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%% input function
close all;
clc;
clear all;
% finding the rate of glucose uptake from each transporter
%  $V_g = (V_{max} \cdot G_o^1) / (K_m + G_o)$ 
hill = @(S,Vmax, K, n) Vmax*S^n / (K^n + S^n); %hill equation. S is
the conc of Go
K1 = 6; % Glut1 Km in mM
K2 = 17; % Glut2 Km in mM
Vmax1 = 1059.54*(10^-3); % mM/min
Vmax2 = 3910.51*(10^-3); % mM/min
Vg1 = @(S) hill(S,Vmax1, K1 ,1); % Rate of glucose uptake for Glut1
Vg2 = @(S) hill(S,Vmax2,K2,1); % Rate of glucose uptake for Glut2
Vg1_2 = @(S) hill(S,Vmax1, K1 ,2); % Rate of glucose uptake for Glut1
Vg2_2 = @(S) hill(S,Vmax2,K2,2); % Rate of glucose uptake for Glut2
Vg1_3 = @(S) hill(S,Vmax1, K1 ,3); % Rate of glucose uptake for Glut1
Vg2_3 = @(S) hill(S,Vmax2,K2,3); % Rate of glucose uptake for Glut2
Vg1_4 = @(S) hill(S,Vmax1, K1 ,4); % Rate of glucose uptake for Glut1
Vg2_4 = @(S) hill(S,Vmax2,K2,4); % Rate of glucose uptake for Glut2
figure(1)
subplot(1,2,1)
hold on
fplot(Vg1, [0,100], 'LineWidth',4) % Hill equation plot for S=1:100
fplot(Vg2, [0,100], 'm', 'LineWidth',4)
legend({'GLUT1' , 'GLUT2'}, 'Location', 'northwest', 'FontSize', 24)
set(gca,'FontSize',24)
xlabel('Go [mM]','FontSize', 24)
ylabel('Rate [mM/min]','FontSize', 24)
title('n=1', 'FontSize', 28)
subplot(1,2,2)
hold on
fplot(Vg1, [0,20], 'LineWidth',4) %Hill equation plot for S=1:20
fplot(Vg2, [0,20], 'm', 'LineWidth',4)
%legend({'GLUT1' , 'GLUT2'}, 'Location', 'northwest', 'FontSize', 24)
set(gca,'FontSize',24)
xlabel('Go [mM]','FontSize', 24)
ylabel('Rate [mM/min]','FontSize', 24)
hold off
figure(2)
subplot(1,2,1)
hold on
fplot(Vg1_2, [0,100], 'LineWidth',4) % Hill equation plot for S=1:100
fplot(Vg2_2, [0,100], 'm', 'LineWidth',4)
%legend({'GLUT1' , 'GLUT2'}, 'Location', 'northwest', 'FontSize', 24)
set(gca,'FontSize',24)
xlabel('Go [mM]','FontSize', 24)
ylabel('Rate [mM/min]','FontSize', 24)
title('n=2','FontSize', 28)
subplot(1,2,2)

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hold on
fplot(Vg1_2, [0,20], 'LineWidth',4) %Hill equation plot for S=1:20
fplot(Vg2_2, [0,20], 'm', 'LineWidth',4)
%legend({'GLUT1' , 'GLUT2'}, 'Location', 'northwest', 'FontSize', 24)
set(gca,'FontSize',24)
xlabel('Go [mM]','FontSize', 24)
ylabel('Rate [mM/min]','FontSize', 24)
figure(3)
subplot(1,2,1)
hold on
fplot(Vg1_3, [0,100], 'LineWidth',4) % Hill equation plot for S=1:100
fplot(Vg2_3, [0,100], 'm', 'LineWidth',4)
%legend({'GLUT1' , 'GLUT2'}, 'Location', 'northwest', 'FontSize', 24)
set(gca,'FontSize',24)
xlabel('Go [mM]','FontSize', 24)
ylabel('Rate [mM/min]','FontSize', 24)
title('n=3','FontSize', 28)
subplot(1,2,2)
hold on
fplot(Vg1_3, [0,20], 'LineWidth',4) %Hill equation plot for S=1:20
fplot(Vg2_3, [0,20], 'm', 'LineWidth',4)
%legend({'GLUT1' , 'GLUT2'}, 'Location', 'northwest', 'FontSize', 24)
set(gca,'FontSize',24)
xlabel('Go [mM]','FontSize', 24)
ylabel('Rate [mM/min]','FontSize', 24)
figure(4)
subplot(1,2,1)
hold on
fplot(Vg1_4, [0,100], 'LineWidth',4) % Hill equation plot for S=1:100
fplot(Vg2_4, [0,100], 'm', 'LineWidth',4)
%legend({'GLUT1' , 'GLUT2'}, 'Location', 'northwest', 'FontSize', 24)
set(gca,'FontSize',24)
xlabel('Go [mM]','FontSize', 24)
ylabel('Rate [mM/min]','FontSize', 24)
title('n=4','FontSize', 28)
subplot(1,2,2)
hold on
fplot(Vg1_4, [0,20], 'LineWidth',4) %Hill equation plot for S=1:20
fplot(Vg2_4, [0,20], 'm', 'LineWidth',4)
%legend({'GLUT1' , 'GLUT2'}, 'Location', 'northwest', 'FontSize', 24)
set(gca,'FontSize',24)
xlabel('Go [mM]','FontSize', 24)
ylabel('Rate [mM/min]','FontSize', 24)
%input function calculation
% f(Gi) = Vg1 * G1 + Vg2 * G2
Vg11 = arrayfun(Vg1,0:1:100); % makes Vg to array from function
Vg21 = arrayfun(Vg2,0:1:100);
Vg11_2 = arrayfun(Vg1_2,0:1:100);
Vg21_2 = arrayfun(Vg2_2,0:1:100);
Vg11_3 = arrayfun(Vg1_3,0:1:100);

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Vg21_3 = arrayfun(Vg2_3,0:1:100);
Vg11_4 = arrayfun(Vg1_4,0:1:100);
Vg21_4 = arrayfun(Vg2_4,0:1:100);
Glut1 = [0:1:100]'; % Range of Glut1 concentration
Glut2 = [0:1:100]'; % Range of Glut2 concentration
G1 = Vg11 .* Glut1;
G2 = Vg21 .* Glut2;
G1_2 = Vg11_2 .* Glut1;
G2_2 = Vg21_2 .* Glut2;
G1_3 = Vg11_3 .* Glut1;
G2_3 = Vg21_3 .* Glut2;
G1_4 = Vg11_4 .* Glut1;
G2_4 = Vg21_4 .* Glut2;
Gi = G1 + G2;
Gi_2 = G1_2 + G2_2;
Gi_3 = G1_3 + G2_3;
Gi_4 = G1_4 + G2_4;
Gii = Gi(1:40,1:40); %zoom in to Gi 1:40
Gii_2 = Gi_2(1:40,1:40);
Gii_3 = Gi_3(1:40,1:40);
Gii_4 = Gi_4(1:40,1:40);
%makes 2D plot of the input function, where GLUT1 and GLUT2 are the x
and y
%axis, and the output is Gi
figure(5)
imagesc(Glut1,Glut2,Gi)
c=colorbar;
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
caxis([0 500]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('n=1', 'FontSize', 16)
hold on
[C,h] = contour(Gi,'LineColor','k');
clabel(C,h);
hold off
figure(6)
imagesc(Glut1,Glut2,Gi_2)
c=colorbar;
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
caxis([0 500]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('n=2', 'FontSize', 16)
hold on
[C,h] = contour(Gi_2,'LineColor','k');

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clabel(C,h);
hold off
figure(7)
imagesc(Glut1,Glut2,Gi_3)
c=colorbar;
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
caxis([0 500]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('n=3', 'FontSize', 16)
hold on
[C,h] = contour(Gi_3,'LineColor','k');
clabel(C,h);
hold off
figure(8)
imagesc(Glut1,Glut2,Gi_4)
c=colorbar;
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
caxis([0 500]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('n=4', 'FontSize', 16)
hold on
[C,h] = contour(Gi_4,'LineColor','k');
clabel(C,h);
hold off
figure(9)
imagesc(Glut1(1:40),Glut2(1:40),Gii)
c=colorbar;
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
caxis([0 190]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('n=1', 'FontSize', 16)
hold on
[C,h] = contour(Gii,'LineColor','k');
clabel(C,h);
hold off
figure(10)
imagesc(Glut1(1:40),Glut2(1:40),Gii_2)
c=colorbar;
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
caxis([0 190]);

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xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('n=2', 'FontSize', 16)
hold on
[C,h] = contour(Gii_2,'LineColor','k');
clabel(C,h);
hold off
figure(11)
imagesc(Glut1(1:40),Glut2(1:40),Gii_3)
c=colorbar;
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
caxis([0 190]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('n=3', 'FontSize', 16)
hold on
[C,h] = contour(Gii_3,'LineColor','k');
clabel(C,h);
hold off
figure(12)
imagesc(Glut1(1:40),Glut2(1:40),Gii_4)
c=colorbar;
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
caxis([0 190]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('n=4', 'FontSize', 16)
hold on
[C,h] = contour(Gii_4,'LineColor','k');
clabel(C,h);
hold off
%Same plot but in 3D
%figure(13)
%surf(Gi, 'LineStyle', 'none')
%ylabel('GLUT2 [mM]','FontSize', 14)
%zlabel('Gi [mM]','FontSize', 14)
%set(gca,'FontSize',14)
% looking at Gi level for specific Go values
s=[0, 2.8, 5, 10, 17, 20]; % vector of Go values
Vg1s = @(s) hill(s,Vmax1, K1 ,2); % Rate of glucose uptake for Glut1
Vg2s = @(s) hill(s,Vmax2,K2,2); % Rate of glucose uptake for Glut2
Vg11s = arrayfun(Vg1s,s);
Vg21s = arrayfun(Vg2s,s);
Glut1 = [0:1:100]'; % Range of Glut1 concentration
Glut2 = [0:1:100]'; % Range of Glut2 concentration

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G1s = ones(101,6);
G2s = ones(101,6);
Gis = ones(101,6);
for i = 1:length(s) %function to find input function for the
specified Go
    G1s(:,i) = Vg11s(i) .* Glut1;
    G2s(:,i) = Vg21s(i) .* Glut2;
    i = i+1;
end
Gis0 = G1s(:,1) +G2s(:,1);
Gis28 = G1s(:,2) +G2s(:,2);
Gis5 = G1s(:,3) +G2s(:,3);
Gis10 = G1s(:,4) +G2s(:,4);
Gis17 = G1s(:,5) +G2s(:,5);
Gis20 = G1s(:,6) +G2s(:,6);
% Finding the specifig Gi value per Go with specified GLUT1 and GLUT2
% values
GI01 = [5,5,5,5,5,5];
GI10 = [5,5,5,5,5,5];
GI50 = [5,5,5,5,5,5];
GI8020 = [5,5,5,5,5,5];
GI2080 = [5,5,5,5,5,5];
GI020 = [5,5,5,5,5,5];
GI80 = [5,5,5,5,5,5];
for i = 1:length(s)
    GI01(i) = Vg11s(i)*0 + Vg21s(i)*100; %rate of uptake*glut
concentration
    GI10(i) = Vg11s(i)*100 + Vg21s(i)*0;
    GI50(i) = Vg11s(i)*50 +Vg21s(i)*50;
    GI8020(i) = Vg11s(i)*80 + Vg21s(i)*20;
    GI2080(i) = Vg11s(i)*20 + Vg21s(i)*80;
    GI020(i) = Vg11s(i)*0 + Vg21s(i)*20;
    GI080(i) = Vg11s(i)*0 + Vg21s(i)*80;
    GI200(i) = Vg11s(i)*20 + Vg21s(i)*0;
    GI9011(i) = Vg11s(i)*90 + Vg21s(i)*11; %islets wt
    GI982(i) = Vg11s(i)*98 + Vg21s(i)*2; %islets wt
    GI980(i) = Vg11s(i)*98+ Vg21s(i)*0; %islets_no glut2
    GI012(i) = Vg11s(i)*0 + Vg21s(i)*11; %islets_no glut1
    GI02(i) = Vg11s(i)*0 + Vg21s(i)*2;
    GI3858(i) = Vg11s(i)*38 + Vg21s(i)*58; %scb wt
    GI380(i) = Vg11s(i)*38 + Vg21s(i)*0; %scb_no glut2
    GI058(i) = Vg11s(i)*0 + Vg21s(i)*58; %scb_no glut1
    GI1002(i) = Vg11s(i)*100 + Vg21s(i)*2;
    i=i+1;
end
cor= [-2 105; 92 5; 48 55; 78 25; 18 85];
figure(13)
imagesc(Glut1,Glut2,Gis0)
c=colorbar;
%brighten(0.4);

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c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
xlim([0 100])
caxis([-1 360]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('Go=0mM', 'FontSize', 16)
hold on
plot3(0,100,GI01(1), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(100,1,GI10(1), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(50,50,GI50(1), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(80,20,GI8020(1), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(20,80,GI2080(1), '*r', 'MarkerSize', 10, 'LineWidth', 2)
d = {GI01(1), GI10(1), GI50(1), GI8020(1), GI2080(1)};
text(cor(:,1), cor(:,2), d, 'FontSize', 14);
hold off
figure(14)
imagesc(Glut1,Glut2,Gis28)
c=colorbar;
%brighten(0.4);
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
xlim([0 100])
caxis([-1 360]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('Go=2.8mM', 'FontSize', 16)
hold on
plot3(0,100,GI01(2), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(100,1,GI10(2), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(50,50,GI50(2), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(80,20,GI8020(2), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(20,80,GI2080(2), '*r', 'MarkerSize', 10, 'LineWidth', 2)
d = {GI01(2), GI10(2), GI50(2), GI8020(2), GI2080(2)};
text(cor(:,1), cor(:,2), d, 'FontSize', 14);
hold off
figure(15)
imagesc(Glut1,Glut2,Gis5)
c=colorbar;
%brighten(0.4);
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
xlim([0 100])
caxis([-1 360]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('Go=5mM', 'FontSize', 16)

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hold on
plot3(0,100,GI01(3), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(100,1,GI10(3), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(50,50,GI50(3), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(80,20,GI8020(3), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(20,80,GI2080(3), '*r', 'MarkerSize', 10, 'LineWidth', 2)
d = {GI01(3), GI10(3), GI50(3), GI8020(3), GI2080(3)};
text(cor(:,1), cor(:,2), d, 'FontSize', 14);
hold off
figure(16)
imagesc(Glut1,Glut2,Gis10)
c=colorbar;
%brighten(0.4);
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
xlim([0 100])
caxis([-1 360]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('Go=10mM', 'FontSize', 16)
hold on
plot3(0,100,GI01(4), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(100,1,GI10(4), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(50,50,GI50(4), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(80,20,GI8020(4), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(20,80,GI2080(4), '*r', 'MarkerSize', 10, 'LineWidth', 2)
d = {GI01(4), GI10(4), GI50(4), GI8020(4), GI2080(4)};
text(cor(:,1), cor(:,2), d, 'FontSize', 14);
hold off
figure(17)
imagesc(Glut1,Glut2,Gis17)
c=colorbar;
%brighten(0.4);
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
xlim([0 100])
caxis([-1 360]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('Go=17mM', 'FontSize', 16)
hold on
plot3(0,100,GI01(5), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(100,1,GI10(5), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(50,50,GI50(5), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(80,20,GI8020(5), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(20,80,GI2080(5), '*r', 'MarkerSize', 10, 'LineWidth', 2)
d = {GI01(5), GI10(5), GI50(5), GI8020(5), GI2080(5)};
text(cor(:,1), cor(:,2), d, 'FontSize', 14);

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hold off
figure(18)
imagesc(Glut1,Glut2,Gis20)
c=colorbar;
%brighten(0.4);
c.Label.String='Gi [mM]','FontSize', 14;
set(gca,'YDir','normal');
xlim([0 100])
caxis([-1 360]);
xlabel('GLUT1 [nM]','FontSize', 14)
ylabel('GLUT2 [nM]','FontSize', 14)
set(gca,'FontSize',14)
title('Go=20mM', 'FontSize', 16)
hold on
plot3(0,100,GI01(6), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(100,1,GI10(6), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(50,50,GI50(6), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(80,20,GI8020(6), '*r', 'MarkerSize', 10, 'LineWidth', 2)
plot3(20,80,GI2080(6), '*r', 'MarkerSize', 10, 'LineWidth', 2)
d = {GI01(6), GI10(6), GI50(6), GI8020(6), GI2080(6)};
text(cor(:,1), cor(:,2), d, 'FontSize', 14);
hold off

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