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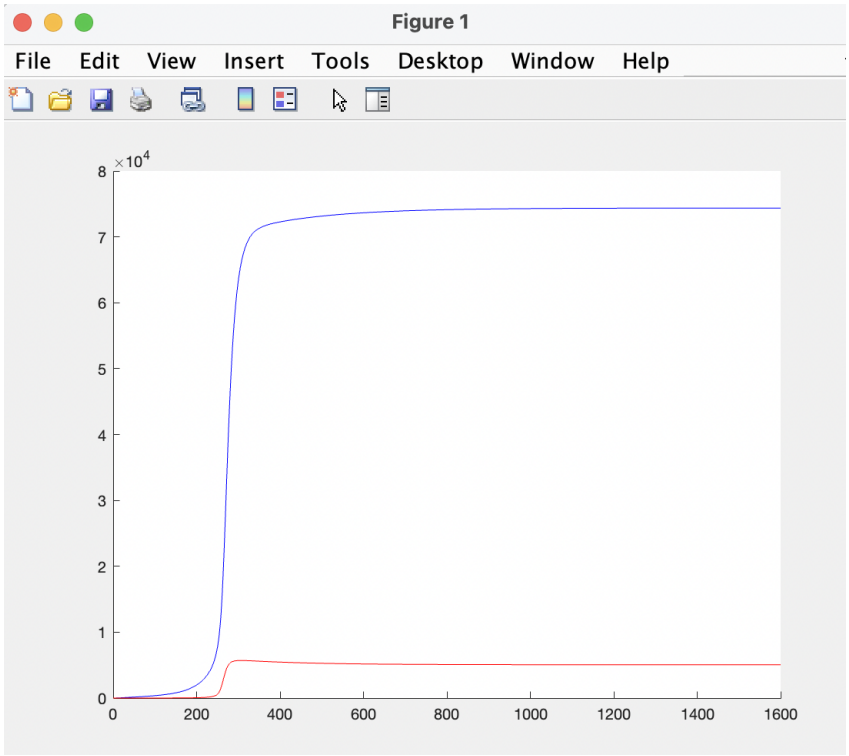
Appendix A (Q1 A)

```
function dx = hw3_q1(t,x)
dx = zeros(8,1);
k1 =507;
k7 = 81.9;
k13 = 40;
k15 = 464;
k2 = 3.9 * 10^(-3);
k4 = 5.8 * 10^(-3);
k6 = 0.21;
k8 =  3.9 * 10^(-3);
k10 = 5.8 * 10^(-3);
k12 = 0.21;
k14 = 1 * 10^(-3);
k16 = 1.16 * 10^(-2);
k18 = 1.16 * 10^(-2);
k19 = 1.73 * 10^(-2);
k3 = 1 * 10^(-5);
k5 = 5 * 10^(-4);
k9 = 5.8 * 10^(-6);
k11 = 5 * 10^(-4);
k17 = 3 * 10^(-4);
I = 112;
%x(1) = [C8](t)
%x(2) = [C8*](t)
%x(3) = [C3](t)
%x(4) = [C3*](t)
%x(5) = [BAR](t) inhibitor
%x(6) = [IAP](t) inhibitor
%x(7) = [C8*BAR](t)
%x(8) = [C3*IAP](t)
if t > 100 && t < 1200
   I = 200;
else
   I = 0;
end
dx(1) = k1 - k2*x(1) - k3*(x(4) + I) * x(1);
dx(2) = k3*(x(4) + I) * x(1) - k4*x(2) - k5*x(2) * x(5) + k6*x(7);
dx(3) = k7 - k8*x(3) - k9*x(2) * x(3);
dx(4) = k9*x(2) * x(3) - k10*x(4) - k11*x(4) * x(6) + k12*x(8);
dx(5) = k13 -k5*x(2) * x(5) + k6*x(7) - k14*x(5);
dx(6) = k15 - k11*x(4) * x(6) + k12*x(8) - (k16 + k17*x(4)) * x(6);
dx(7) = k5*x(2) * x(5) - k6*x(7) - k18*x(7);
dx(8) = k11*x(4) * x(6) - k12*x(8) - k19*x(8);
```

```
clear
[T,X] = ode45(@hw3_q1, [0:1600], [0 0 0 0 0 0 0 0]);
%random
figure(1)
hold on
plot(T, X(:,2),'blue');
plot(T, X(:,4),'red');
```



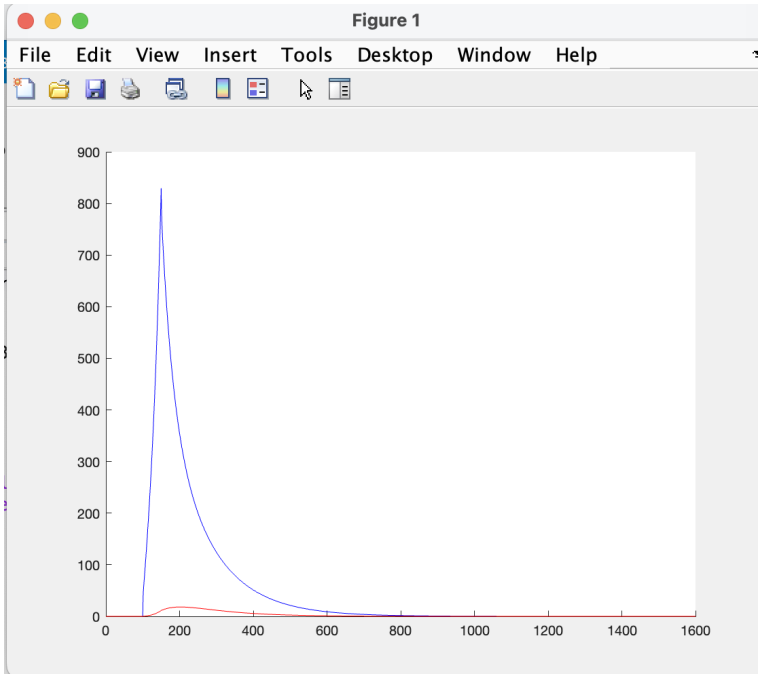
Figure

Appendix B (Q1 B)

```
function dx = hw3_q1(t,x)
dx = zeros(8,1);
k1 =507;
k7 = 81.9;
k13 = 40;
k15 = 464;
k2 = 3.9 * 10^(-3);
k4 = 5.8 * 10^(-3);
k6 = 0.21;
k8 =  3.9 * 10^(-3);
k10 = 5.8 * 10^(-3);
k12 = 0.21;
k14 = 1 * 10^(-3);
k16 = 1.16 * 10^(-2);
k18 = 1.16 * 10^(-2);
```

```
k19 = 1.73 * 10^(-2);
k3 = 1 * 10^(-5);
k5 = 5 * 10^(-4);
k9 = 5.8 * 10^(-6);
k11 = 5 * 10^(-4);
k17 = 3 * 10^(-4);
I = 112;
%x(1) = [C8](t)
%x(2) = [C8*](t)
%x(3) = [C3](t)
%x(4) = [C3*](t)
%x(5) = [BAR](t) inhibitor
%x(6) = [IAP](t) inhibitor
%x(7) = [C8*BAR](t)
%x(8) = [C3*IAP](t)
if t > 100 && t < 150
   I = 200;
else
   I = 0;
end
dx(1) = k1 - k2*x(1) - k3*(x(4) + I) * x(1);
dx(2) = k3*(x(4) + I) * x(1) - k4*x(2) - k5*x(2) * x(5) + k6*x(7);
dx(3) = k7 - k8*x(3) - k9*x(2) * x(3);
dx(4) = k9*x(2) * x(3) - k10*x(4) - k11*x(4) * x(6) + k12*x(8);
dx(5) = k13 -k5*x(2) * x(5) + k6*x(7) - k14*x(5);
dx(6) = k15 - k11*x(4) * x(6) + k12*x(8) - (k16 + k17*x(4)) * x(6);
dx(7) = k5*x(2) * x(5) - k6*x(7) - k18*x(7);
dx(8) = k11*x(4) * x(6) - k12*x(8) - k19*x(8);

clear
[T,X] = ode45(@hw3_q1, [0:1600], [0 0 0 0 0 0 0 0]);
%random
figure(1)
hold on
plot(T, X(:,2),'blue');
plot(T, X(:,4),'red');
```



Figure

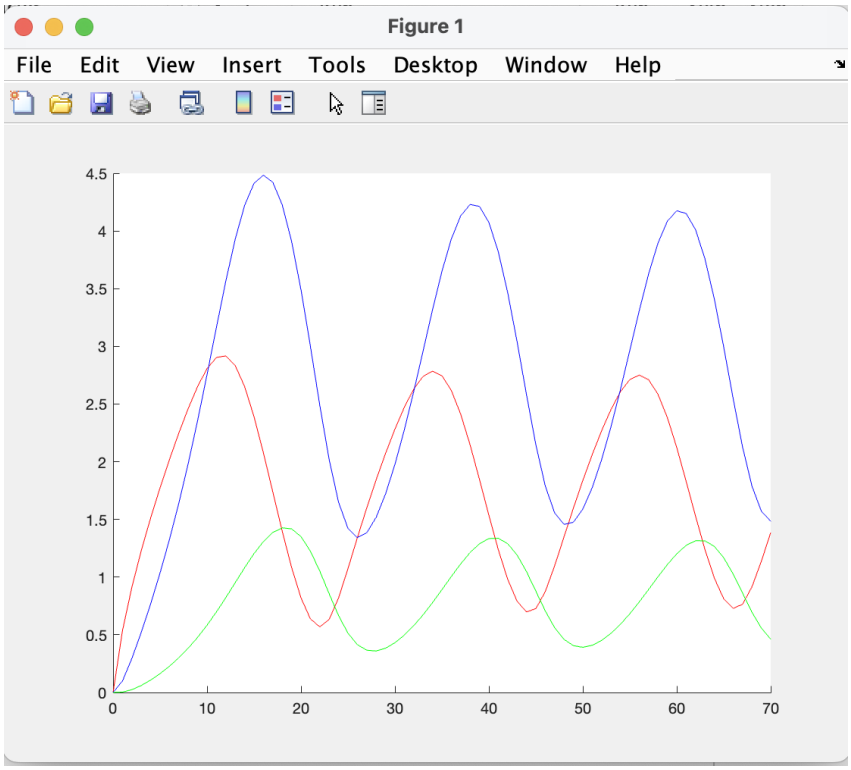
I changed the t < 1200 to t < 150 and disrupted apoptosis in the experiment. If the t is between t > 100 and t < 1200, then the I= 200 and if the t is between t > 100 and t < 150 then the I = 200, but that's a more narrow window. If the concentration changes from I = 200 to I = 0, then the inhibitor is stronger and prevents apoptosis from occurring.

Appendix C (Q2 A)

```
function dx = hw3_q2(t,x)
dx = zeros(5,1);
vs =0.76;
vm = 0.65;
vd = 0.95;
ks = 0.38;
k1 = 1.9;
k2 = 1.3;
V1 = 3.2;
V2 = 1.58;
V3 = 5;
V4 = 2.5;
K1 = 1;
K2 = 1;
K3 = 2;
K4 = 2;
Ki = 1;
```

```
Km1 = 0.5;
Kd = 0.2;
n = 4;
%x(1)= m(t)
%x(2)= p0(t);
%x(3)= p1(t);
%x(4)= p2(t);
%x(5)= pN(t);
dx(1) = ((vs) / (1 + (x(5) / Ki)^(n))) - ((vm*x(1)) / (Km1 + x(1)));
dx(2) = ks*x(1) - ((V1*x(2)) / (K1 + x(2))) + ((V2*x(3)) / (K2 + x(3)));
dx(3) = ((V1*x(2)) / (K1 + x(2))) - ((V2*x(3)) / (K2 + x(3))) - ((V3*x(3)) /
(K3 + x(3))) + ((V4*x(4)) / (K4 + x(4)));
dx(4) = ((V3*x(3)) / (K3 + x(3))) - ((V4*x(4)) / (K4 + x(4))) - k1*x(4) +
k2*x(5) - ((vd*x(4)) / (Kd + x(4)));
dx(5) = k1*x(4) - k2*x(5);

clear
[T,X] = ode45(@hw3_q2, [0:70], [0 0 0 0 0]);
Pt = X(:,2) + X(:,3) + X(:,4) + X(:,5);
%random
figure(1)
hold on
plot(T, X(:,1),'red');
plot(T, Pt,'blue');
plot(T, X(:,5),'green');
```



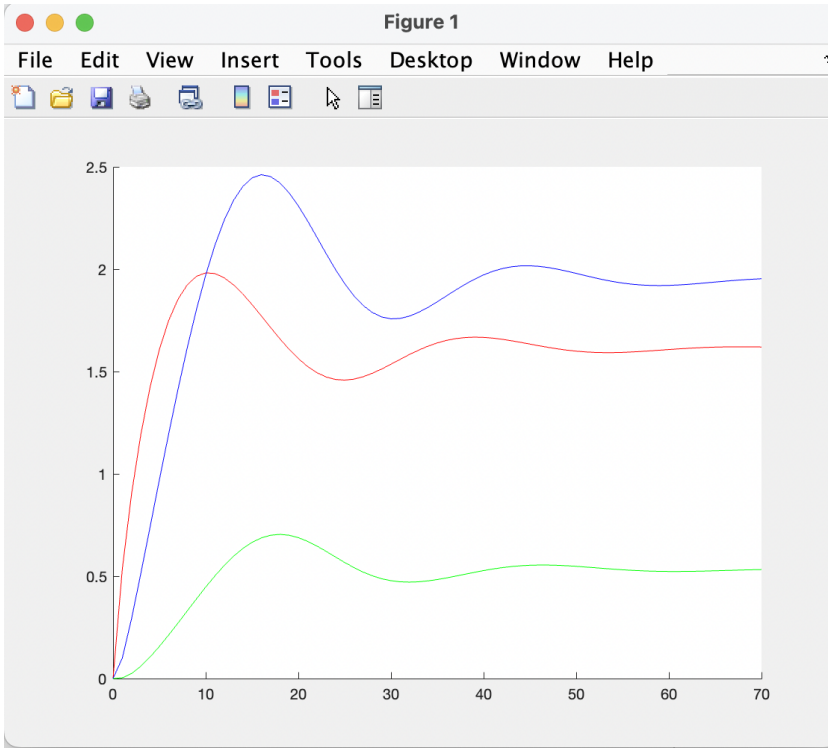
Figure

Appendix D (Q2 B)

When n = 1

```
function dx = hw3_q2(t,x)
dx = zeros(5,1);
vs =0.76;
vm = 0.65;
vd = 0.95;
ks = 0.38;
k1 = 1.9;
k2 = 1.3;
V1 = 3.2;
V2 = 1.58;
V3 = 5;
V4 = 2.5;
K1 = 1;
K2 = 1;
K3 = 2;
K4 = 2;
Ki = 1;
Km1 = 0.5;
Kd = 0.2;
n = 1;
%x(1)= m(t)
%x(2)= p0(t);
%x(3)= p1(t);
%x(4)= p2(t);
%x(5)= pN(t);
dx(1) = ((vs) / (1 + (x(5) / Ki)^(n))) - ((vm*x(1)) / (Km1 + x(1)));
dx(2) = ks*x(1) - ((V1*x(2)) / (K1 + x(2))) + ((V2*x(3)) / (K2 + x(3)));
dx(3) = ((V1*x(2)) / (K1 + x(2))) - ((V2*x(3)) / (K2 + x(3))) - ((V3*x(3)) /
(K3 + x(3))) + ((V4*x(4)) / (K4 + x(4)));
dx(4) = ((V3*x(3)) / (K3 + x(3))) - ((V4*x(4)) / (K4 + x(4))) - k1*x(4) +
k2*x(5) - ((vd*x(4)) / (Kd + x(4)));
dx(5) = k1*x(4) - k2*x(5);

clear
[T,X] = ode45(@hw3_q2, [0:70], [0 0 0 0 0]);
Pt = X(:,2) + X(:,3) + X(:,4) + X(:,5);
%random
figure(1)
hold on
plot(T, X(:,1),'red');
plot(T, Pt,'blue');
plot(T, X(:,5),'green');
```



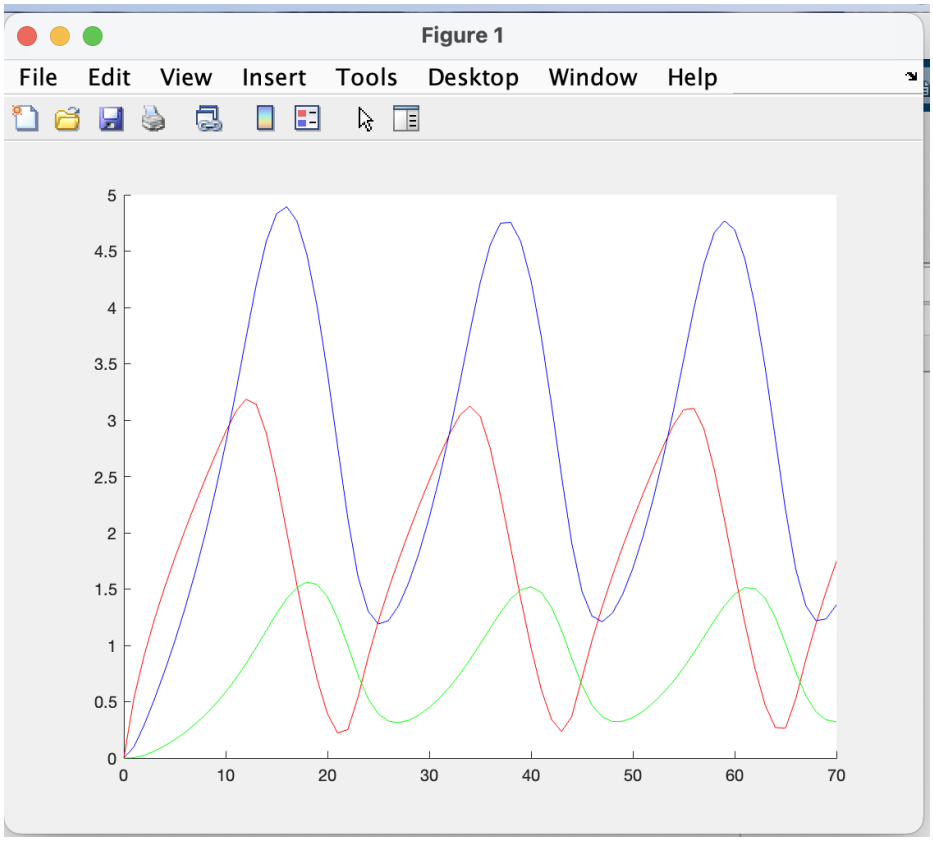
Figure

When n = 8

```
function dx = hw3_q2(t,x)
dx = zeros(5,1);
vs =0.76;
vm = 0.65;
vd = 0.95;
ks = 0.38;
k1 = 1.9;
k2 = 1.3;
V1 = 3.2;
V2 = 1.58;
V3 = 5;
V4 = 2.5;
K1 = 1;
K2 = 1;
K3 = 2;
K4 = 2;
Ki = 1;
Km1 = 0.5;
Kd = 0.2;
n = 8;
%x(1)= m(t)
%x(2)= p0(t);
```

```
%x(3)= p1(t);
%x(4)= p2(t);
%x(5)= pN(t);
dx(1) = ((vs) / (1 + (x(5) / Ki)^(n))) - ((vm*x(1)) / (Km1 + x(1)));
dx(2) = ks*x(1) - ((V1*x(2)) / (K1 + x(2))) + ((V2*x(3)) / (K2 + x(3)));
dx(3) = ((V1*x(2)) / (K1 + x(2))) - ((V2*x(3)) / (K2 + x(3))) - ((V3*x(3)) /
(K3 + x(3))) + ((V4*x(4)) / (K4 + x(4)));
dx(4) = ((V3*x(3)) / (K3 + x(3))) - ((V4*x(4)) / (K4 + x(4))) - k1*x(4) +
k2*x(5) - ((vd*x(4)) / (Kd + x(4)));
dx(5) = k1*x(4) - k2*x(5);

clear
[T,X] = ode45(@hw3_q2, [0:70], [0 0 0 0 0]);
Pt = X(:,2) + X(:,3) + X(:,4) + X(:,5);
%random
figure(1)
hold on
plot(T, X(:,1),'red');
plot(T, Pt,'blue');
plot(T, X(:,5),'green');
```



Figure

Changing N does not affect period, the period remains about the same, meaning the period of circadian rhythm is not dependent on this cooperativity. This can be seen in the similarities between Figure , Figure, and Figure