

# Online Measurement of Urea Concentration in Spent Dialysate During Hemodialysis

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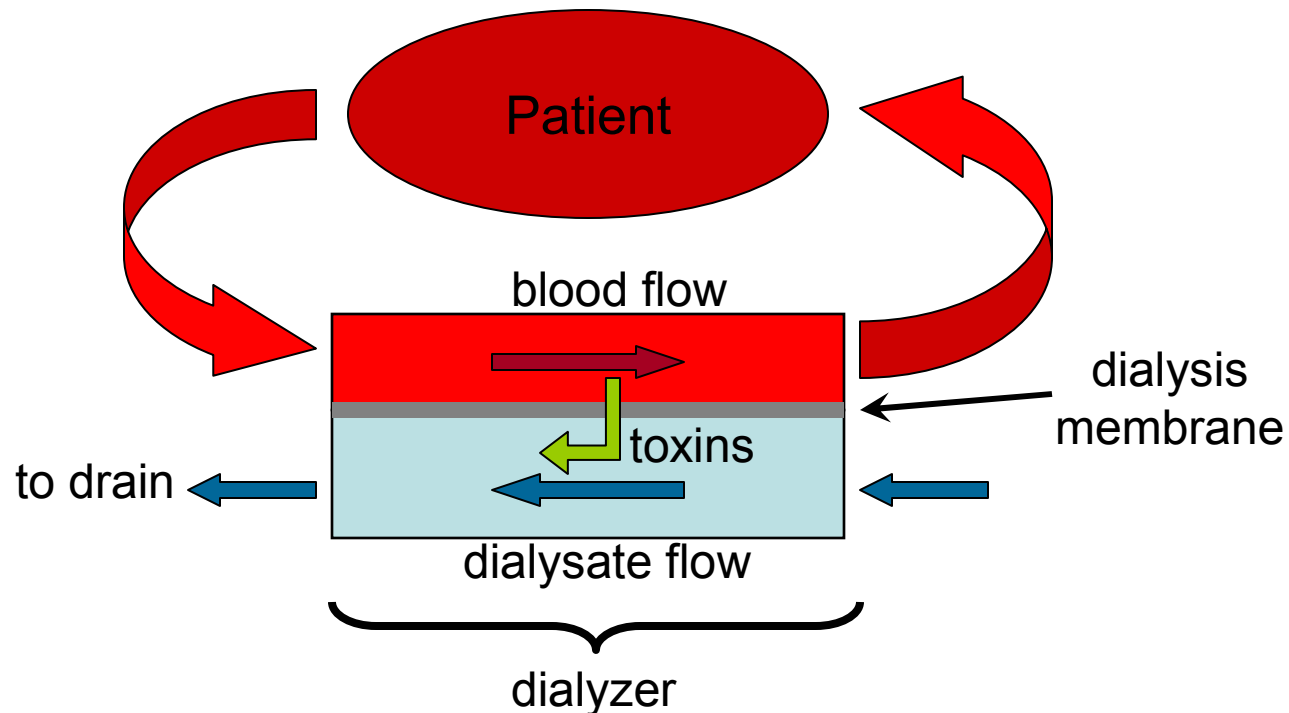
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# Hemodialysis

Approximately 260,000 Americans undergo dialysis due to kidney failure

## Hemodialysis

- Process for removing toxins from the blood stream that would normally be removed by functioning kidneys.
- 3 times per week, 4 hours per session
- Remove blood from patient, pass across a dialysis membrane, return



# Monitoring Hemodialysis Effectiveness

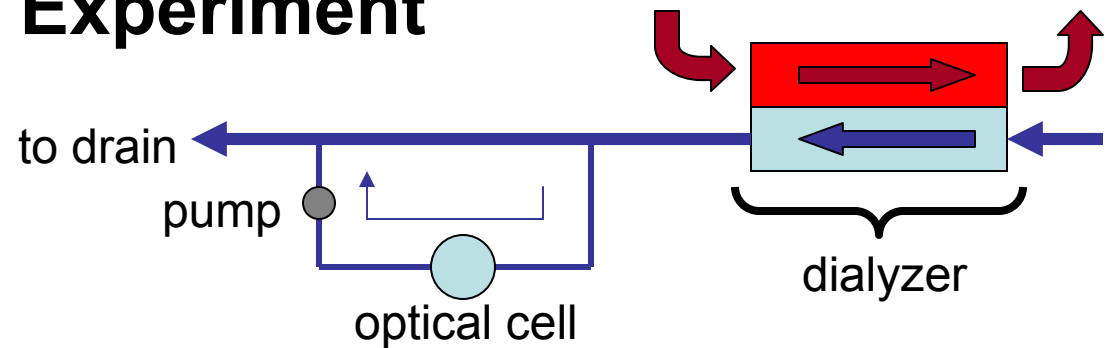
**Dialysis dose has a strong impact on patient health**

## **Conventional monitoring**

- Blood samples drawn before and after dialysis once per month
- Chemical assay of urea concentration before and after
- Relative reduction of urea is used as a marker for the removal of small molecular weight toxins

**How effectively can urea removal be monitored using near-infrared spectroscopy?**

# Experiment



## Optical measurement

- Dialysate drawn through an optical cell downstream from dialyzer
- FTIR spectrometer
- 5000-4000  $\text{cm}^{-1}$  range (2.0-2.5  $\mu\text{m}$ )
- Spectra collected continuously, recorded at 1-minute intervals

## Chemical measurement

- Liquid samples collected for chemical assay 7 times per treatment
  - Urea, creatinine, glucose, and lactate
- Corresponding spectra used for model calibration and verification

## Temperature

- No temperature control used
- Observed range was 28-34  $^{\circ}\text{C}$

**10 treatments over a 15 day period**

# Composition of Dialysate

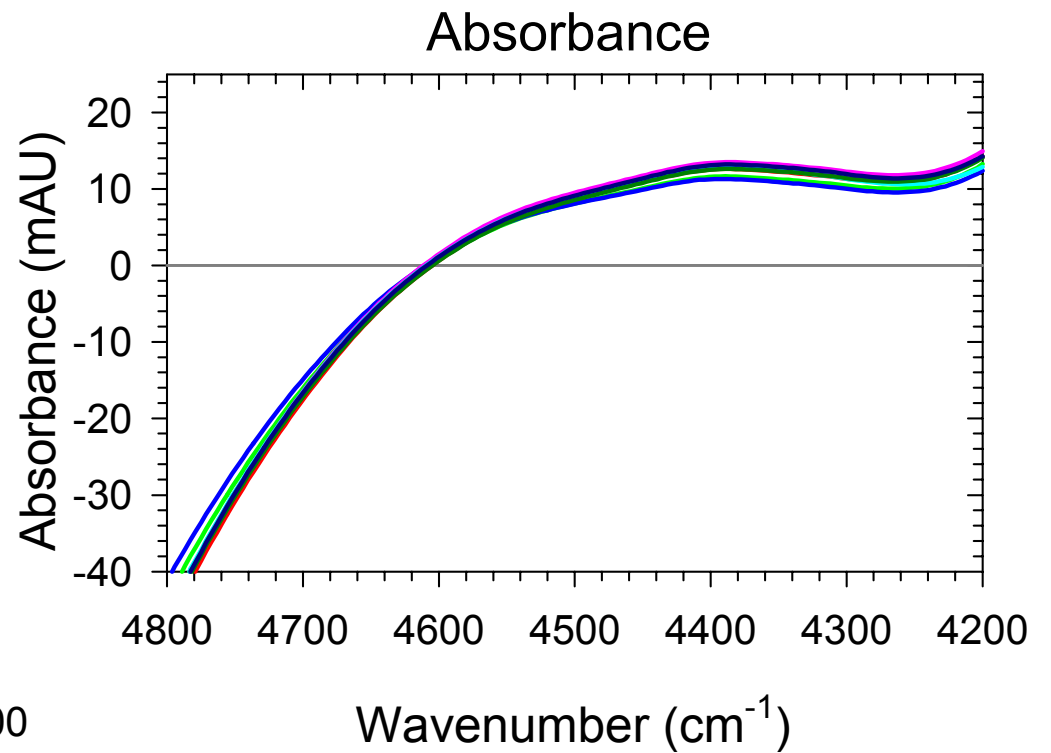
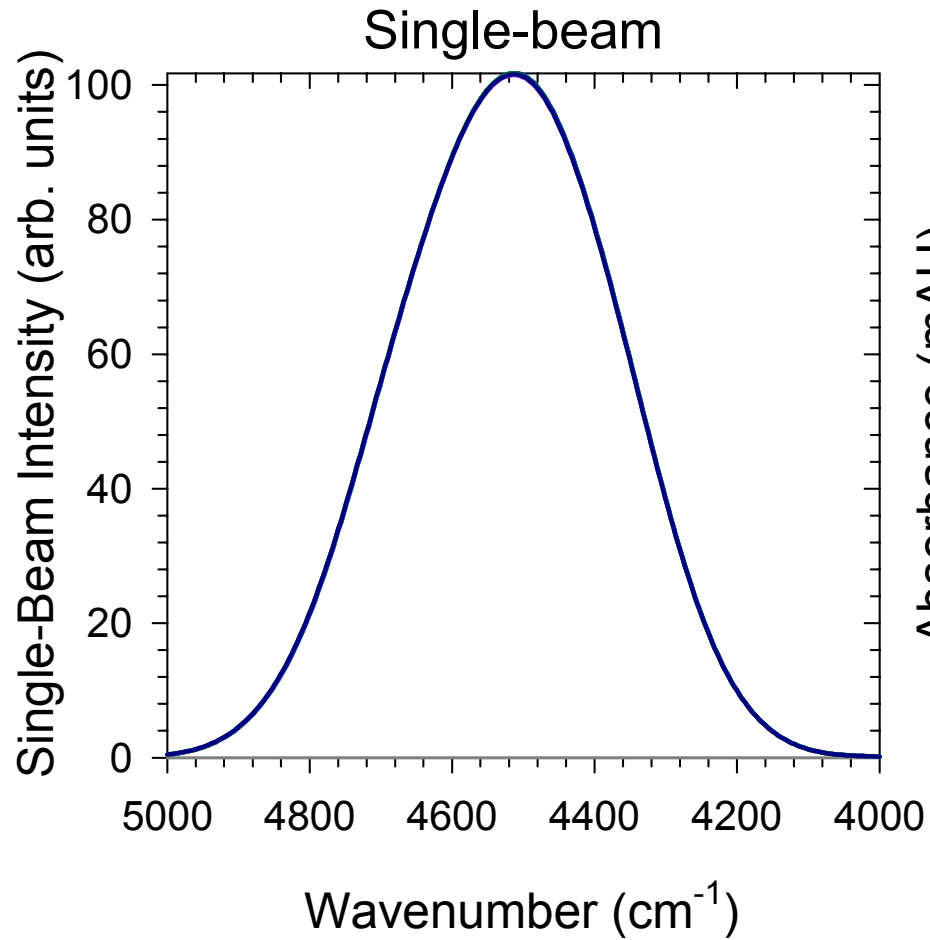
## Fresh dialysate

- pH 7.7
- Glucose (10 mM)
- Acetate (4 mM)
- Bicarbonate (33 mM)
- Salts (Na, Cl, Ca, K, Mg)

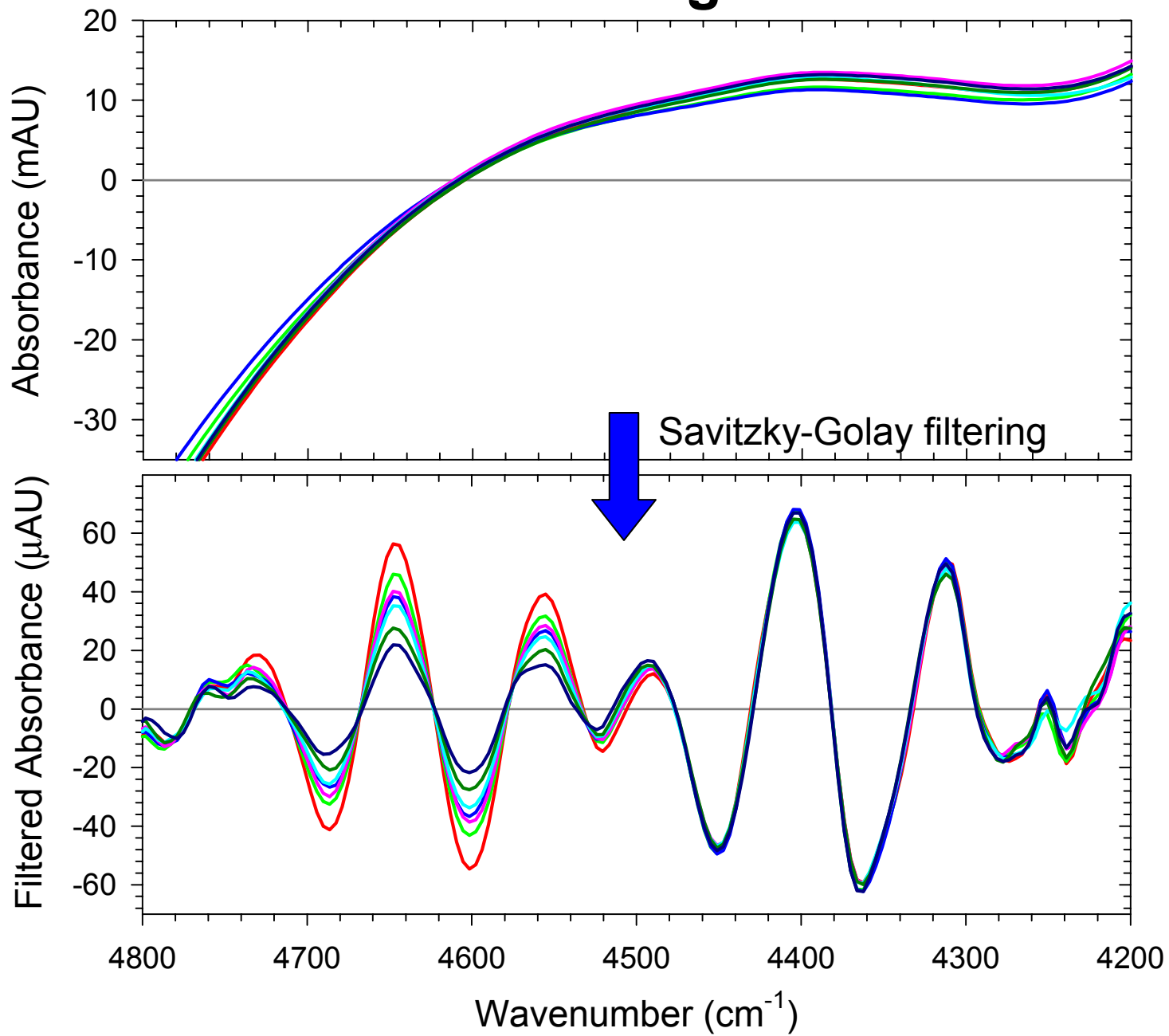
## Spent dialysate

- Urea (0-11 mM)
- Creatinine (0-0.35 mM)
- Lactate (0-0.8 mM)
- other low molecular weight toxins

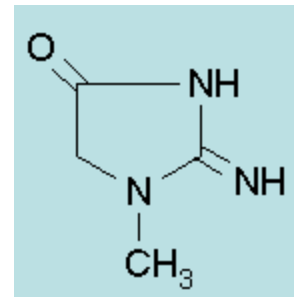
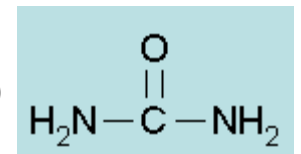
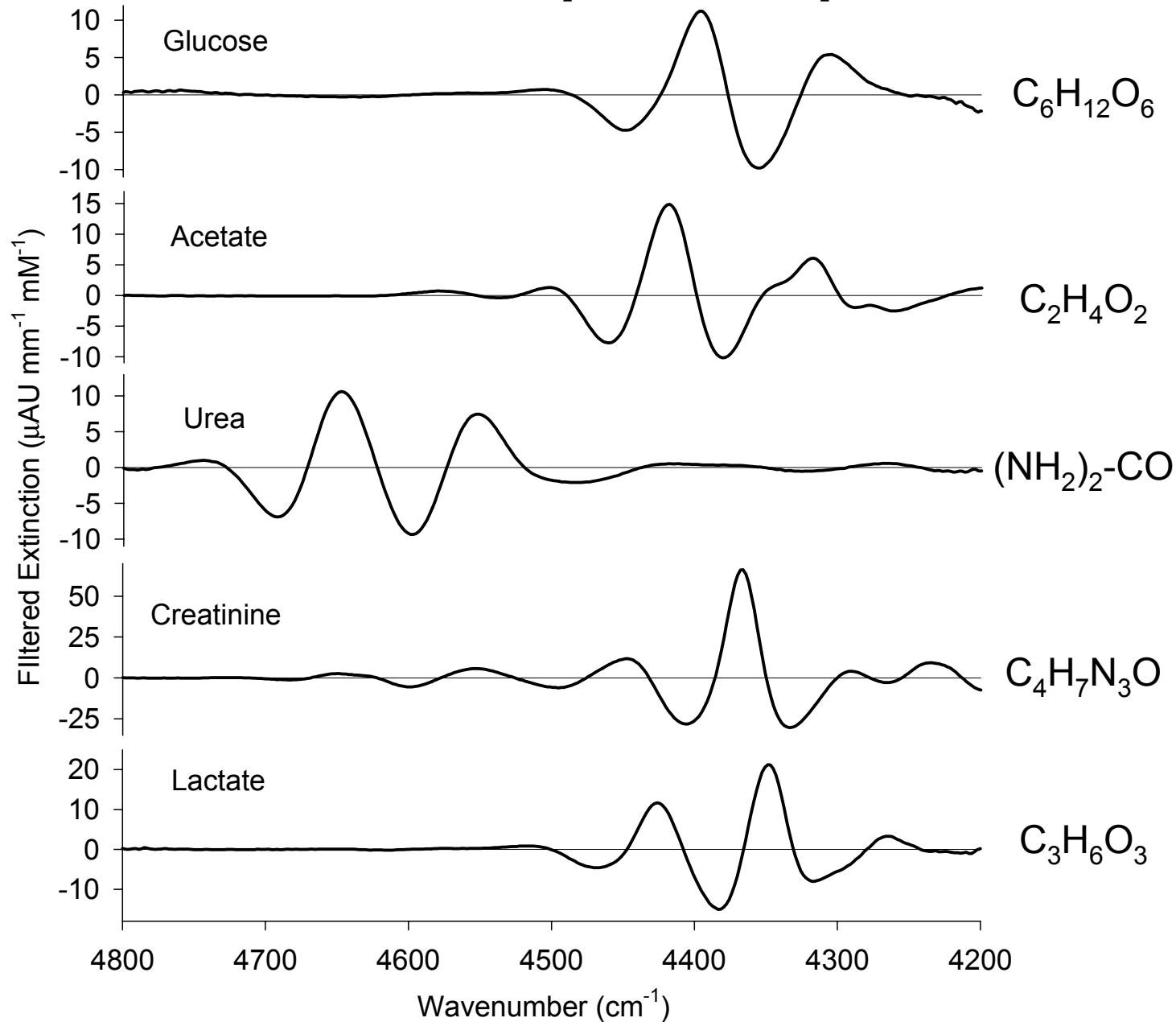
# Example Online Spectra



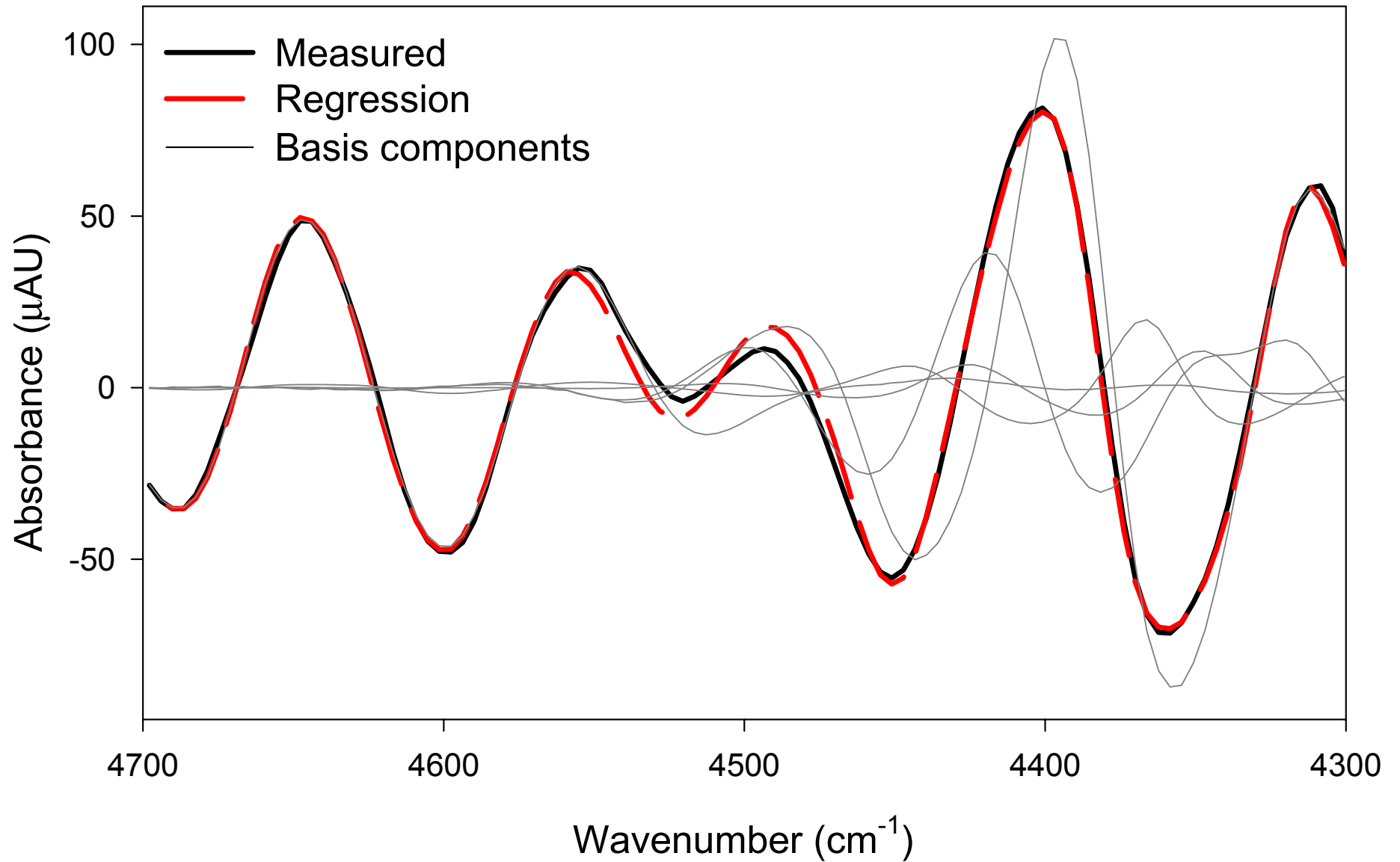
# Filtering



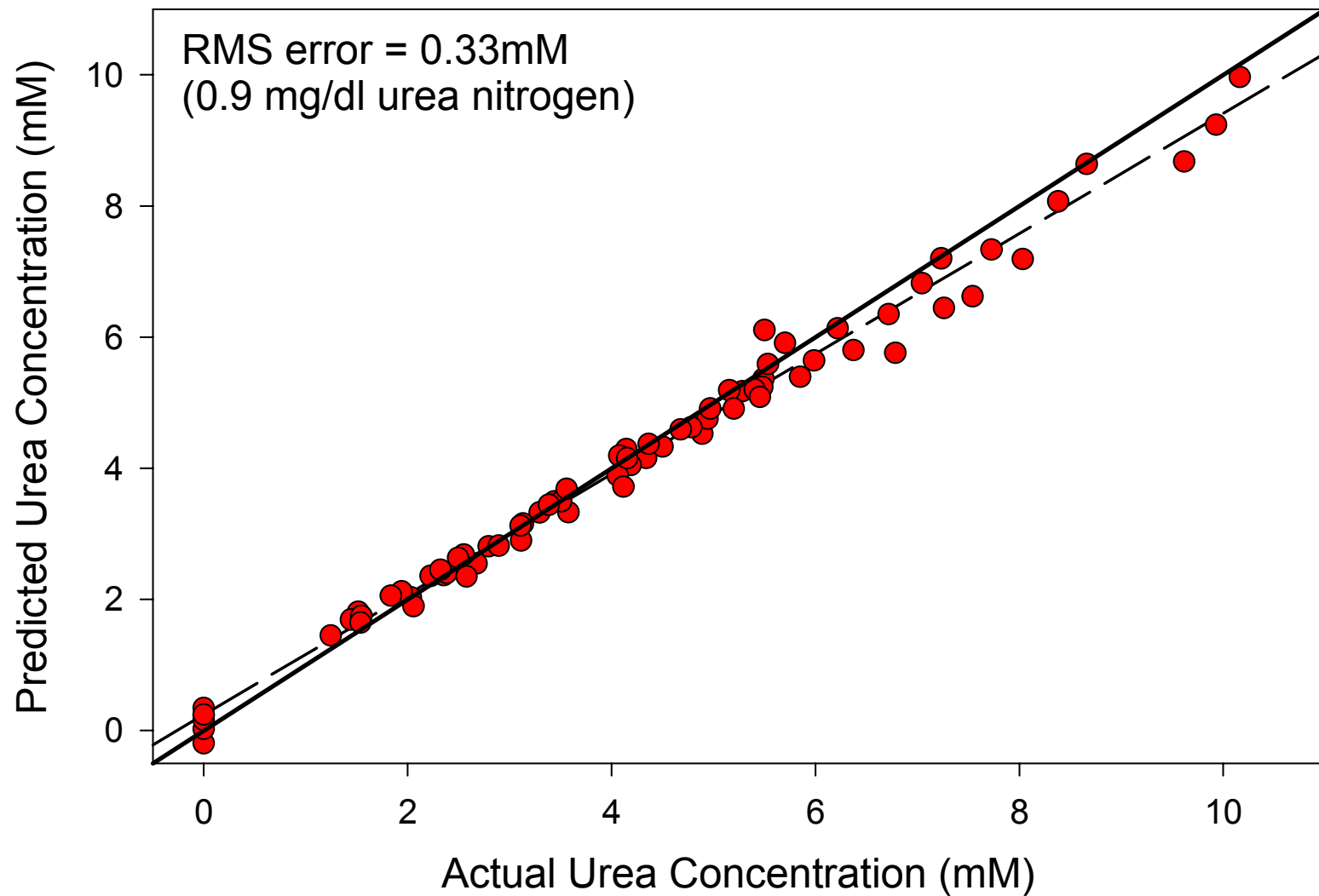
# Pure Component Spectra



# Regression Strategy



# Results for Urea



- No temperature control required
- No model training
- Calibration built using information from before the first dialysis treatment

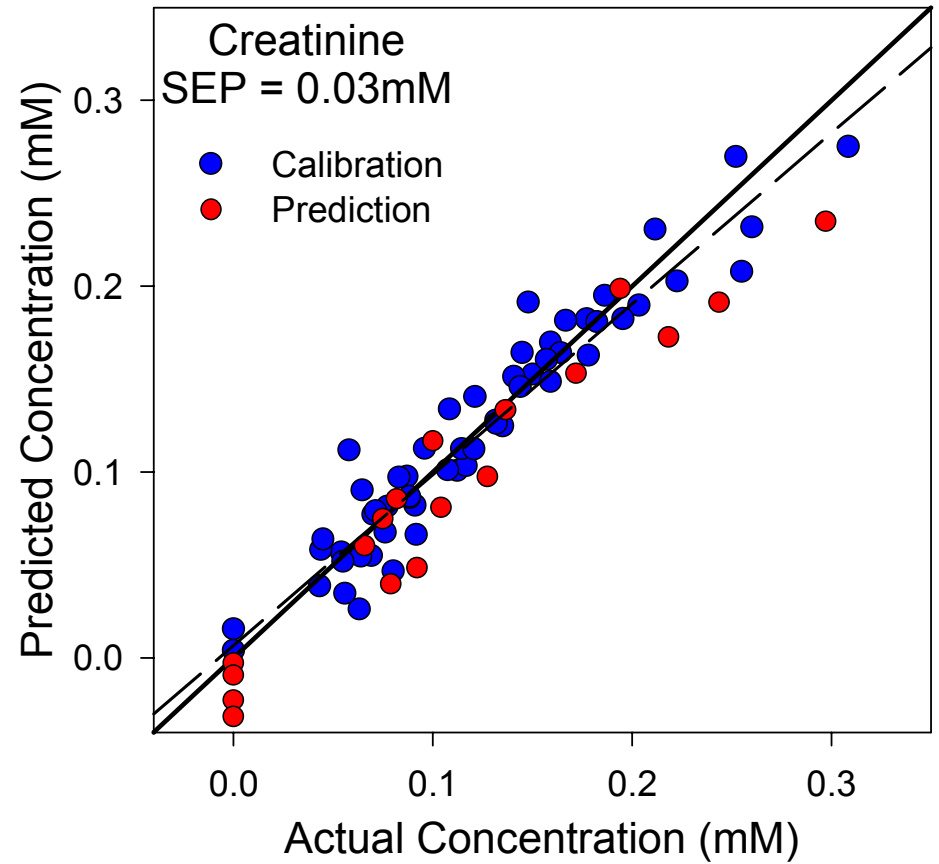
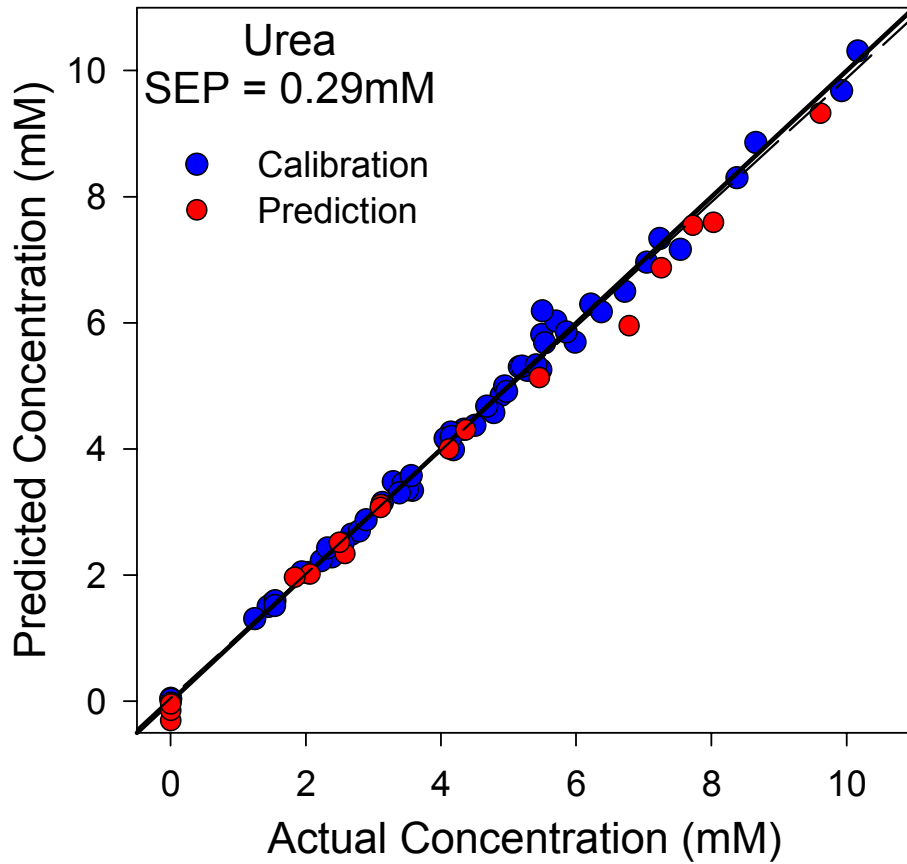
# Partial Least Squares

## Calibration

- Use first 8 treatments to build calibration
- Use final 2 treatments as independent prediction set
- Choose optimal number of factors using cross-validation of the calibration set
- All calibrations use the 4700-4300  $\text{cm}^{-1}$  range

Analyte	Number of Factors	Standard Error of Prediction (mM)	Concentration Range (mM)
Urea	8	0.29	0 - 11
Creatinine	7	0.03	0 – 0.35
Glucose	15	0.22	9 – 13
Lactate	13	0.11	0 – 0.8

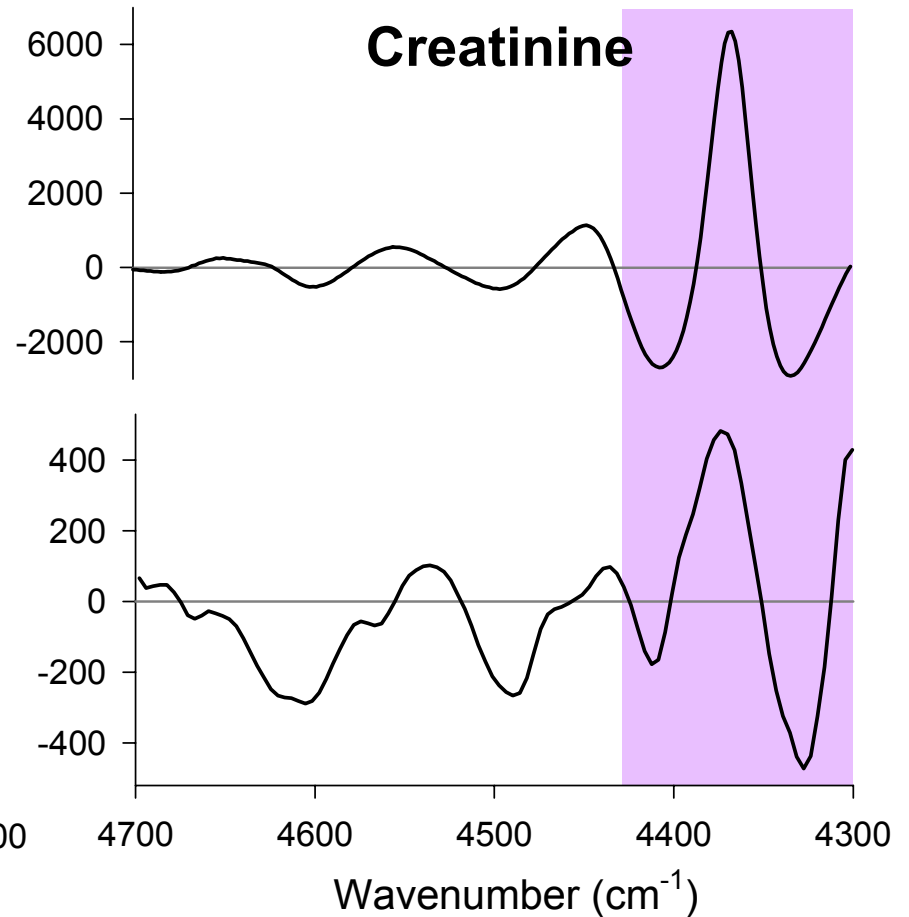
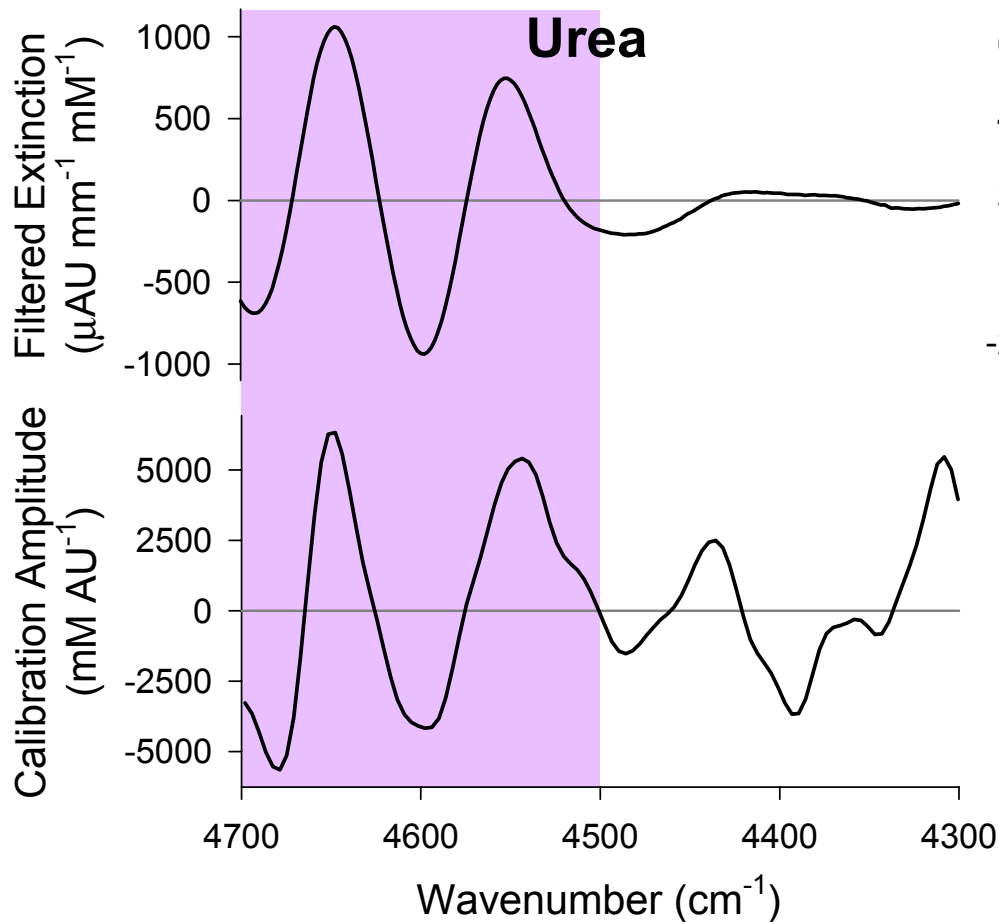
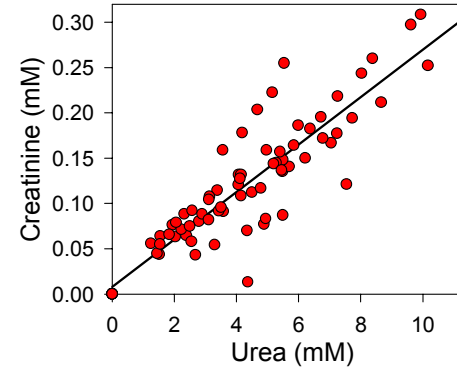
# PLS Results



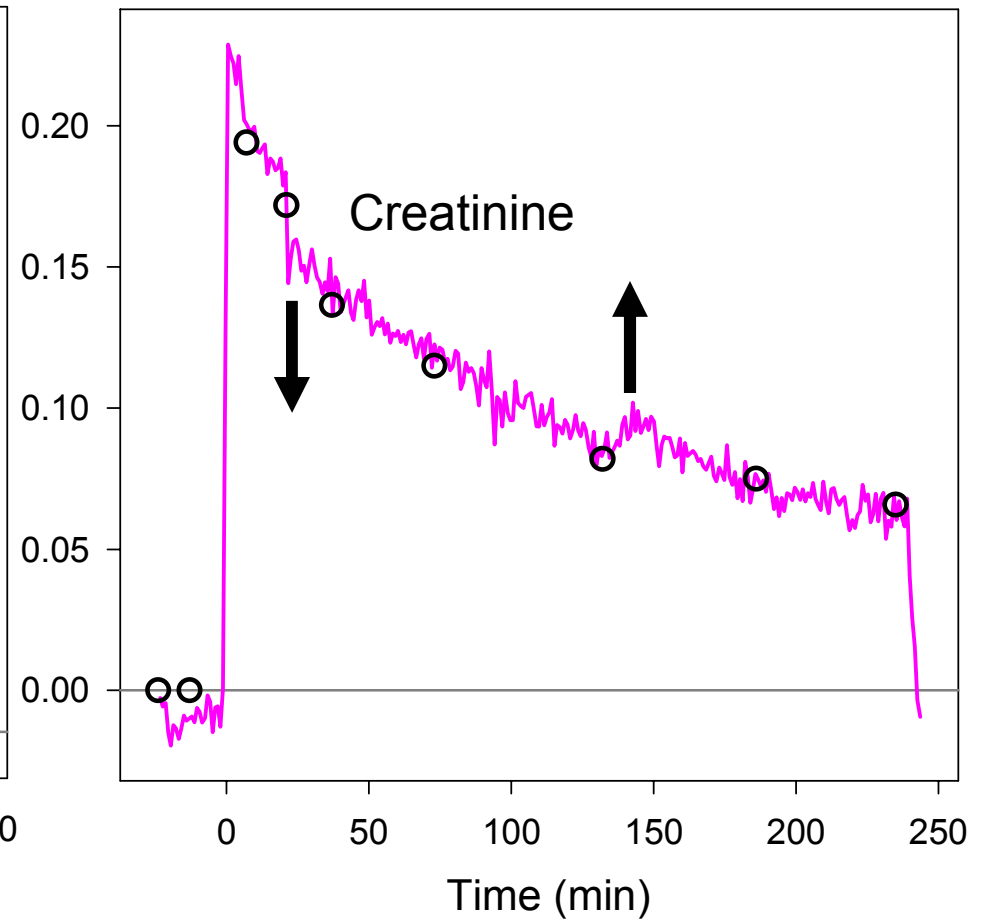
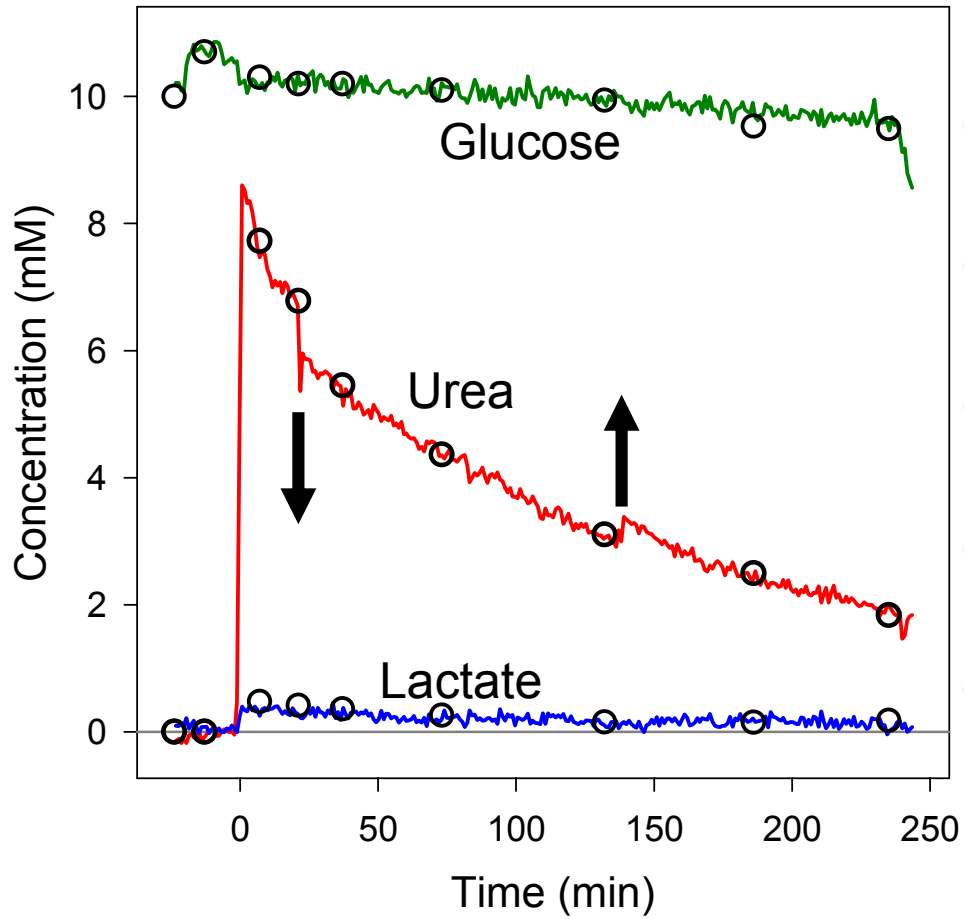
# Calibration Vectors for Urea and Creatinine

## Urea and creatinine correlation

•  $r^2 = 0.82$



# Time Profile



## Change in blood flow rate

- 330 to 260 ml/min at 20 minutes
- 260 to 300 ml/min at 140 minutes

# Summary

## Online optical measurements of urea, creatinine, glucose, and lactate

### Regression Strategy

- 0.33 mM standard error
- No model building step required
- No temperature control required

### PLS

- 0.29 mM standard error for urea
- 0.03 mM standard error for creatinine
- Calibration vectors contain analyte specific information
- No temperature control required

### Future work

- Larger study to investigate calibration stability
- Miniaturizing spectroscopic system