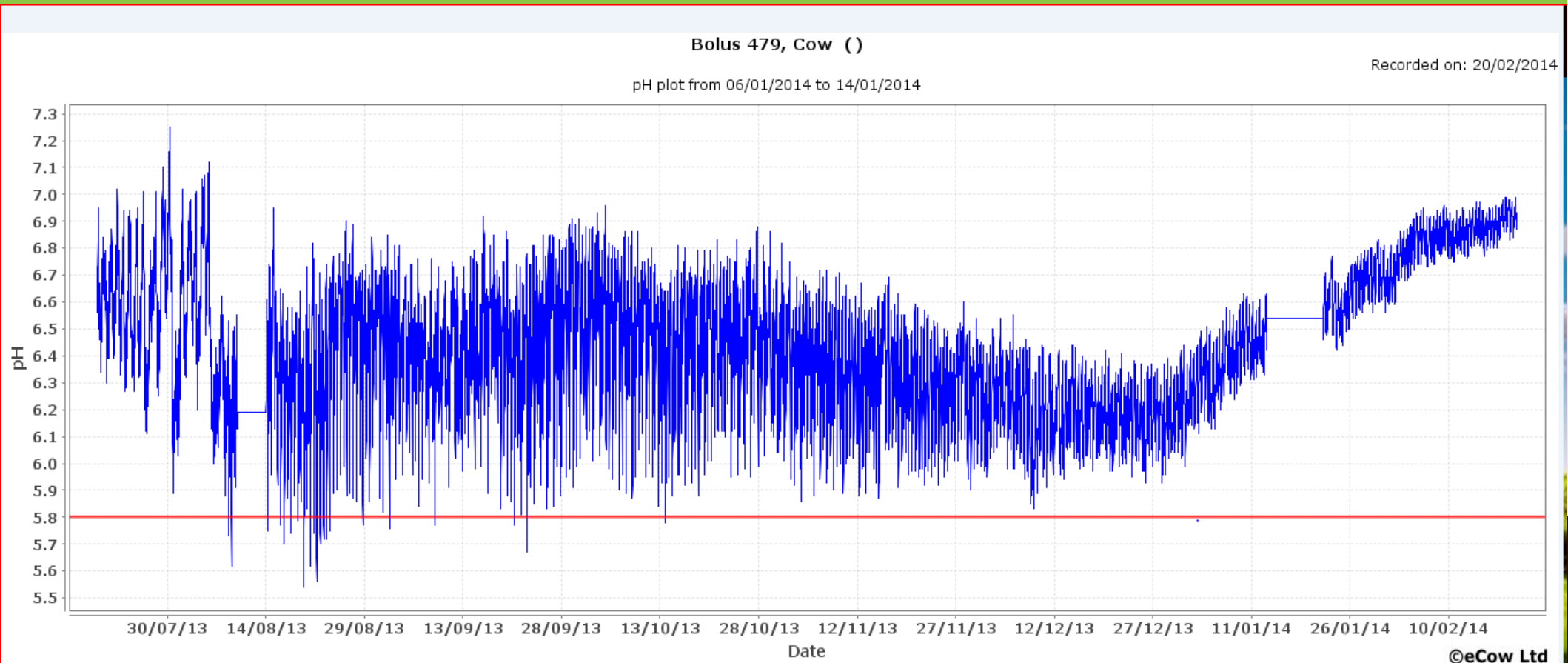
Why would data tend to 7 pH ?



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Remember the pH scale

Concentration of Hydrogen ions compared to distilled water				Examples of solutions and their respective pH
	1/10,000,000	14	Liquid drain cleaner, Caustic soda	
	1/1,000,000	13	bleaches, oven cleaner	
	1/100,000	12	Soapy water	
	1/10,000	11	Household Ammonia (11.9)	
	1/1,000	10	Milk of magnesium (10.5)	
	1/100	9	Toothpaste (9.9)	
	1/10	8	Baking soda (8.4), Seawater, Eggs	
	0	7	"Pure" water (7)	
	10	6	Urine (6) Milk (6.6)	
	100	5	Acid rain (5.6) Black coffee (5)	
	1,000	4	Tomato juice (4.1)	
	10,000	3	Grapefruit & Orange juice, Soft drink	
	100,000	2	Lemon juice (2.3) Vinegar (2.9)	
	1,000,000	1	Hydrochloric acid secreted from the stomach lining (1)	
	10,000,000	0	Battery Acid	

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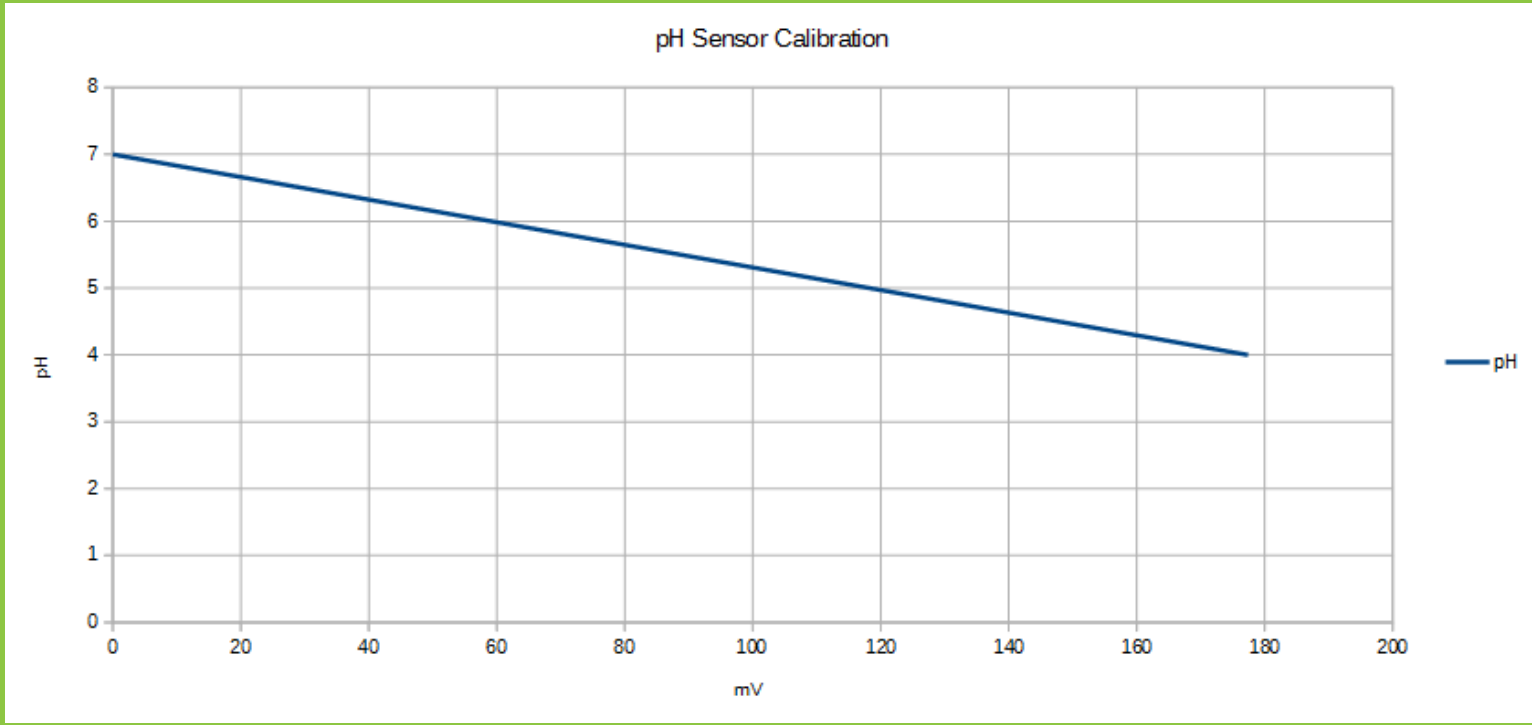
At 7 pH sensor output is zero mV



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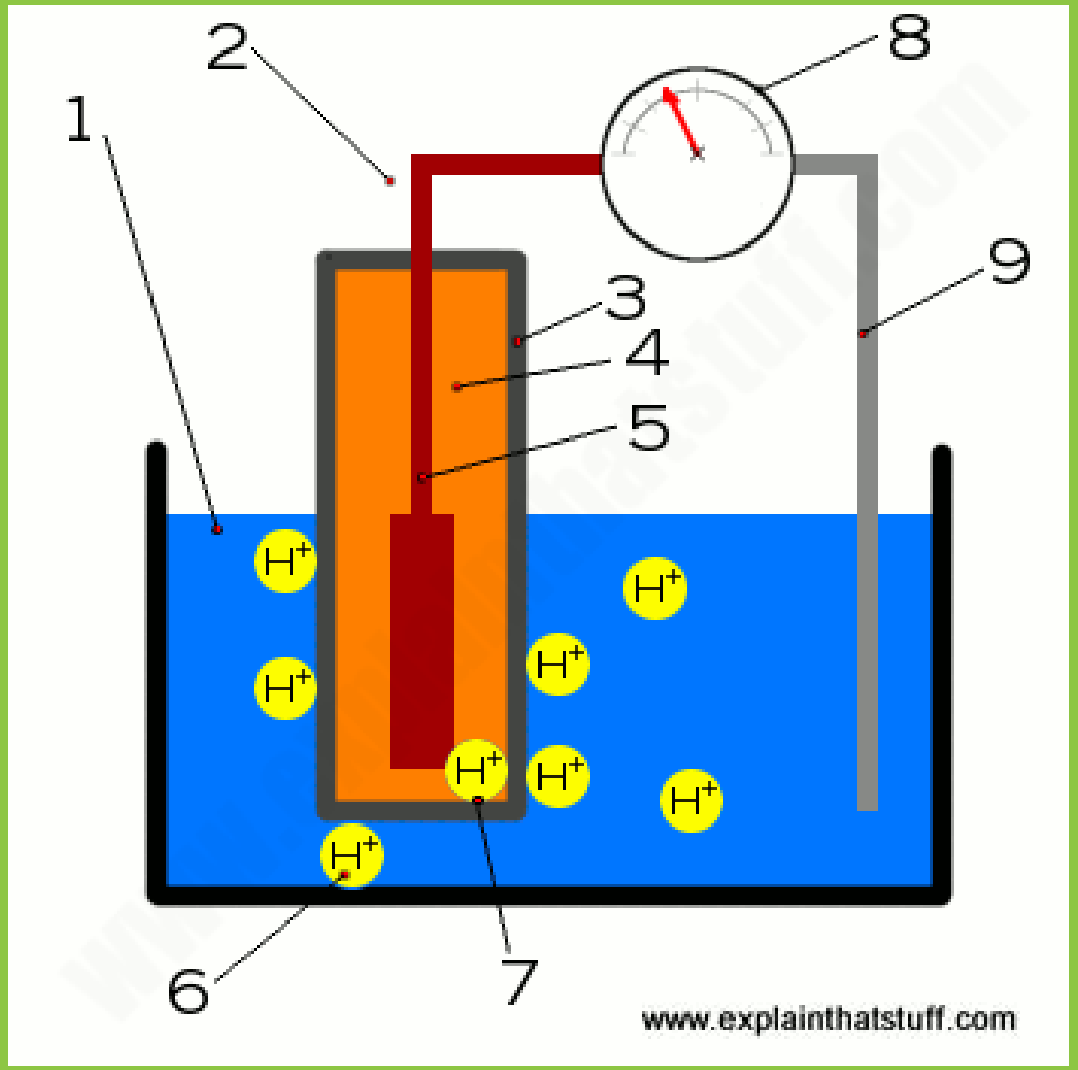
Revision of pH Fundamentals



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Why would data tend to 7 pH ?

Because the reference junction has been penetrated by rumen liquor and is reading the same as the measurement electrode

So potential difference = 0 mV so ADC reads 7 pH

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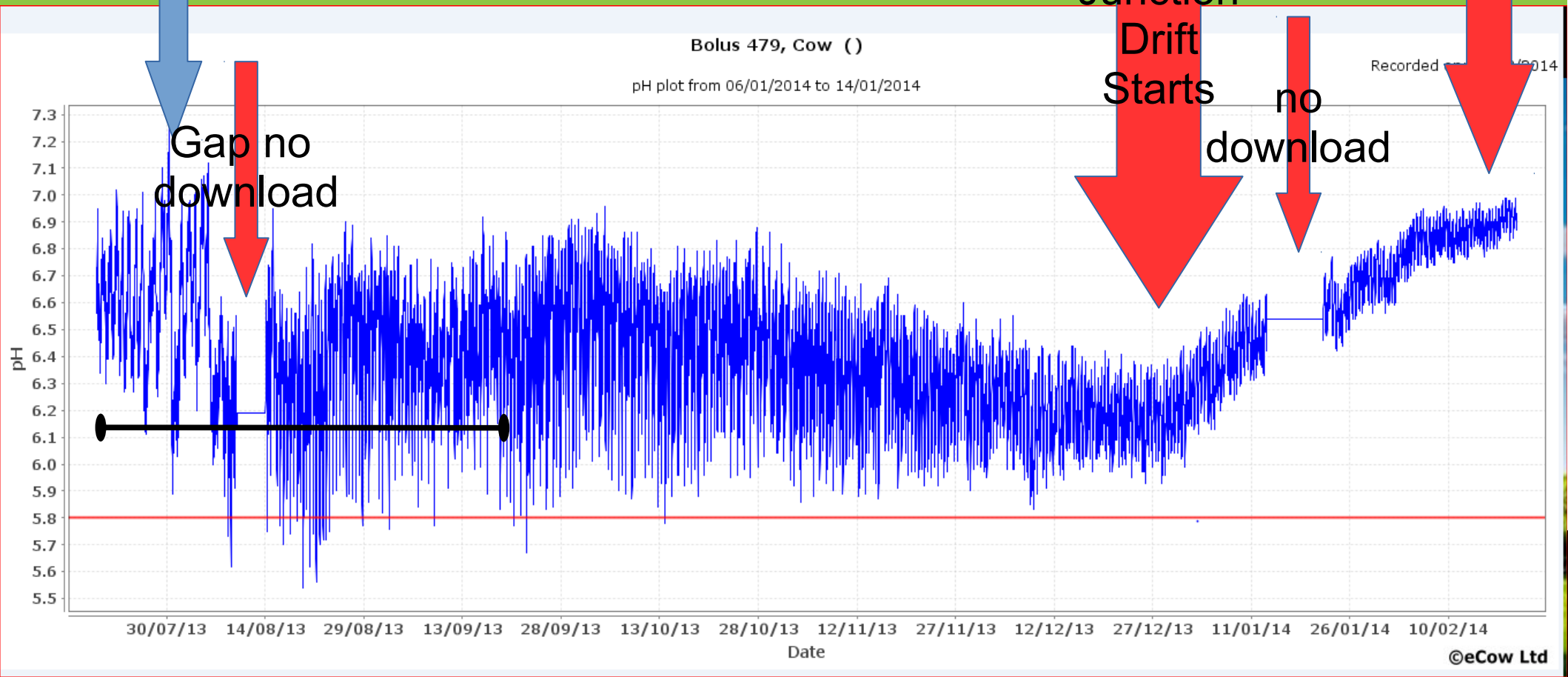
Data from a bolus over 180 days



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Observations

- Inspect data over 90 days
- Distrust data over 120 days
- Apply an algorithm to calculate daily range
- Distrust daily means above 6.7 pH

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Conclusions

Sensor data can be analysed to determine failure modes

Sensor drift is non-linear

Drift can be detected by data inspection

If pH < 4 for more than 1 reading

OR

If normalised max pH per day – (difference between min/max per day) >0.2

AND days in operation > 90

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Thank you

And thanks to all the researchers and farmers who share their data

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