Computational Lab: Renal

Part 1:

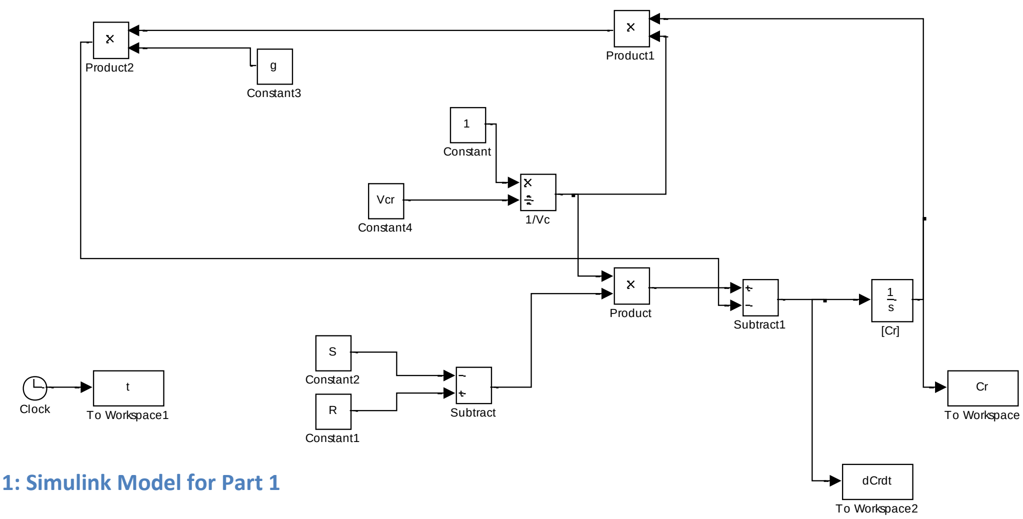


Figure 1: Simulink Model for Part 1

```
close all;clear all;clc;

R = 1600;  %creatinine production rate
S = 150; %creatinine secretion rate
Vcr = 420; %total body water
g = 1150; %glomerular filtration
Cr_initial_value = 1.261;  %initial value for the integrator
sim 'problem_1_model'

g_vec = zeros(1,length(t));
S_vec = zeros(1,length(t));
for i=1:length(t)
    g_vec(i) = g;
    S_vec(i) = S;
end

subplot(4,1,1); hold all;
plot(t,Cr,t,g_vec,t,S_vec,'linewidth', 2); title('Cr, GFR and S together');
legend('Measured Creatinine Cr','glomerular filtration rate g','tubular secretion S');
grid on;
subplot(4,1,2);
plot(t,Cr); grid on;title('Creatinine');  xlabel('Time (days)'); ylabel('[Creatinine] mg/dL');
subplot(4,1,3);
plot(t,g_vec); grid on; title('Glomerular Filtration Rate');
xlabel('Time (days)'); ylabel('GFR dL/day');
subplot(4,1,4);
plot(t,S_vec); grid on;  title('Tubular Seccretion');
xlabel('Time (days)'); ylabel('Secretion mg/day');

figure;
subplot(1,2,1);
plot(Cr,dCrdt,'o','LineWidth',4); grid on; title('dCr/dt vs Cr  closeup');
xlabel('[Creatinine] mg/dL'); ylabel('Creatinine mg/dL*day');
subplot(1,2,2);
plot(Cr,dCrdt,'o','LineWidth',4);
axis([0,6,-15,15]); grid on; title('dCr/dt vs Cr');
xlabel('[Creatinine] mg/dL'); ylabel('Creatinine mg/dL*day');
```

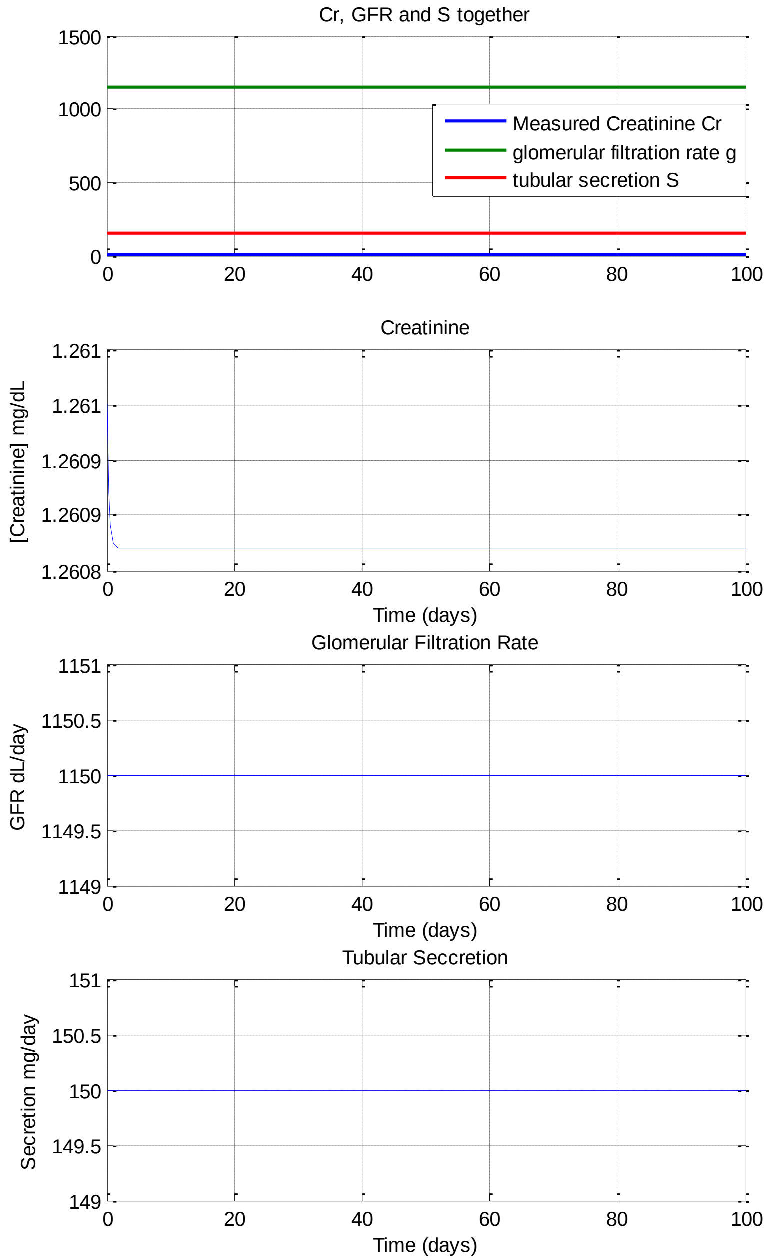


Figure 2: Parameters for Model 1

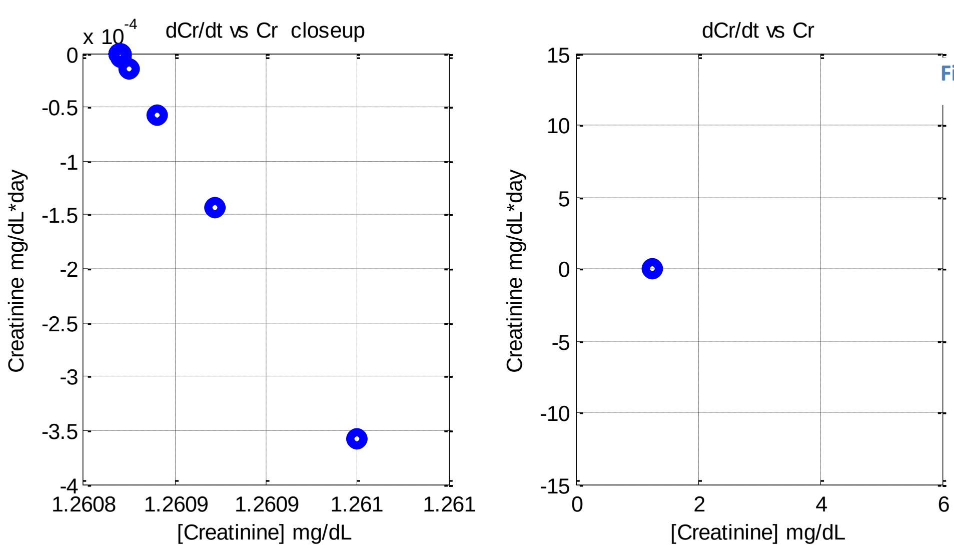


Figure 3: change in Cr vs. Cr

With a constant tubular secretion and a constant GFR… and a constant supply of creatinine, the net change in creatinine is zero after steady state is reached. (Fig 2) IE: a constant total body creatinine concentration results from a steady input and output of creatinine… this is shown by the first plot. The plot of the change in creatinine over the concentration of creatinine stabilizes to a point rather quickly…. (Fig 3) This is again because there is no change in the concentration of creatinine once the concentration has reached the steady state provided constant GFR, tubular secretion and synthesis of creatinine. Ie the curve converges to a stable point.

Part 2:

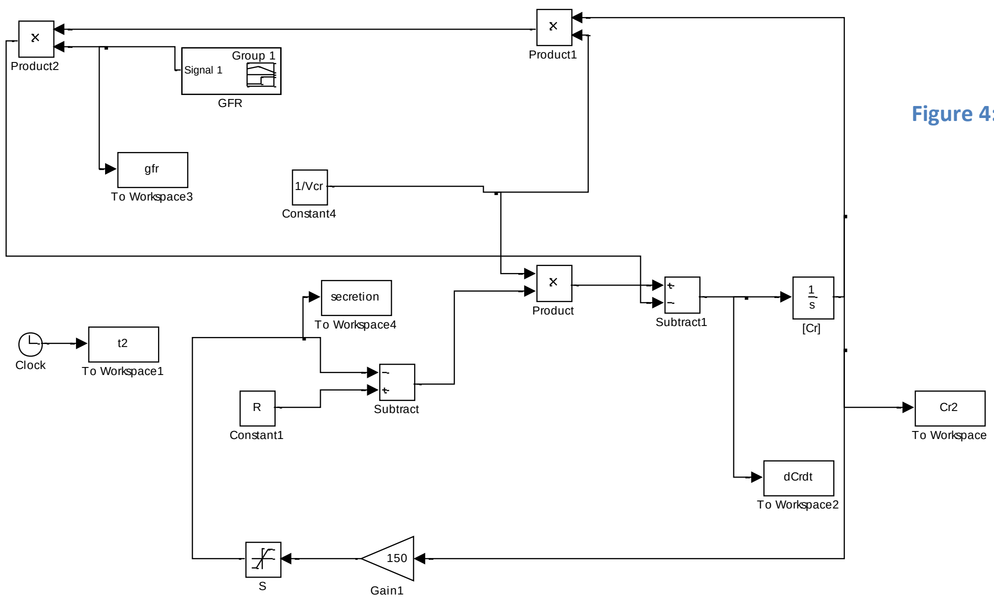
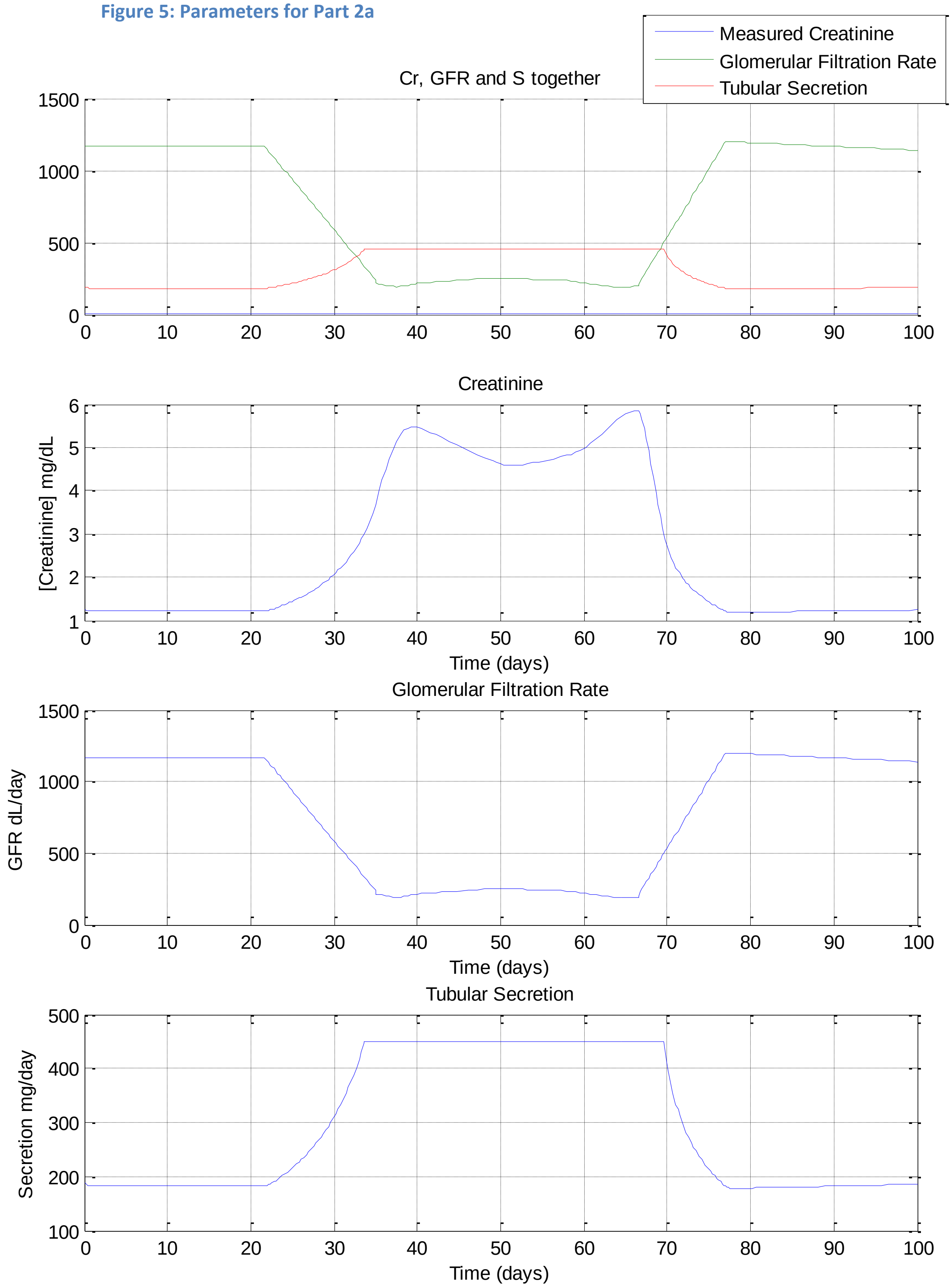


Figure 4: Model for Part 2a

```
clear all;close all;clc;

R = 1600;  %creatinine production rate
Vcr = 420; %total body water
Cr_initial_value = 1.261;  %initial value for the integrator
sim 'problem_2_model'
 subplot(4,1,1);hold all;
plot(t2,Cr2,t2,gfr,t2,secretion); grid on; title('Cr, GFR and S together');
legend('Measured Creatinine','Glomerular Filtration Rate','Tubular Secretion');
subplot(4,1,2);
plot(t2,Cr2); grid on; title('Creatinine');
xlabel('Time (days)'); ylabel('[Creatinine] mg/dL');
subplot(4,1,3);
plot(t2,gfr); grid on; title('Glomerular Filtration Rate');
xlabel('Time (days)'); ylabel('GFR dL/day');
subplot(4,1,4);
plot(t2,secretion); grid on; title('Tubular Secretion');
xlabel('Time (days)'); ylabel('Secretion mg/day');
 figure;
subplot(1,2,1);
plot(Cr2,dCrdt,'LineWidth',4); grid on;
title('dCr/dt vs Cr  closeup');
xlabel('[Creatinine] mg/dL'); ylabel('Creatinine mg/dL*day');
subplot(1,2,2);
plot(Cr2,dCrdt,'LineWidth',4);
xlabel('[Creatinine] mg/dL'); ylabel('Creatinine mg/dL*day');
title('dCr/dt vs Cr');
axis([0,8,-15,15]); grid on;
```

Figure 5: Parameters for Part 2a



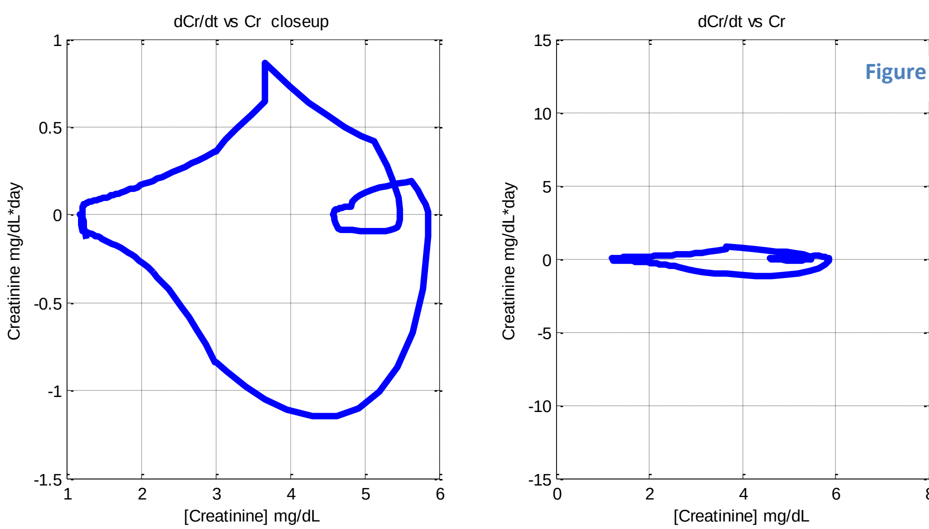


Figure 6: change in Cr vs. Cr

As GFR drops, you will see an increase in the total body concentration of creatinine (shown in the plot) as well as an increase in the tubular secretion of creatinine which is dependent on total body concentration of creatinine up to a saturation point. Similarly an increase in GFR will have the opposite effect.

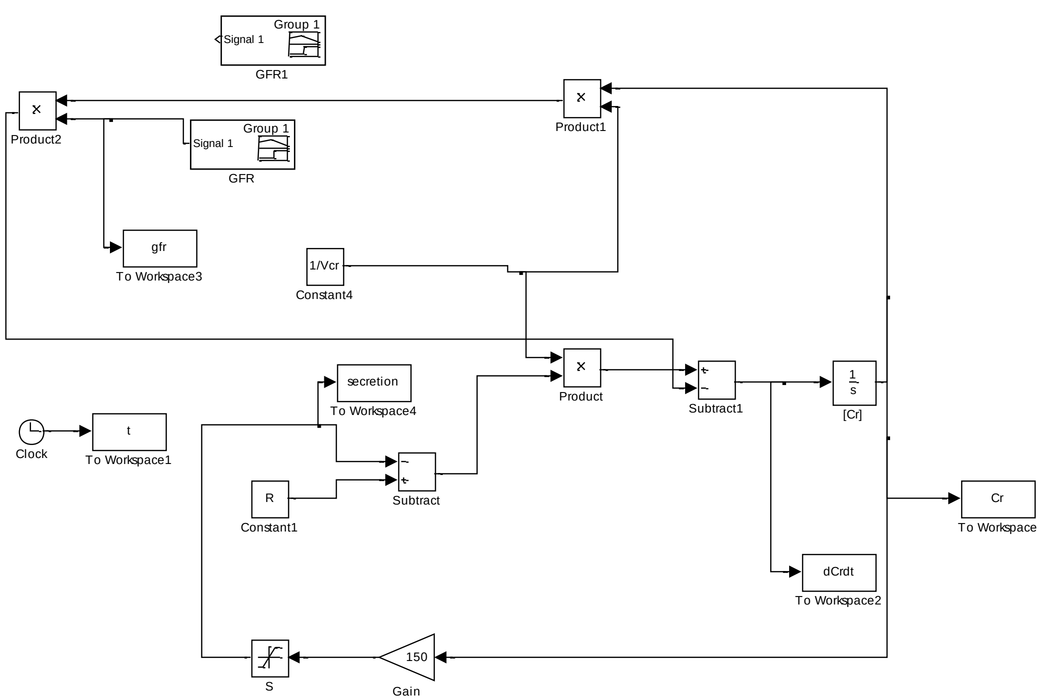
The loop on the graph of dCr/dt vs. Cr (Fig 6) is easiest to analyze when comparing it to the plot of creatinine on the previous figure (Fig 5).

- The plot starts at 0 and ramps up as creatinine changes due to decrease in GFR….
- Then the plot slows in decrease in dCR/dt but still positive as the GFR tables and the [creatinine] reaches a maximum
- Then the plot shows a loop than runs negative and then positive again corresponding with the divot in the previous plot for Creatinine…
- Then the plot shows a negative change in creatinine as the GFR picks back up and the [Cr] decreases

A doctor could estimate the time-course of GFR by looking at the dCr/dt plot because most generally…an increase in dCR/dt is a decrease in GFR, and a decrease in dCR/dt is an increase in GFR.

Part 2b:

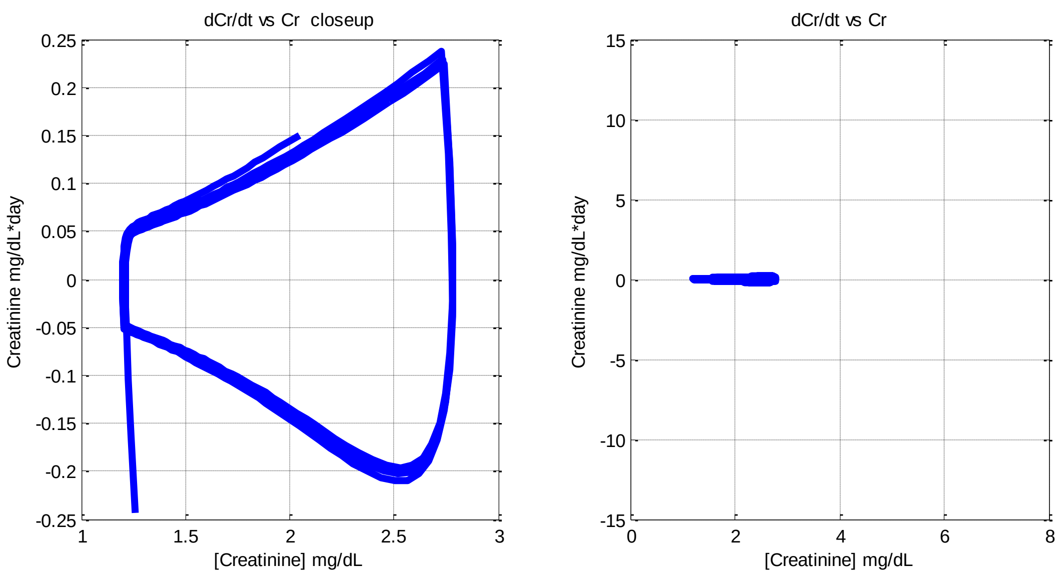
Figure 7: Model for Part 2b




```
clear all;close all;clc;
```

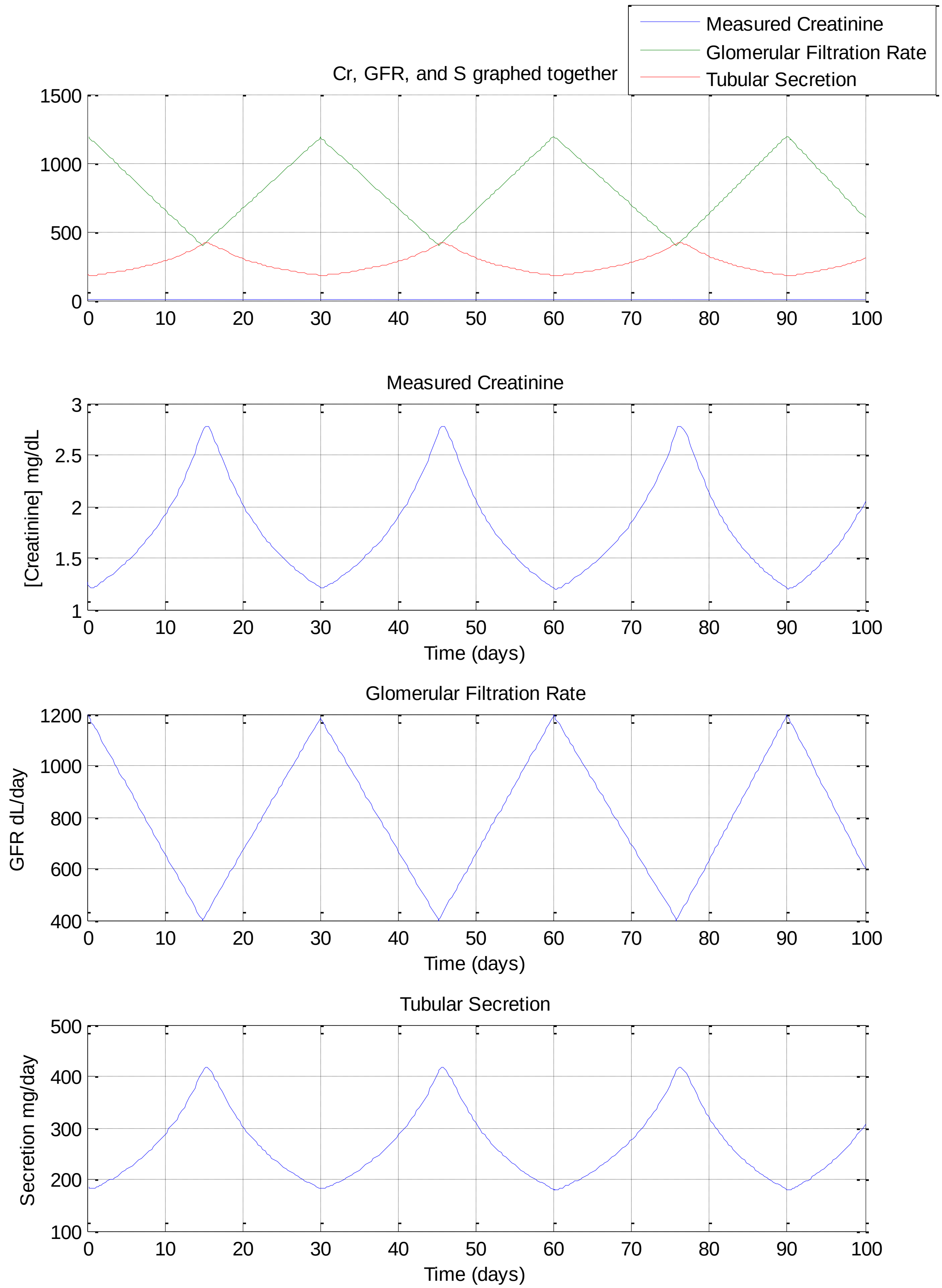
```
R = 1600;  %creatinine production rate
Vcr = 420; %total body water
Cr_initial_value = 1.261;  %initial value for the integrator
sim 'problem_2b_model'

subplot(4,1,1);hold all;
plot(t,Cr,t,gfr,t,secretion); grid on; title('Cr, GFR, and S graphed together');
legend('Measured Creatinine','Glomerular Filtration Rate','Tubular Secretion');
subplot(4,1,2);
plot(t,Cr); grid on; title('Measured Creatinine');
xlabel('Time (days)'); ylabel('[Creatinine] mg/dL');
subplot(4,1,3);
plot(t,gfr); grid on; title('Glomerular Filtration Rate');
xlabel('Time (days)'); ylabel('GFR dL/day');
subplot(4,1,4);
plot(t,secretion); grid on; title('Tubular Secretion');
xlabel('Time (days)'); ylabel('Secretion mg/day');

figure;
subplot(1,2,1);
plot(Cr,dCrdt,'LineWidth',4); grid on;
title('dCr/dt vs Cr  closeup');
xlabel('[Creatinine] mg/dL'); ylabel('Creatinine mg/dL*day');
subplot(1,2,2);
plot(Cr,dCrdt,'LineWidth',4);
xlabel('[Creatinine] mg/dL'); ylabel('Creatinine mg/dL*day');
title('dCr/dt vs Cr');
axis([0,8,-15,15]); grid on;
```

Figure 8: Change in Cr vs Cr



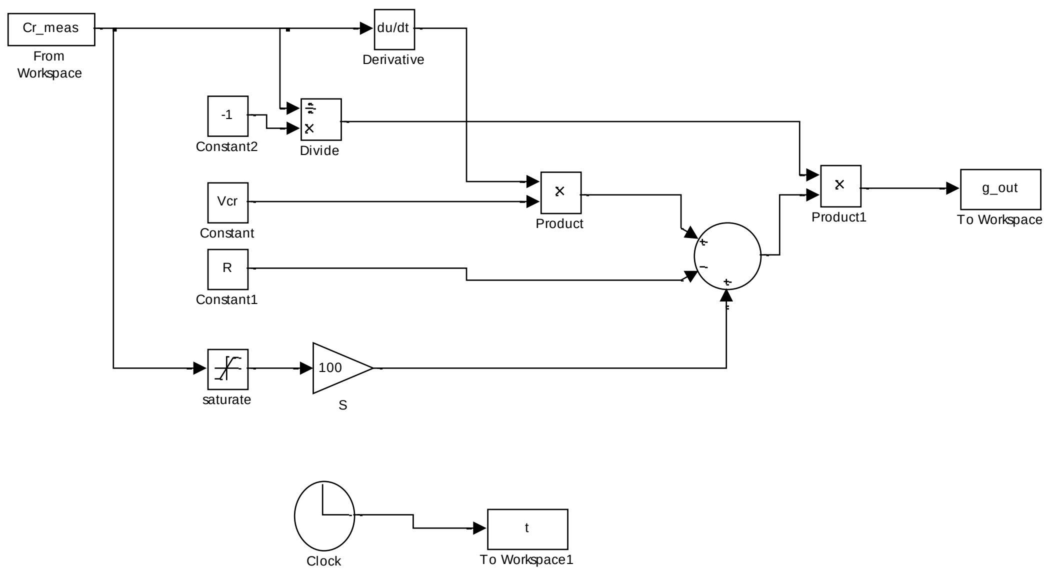
A constant decreasing GFR leads to a solidly increasing dCR/dt as expected… and a constantly increasing GFR leads to a solidly decreasing dCR/dt. Both part 2a and 2b shown this occurrence. Part 2b uses the GFR profile created below in Figure9. The resultant dCr/dt vs. Cr graph is shown above in Figure 8.

Figure 9: Parameters including GFR profile for Part 2b



Part 3:

Figure 10: Model for Part 3




```
close all;clear all;clc;
 load Mystery_Measured_Creatinine
 R = 1600;  %creatinine production rate
Vcr = 420; %total body water
 sim actual_problem_3_model;
figure;
plot(t,g_out); grid on; title('Glomerular Filtration Rate vs. Time');
xlabel('time (days)');
ylabel('Glomerular Filtration Rate (dL/day)');
```

The kidney function appears to return to a stable value after all the fluctuation. (Fig. 11) The final resting value is within healthy range. Therefore the kidney function is stable, it corrects itself… converging.

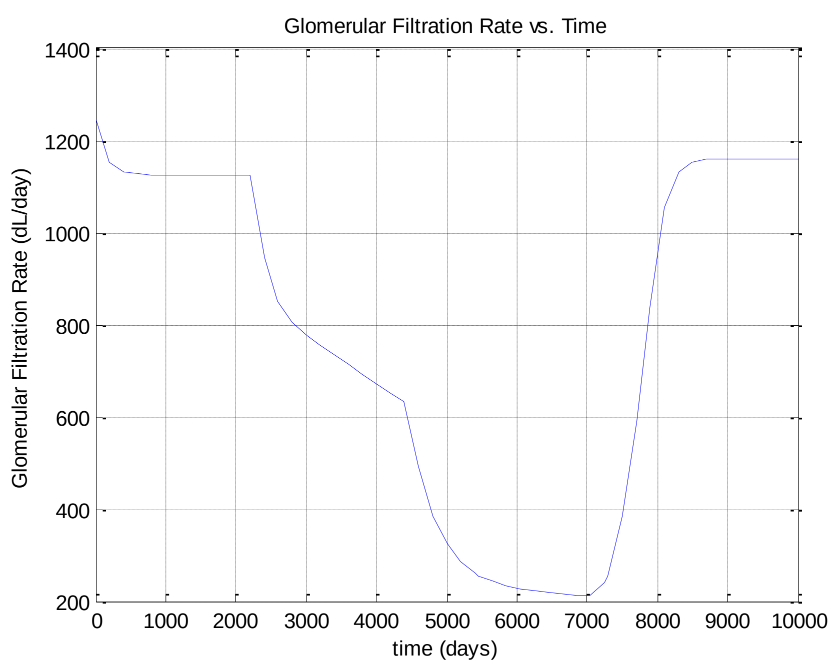


Figure 11: GFR for Part 3