```
#####################################
# Thalassemia Model Source Code
# Supplementary Material
#####################################
require(FME)
require(deSolve)
library(RColorBrewer)
library(broman)
# plot_crayons()

color_name<-c(brocolors("crayons")["Pine Green"], #1
        brocolors("crayons")["Jungle Green"],#2
        brocolors("crayons")["Yellow"], #3
        brocolors("crayons")["Goldenrod"],#4
        brocolors("crayons")["Maize"],#5
        brocolors("crayons")["Red"], #6
        brocolors("crayons")["Maroon"], #7
        brocolors("crayons")["Salmon"], #8
        brocolors("crayons")["Wild Blue Yonder"], #9
        brocolors("crayons")["Indigo"], #10
        brocolors("crayons")["Violet Blue"], #11
        brocolors("crayons")["Cornflower"], #12
        brocolors("crayons")["Navy Blue"], #13
        brocolors("crayons")["Cerulean"], #14
        brocolors("crayons")["Blue Green"], #15
        brocolors("crayons")["Blizzard Blue"], #16
        brocolors("crayons")["Sky Blue"], #17
        brocolors("crayons")["Magic Mint"], #18
        brocolors("crayons")["Mango Tango"], #19 #prs1
        brocolors("crayons")["Red Violet"], #20  #prs2
        brocolors("crayons")["Hot Magenta"],#21  #prs3
        brocolors("crayons")["Raw Umber"], #22   #prs4
        brocolors("crayons")["Royal Purple"],#23 #prs5
        brocolors("crayons")["Sepia"],#24        #prs6
        brocolors("crayons")["Screamin' Green"],#25 #prs7
        brocolors("crayons")["Eggplant"],#26        #prs8
        brocolors("crayons")["Outer Space"],#27    #prs9
        brocolors("crayons")["Hot Magenta"], #28
        brocolors("crayons")["Caribbean Green"],#29
        brocolors("crayons")["Royal Purple"],#30
        brocolors("crayons")["Wild Strawberry"]) #31

#++++++++++++++++++++++++++++++++++++++++++++++
#     Changing certain parameters
```

```
#++++++++++++++++++++++++++++++++++++++++++++++++
#####################################
# Thalassemia function2
#####################################
Thalassemia2<-function(pars,yr,bM=8716,gM=7954,etaMT=0.0083, etaFT=0.0075,
etaMC=1/24,etaFC=1.3/24,
                    gamma_M=0.0433, gamma_F = 0.0447, betaM=1,betaF=1,
                    dc_M = 0.014,dc_F = 0.008,d_T=0.016, d_M=0.0030,d_F=0.0019,
mu=0.0091,
                    alphaMS=0.0227,alphaFS=0.0223){
  derivs<-function(t,state,pars){
    with(as.list(c(state,pars)),{
      U<-U1+U2+U3
      zeta1<-U3/U
      zeta2<-(U2+U3)/U


      dG_M<- bM-zeta1*etaMT*betaM*G_M-zeta2*etaMC*betaM*G_M-gamma_M*G_M -
dc_M*G_M
      dG_F<- gM-zeta1*etaFT*betaF*G_F-zeta2*etaFC*betaF*G_F-gamma_F*G_F-
dc_F*G_F

      dG_CM<-zeta2*etaMC*betaM*G_M-gamma_M*G_CM - dc_M*G_CM
      dG_CF<-zeta2*etaFC*betaF*G_F-gamma_F*G_CF- dc_F*G_CF

      dT_M<- zeta1*etaMT*betaM*G_M-d_T*T_M #-0.25*r
      dT_F<- zeta1*etaFT*betaF*G_F-d_T*T_F #-0.25*r

      dS_M<- gamma_M*G_M - (alphaMS+d_M)*S_M
      dS_F<- gamma_F*G_F -(alphaFS+d_F)*S_F

      dC_M<- gamma_M*G_CM-alphaMS*C_M+nu*(1-ep2)*alphaMS*C_M-d_M*C_M
      dC_F<- gamma_F*G_CF-alphaFS*C_F+nu*(1-ep2)*alphaFS*C_F-d_F*C_F

      dU1<-(1-ep1)*(alphaMS*S_M+alphaFS*S_F)-mu*U1
      dU2<-ep1*(alphaMS*S_M+alphaFS*S_F)+ep2*(alphaMS*C_M+alphaFS*C_F)-
mu*U2
      dU3<-(1-nu)*(1-ep2)*(alphaMS*C_M+alphaFS*C_F)-mu*U3

      return(list(c(dG_M, dG_F,dG_CM,dG_CF, dT_M, dT_F, dS_M,dS_F,
dC_M,dC_F,dU1, dU2,
dU3),H=G_M+G_F+G_CM+G_CF+T_M+T_F+S_M+S_F+C_M+C_F+U1+U2+U3))
      #   (1,    2,    3,   4,    5,    6,    7,    8,    9,    10, 11, 12,   13)
    })
```

```
  }
  #state<-c(G_M=10,G_F=10, T_M=10, T_F=10,S_M=1000,S_EM=0,S_AEM=0,
C_AEM=0, S_AM=300,C_AM=100, S_F=1000, S_EF=0, S_AEF=0, C_AEF=0,
S_AF=300, C_AF=100, M=10,r=1 )
  # state<-c(G_M=1604,G_F=1535, T_M=25,
T_F=24,S_M=80000,S_EM=20000,S_AEM=450, C_AEM=45, S_AM=1800,C_AM=150,
S_F=80000, S_EF=20000, S_AEF=440, C_AEF=36, S_AF=1700, C_AF=140, M=1500)
  state<-
c(G_M=160400,G_F=153500,G_CM=160400,G_CF=153500,T_M=120,T_F=100,S_M=
100000,S_F= 100000,C_M= 85000, C_F=90000,
        U1=15000,U2=30000,U3=5000)

  times<- seq(0,yr,by=0.1)
  return(as.data.frame(lsode(y=state,times=times,func=derivs,parms=pars)))
}


yr<-100;
############################################
# Changing nu: Marriage recondieration rate
############################################
Thal_M=NULL;Thal_F=NULL;
Carr_M=NULL;Carr_F=NULL;
Nor_M=NULL ;Nor_F=NULL;
U1=NULL;U2=NULL;U3=NULL;

#GCarr_M=NULL; GCarr_F=NULL;
for(i in seq(0.1,1,0.1)){
  pars<-list(ep1 = 0.5, ep2=0.5,nu=i)
  out2<-Thalassemia2(pars,yr)
  Thal_M=cbind(Thal_M,out2[,6]);
  Thal_F=cbind(Thal_F,out2[,7]);
#  GCarr_M=cbind(GCarr_M,out2[,4]);
#  GCarr_F=cbind(GCarr_F,out2[,5]);
  Carr_M=cbind(Carr_M,out2[,10]);
  Carr_F=cbind(Carr_F,out2[,11]);
  Nor_M=cbind(Nor_M,out2[,8]);
  Nor_F=cbind(Nor_F,out2[,9]);
  U1=cbind(U1,out2[,12]);
  U2=cbind(U2,out2[,13]);
  U3=cbind(U3,out2[,14]);
}

#------------------------------
```

```
#thalassima male
#-------------------------------
matplot(x = out2[,1], y = Thal_M[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(T[M]," with various
",nu,sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(nu,"=0.2")),
                  expression(paste(nu,"=0.4")),
                  expression(paste(nu,"=0.6")),
                  expression(paste(nu,"=0.8")),
                  expression(paste(nu,"=1"))),
       lwd = 3,cex=1.2,bty="n")


## U1
matplot(x = out2[,1], y = U1[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(U[1]," with various
",nu,sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(nu,"=0.2")),
                  expression(paste(nu,"=0.4")),
                  expression(paste(nu,"=0.6")),
                  expression(paste(nu,"=0.8")),
                  expression(paste(nu,"=1"))),
       lwd = 3,cex=1.2,bty="n")


## U2
matplot(x = out2[,1], y = U2[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(U[2]," with various
",nu,sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(nu,"=0.2")),
                  expression(paste(nu,"=0.4")),
                  expression(paste(nu,"=0.6")),
                  expression(paste(nu,"=0.8")),
                  expression(paste(nu,"=1"))),
       lwd = 3,cex=1.2,bty="n")


## U3
```

```
matplot(x = out2[,1], y = U3[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(U[3]," with various
",nu,sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(nu,"=0.2")),
                  expression(paste(nu,"=0.4")),
                  expression(paste(nu,"=0.6")),
                  expression(paste(nu,"=0.8")),
                  expression(paste(nu,"=1"))),
       lwd = 3,cex=1.2,bty="n")


## CM
matplot(x = out2[,1], y = Carr_M[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(C[M]," with various
",nu,sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("bottomright", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(nu,"=0.2")),
                  expression(paste(nu,"=0.4")),
                  expression(paste(nu,"=0.6")),
                  expression(paste(nu,"=0.8")),
                  expression(paste(nu,"=1"))),
       lwd = 3,cex=1.2,bty="n")


####################################################
# Changing ep1: Chance of normal-to-carrier marriage
####################################################
Thal_M=NULL;Thal_F=NULL;
Carr_M=NULL;Carr_F=NULL;
Nor_M=NULL ;Nor_F=NULL;
U1=NULL;U2=NULL;U3=NULL;
for(i in seq(0.1,1,0.1)){
  pars<-list(ep1 = i, ep2=0.2,nu=0.3)
  out2<-Thalassemia2(pars,yr)
  Thal_M=cbind(Thal_M,out2[,6]);
  Thal_F=cbind(Thal_F,out2[,7]);
#  GCarr_M=cbind(GCarr_M,out2[,4]);
#  GCarr_F=cbind(GCarr_F,out2[,5]);
  Carr_M=cbind(Carr_M,out2[,10]);
  Carr_F=cbind(Carr_F,out2[,11]);
  Nor_M=cbind(Nor_M,out2[,8]);
```

```
  Nor_F=cbind(Nor_F,out2[,9]);
  U1=cbind(U1,out2[,12]);
  U2=cbind(U2,out2[,13]);
  U3=cbind(U3,out2[,14]);
}

#------------------------------
#thalassima male
#------------------------------
matplot(x = out2[,1], y = Thal_M[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(T[M]," with various
",epsilon[1],sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(epsilon[1],"=0.2")),
                  expression(paste(epsilon[1],"=0.4")),
                  expression(paste(epsilon[1],"=0.6")),
                  expression(paste(epsilon[1],"=0.8")),
                  expression(paste(epsilon[1],"=1"))),
       lwd = 3,cex=1.2,bty="n")

## U1
matplot(x = out2[,1], y = U1[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(U[1]," with various
",epsilon[1],sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(epsilon[1],"=0.2")),
                  expression(paste(epsilon[1],"=0.4")),
                  expression(paste(epsilon[1],"=0.6")),
                  expression(paste(epsilon[1],"=0.8")),
                  expression(paste(epsilon[1],"=1"))),
       lwd = 3,cex=1.2,bty="n")

## U2
matplot(x = out2[,1], y = U2[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(U[2]," with various
",epsilon[1],sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(epsilon[1],"=0.2")),
                  expression(paste(epsilon[1],"=0.4")),
                  expression(paste(epsilon[1],"=0.6")),
                  expression(paste(epsilon[1],"=0.8")),
```

```
                expression(paste(epsilon[1],"=1"))),
       lwd = 3,cex=1.2,bty="n")

## U3
matplot(x = out2[,1], y = U3[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(U[3]," with various
",epsilon[1],sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(epsilon[1],"=0.2")),
                expression(paste(epsilon[1],"=0.4")),
                expression(paste(epsilon[1],"=0.6")),
                expression(paste(epsilon[1],"=0.8")),
                expression(paste(epsilon[1],"=1"))),
       lwd = 3,cex=1.2,bty="n")

## CM
matplot(x = out2[,1], y = Carr_M[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(C[M]," with various
",epsilon[1],sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("bottomright", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(epsilon[1],"=0.2")),
                expression(paste(epsilon[1],"=0.4")),
                expression(paste(epsilon[1],"=0.6")),
                expression(paste(epsilon[1],"=0.8")),
                expression(paste(epsilon[1],"=1"))),
       lwd = 3,cex=1.2,bty="n")


###################################################
# Changing ep2: Chance of carrier-to-normal marriage
###################################################
Thal_M=NULL;Thal_F=NULL;
Carr_M=NULL;Carr_F=NULL;
Nor_M=NULL ;Nor_F=NULL;
U1=NULL;U2=NULL;U3=NULL;
for(i in seq(0.1,1,0.1)){
  pars<-list(ep1 = 0.2, ep2=i,nu=0.3)
  out2<-Thalassemia2(pars,yr)
  Thal_M=cbind(Thal_M,out2[,6]);
  Thal_F=cbind(Thal_F,out2[,7]);
#  GCarr_M=cbind(GCarr_M,out2[,4]);
#  GCarr_F=cbind(GCarr_F,out2[,5]);
```

```
  Carr_M=cbind(Carr_M,out2[,10]);
  Carr_F=cbind(Carr_F,out2[,11]);
  Nor_M=cbind(Nor_M,out2[,8]);
  Nor_F=cbind(Nor_F,out2[,9]);
  U1=cbind(U1,out2[,12]);
  U2=cbind(U2,out2[,13]);
  U3=cbind(U3,out2[,14]);
}
#-------------------------------
#thalassima male
#-------------------------------
matplot(x = out2[,1], y = Thal_M[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(T[M]," with various
",epsilon[2],sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(epsilon[2],"=0.2")),
                  expression(paste(epsilon[2],"=0.4")),
                  expression(paste(epsilon[2],"=0.6")),
                  expression(paste(epsilon[2],"=0.8")),
                  expression(paste(epsilon[2],"=1"))),
       lwd = 3,cex=1.2,bty="n")

## U1
matplot(x = out2[,1], y = U1[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(U[1]," with various
",epsilon[2],sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(epsilon[2],"=0.2")),
                  expression(paste(epsilon[2],"=0.4")),
                  expression(paste(epsilon[2],"=0.6")),
                  expression(paste(epsilon[2],"=0.8")),
                  expression(paste(epsilon[2],"=1"))),
       lwd = 3,cex=1.2,bty="n")

## U2
matplot(x = out2[,1], y = U2[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(U[2]," with various
",epsilon[2],sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(epsilon[2],"=0.2")),
                  expression(paste(epsilon[2],"=0.4")),
```

```
            expression(paste(epsilon[2],"=0.6")),
            expression(paste(epsilon[2],"=0.8")),
            expression(paste(epsilon[2],"=1"))),
       lwd = 3,cex=1.2,bty="n")

## U3
matplot(x = out2[,1], y = U3[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(U[3]," with various
",epsilon[2],sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topleft", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(epsilon[2],"=0.2")),
            expression(paste(epsilon[2],"=0.4")),
            expression(paste(epsilon[2],"=0.6")),
            expression(paste(epsilon[2],"=0.8")),
            expression(paste(epsilon[2],"=1"))),
       lwd = 3,cex=1.2,bty="n")
## Generating tiff file
file_name<-paste("Figures/Varying/U3_ep2",sep="")
dev.copy(tiff,paste(file_name,".tif",sep=""),width = 6, height = 5.5, units = 'in', res = 300,
compression = 'lzw')
dev.off()
## Generating png file
dev.copy(png,paste(file_name,".png",sep=""),width = 6, height = 5.5, units = 'in', res =
300)
dev.off()
## Generating jpg file
dev.copy(jpeg,paste(file_name,".jpg",sep=""),width = 6, height = 5.5, units = 'in', res =
300)
dev.off()


## CM
matplot(x = out2[,1], y = Carr_M[,c(2,4,6,8,10)], type = "l", lwd = 4,
        lty = "solid", col =c(1,brewer.pal(n=6,name="Dark2")),
        xlab = "years", ylab = "Population", main=expression(paste(C[M]," with various
",epsilon[2],sep="")),cex.axis=1.7,cex.lab=1.7,cex.main=1.7)
legend("topright", col = c(1,brewer.pal(n=6,name="Dark2")),
       legend = c(expression(paste(epsilon[2],"=0.2")),
            expression(paste(epsilon[2],"=0.4")),
            expression(paste(epsilon[2],"=0.6")),
            expression(paste(epsilon[2],"=0.8")),
            expression(paste(epsilon[2],"=1"))),
       lwd = 3,cex=1.2,bty="n")
```

```
#+++++++++++++++++++++++++++++++++++++++++++#
#       Sensitivity analysis
#+++++++++++++++++++++++++++++++++++++++++++#
pars2<-list(ep1 = 0.4, ep2=0.9,nu=0.1,etaMT=0.0083, etaFT=0.0075,
etaMC=1/24,etaFC=1.3/24,
          gamma_M=0.0433, gamma_F = 0.0447,alphaMS=0.0227,alphaFS=0.0223)
Thalassemia2<-function(pars2,yr=100,bM=8716,gM=7954, betaM=1,betaF=1,
                     dc_M = 0.014,dc_F = 0.008,d_T=0.016, d_M=0.0030,d_F=0.0019,
mu=0.0091){
  derivs<-function(t,state,pars){
    with(as.list(c(state,pars)),{
      U<-U1+U2+U3
      zeta1<-U3/U
      zeta2<-(U2+U3)/U

      dG_M<- bM-zeta1*etaMT*betaM*G_M-zeta2*etaMC*betaM*G_M-gamma_M*G_M -
dc_M*G_M
      dG_F<- gM-zeta1*etaFT*betaF*G_F-zeta2*etaFC*betaF*G_F-gamma_F*G_F-
dc_F*G_F

      dG_CM<-zeta2*etaMC*betaM*G_M-gamma_M*G_CM - dc_M*G_CM
      dG_CF<-zeta2*etaFC*betaF*G_F-gamma_F*G_CF- dc_F*G_CF

      dT_M<- zeta1*etaMT*betaM*G_M-d_T*T_M #-0.25*r
      dT_F<- zeta1*etaFT*betaF*G_F-d_T*T_F #-0.25*r

      dS_M<- gamma_M*G_M - (alphaMS+d_M)*S_M
      dS_F<- gamma_F*G_F -(alphaFS+d_F)*S_F

      dC_M<- gamma_M*G_CM-alphaMS*C_M+nu*(1-ep2)*alphaMS*C_M-d_M*C_M
      dC_F<- gamma_F*G_CF-alphaFS*C_F+nu*(1-ep2)*alphaFS*C_F-d_F*C_F

      dU1<-(1-ep1)*(alphaMS*S_M+alphaFS*S_F)-mu*U1
      dU2<-ep1*(alphaMS*S_M+alphaFS*S_F)+ep2*(alphaMS*C_M+alphaFS*C_F)-
mu*U2
      dU3<-(1-nu)*(1-ep2)*(alphaMS*C_M+alphaFS*C_F)-mu*U3

      return(list(c(dG_M, dG_F,dG_CM,dG_CF, dT_M, dT_F, dS_M,dS_F,
dC_M,dC_F,dU1, dU2,
dU3),H=G_M+G_F+G_CM+G_CF+T_M+T_F+S_M+S_F+C_M+C_F+U1+U2+U3))
      #   (1,    2,    3,   4,    5,    6,    7,    8,    9,    10, 11, 12,   13)
```

```
    })
  }
  state<-
c(G_M=160400,G_F=153500,G_CM=160400,G_CF=153500,T_M=120,T_F=100,S_M=
100000,S_F= 100000,C_M= 85000, C_F=90000,
          U1=15000,U2=30000,U3=5000)

  times<- seq(0,yr,by=0.1)
  return(as.data.frame(lsode(y=state,times=times,func=derivs,parms=pars2)))
}
SnsC_M<-sensFun(func=Thalassemia2,parms=pars2, sensvar="C_M",varscale=1)
summary(SnsC_M)

SnsC_F<-sensFun(func=Thalassemia2,parms=pars2, sensvar="C_F",varscale=1)
summary(SnsC_F)

SnsS_M<-sensFun(func=Thalassemia2,parms=pars2, sensvar="S_M",varscale=1)
summary(SnsS_M)

SnsS_F<-sensFun(func=Thalassemia2,parms=pars2, sensvar="S_F",varscale=1)
summary(SnsS_F)

SnsT_F<-sensFun(func=Thalassemia2,parms=pars2, sensvar="T_F",varscale=1)
summary(SnsT_F)

SnsT_M<-sensFun(func=Thalassemia2,parms=pars2, sensvar="T_M",varscale=1)
summary(SnsT_M)

SnsU1<-sensFun(func=Thalassemia2,parms=pars2, sensvar="U1",varscale=1)
summary(SnsU1)

SnsU2<-sensFun(func=Thalassemia2,parms=pars2, sensvar="U2",varscale=1)
summary(SnsU2)

SnsU3<-sensFun(func=Thalassemia2,parms=pars2, sensvar="U3",varscale=1)
summary(SnsU3)

SnsG_M<-sensFun(func=Thalassemia2,parms=pars2, sensvar="G_M",varscale=1)
summary(SnsG_M)

SnsG_F<-sensFun(func=Thalassemia2,parms=pars2, sensvar="G_F",varscale=1)
summary(SnsG_F)

SnsG_CM<-sensFun(func=Thalassemia2,parms=pars2, sensvar="G_CM",varscale=1)
```

```
summary(SnsG_CM)

SnsG_CF<-sensFun(func=Thalassemia2,parms=pars2, sensvar="G_CF",varscale=1)
summary(SnsG_CF)


#####################################
# Box Plots of Sensitivity
#####################################
# Soring absolute impact of parameters on the variables
xx=list();sig_par=list();
k=1;
xx[[k]]<-sort(abs(summary(SnsC_M)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsC_M)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

k=2;
xx[[k]]<-sort(abs(summary(SnsC_F)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsC_F)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

k=3;
xx[[k]]<-sort(abs(summary(SnsS_M)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsS_M)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

k=4;
xx[[k]]<-sort(abs(summary(SnsS_F)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsS_F)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

k=5;
xx[[k]]<-sort(abs(summary(SnsT_M)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsT_M)$Mean[as.matrix(xx[[k]]$ix)])
```

```
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

k=6;
xx[[k]]<-sort(abs(summary(SnsT_F)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsT_F)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

## New
k=7;
xx[[k]]<-sort(abs(summary(SnsU1)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsU1)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

k=8;
xx[[k]]<-sort(abs(summary(SnsU2)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsU2)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

k=9;
xx[[k]]<-sort(abs(summary(SnsU3)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsU3)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

k=10;
xx[[k]]<-sort(abs(summary(SnsG_M)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsG_M)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

k=11;
xx[[k]]<-sort(abs(summary(SnsG_F)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsG_F)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];
```

```
k=12;
xx[[k]]<-sort(abs(summary(SnsG_CM)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsG_CM)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

k=13;
xx[[k]]<-sort(abs(summary(SnsG_CF)$Mean),decreasing=TRUE,index.return=TRUE);
xx[[k]]$ix;
sig_par[[k]]<-
cbind(names(pars2)[xx[[k]]$ix],summary(SnsG_CF)$Mean[as.matrix(xx[[k]]$ix)])
colnames(sig_par[[k]])=c("Pars","SensMean");sig_par[[k]];

## Check common parameters of sensitivity (Change this)
Par_rankx<-NULL;
Par_rankx<-
t(rbind(xx[[1]]$ix,xx[[2]]$ix,xx[[3]]$ix,xx[[4]]$ix,xx[[5]]$ix,xx[[6]]$ix,xx[[7]]$ix,xx[[8]]$ix,xx[[9
]]$ix,xx[[10]]$ix,xx[[11]]$ix,xx[[12]]$ix,xx[[13]]$ix));
colnames(Par_rankx)=c("C_M","C_F","S_M","S_F","T_M","T_F","U1","U2","U3","G_M","
G_F","G_CM","G_CF");
Par_rankx+2;

Q1<-SnsC_M
Q2<-SnsC_F
Q3<-SnsS_M
Q4<-SnsS_F
Q5<-SnsT_M
Q6<-SnsT_F
Q7<-SnsU1
Q8<-SnsU2
Q9<-SnsU3
Q10<-SnsG_M
Q11<-SnsG_F
Q12<-SnsG_CM
Q13<-SnsG_CF

name_order<-rownames(summary(SnsC_M))
######################################
# 1. C_M
######################################
name_order[Par_rankx[,1]]
sig_par[[1]];
```

```
Par_rankx+2;
boxplot(Q1[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q1)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", C[M])),cex.axis=1.2)

boxplot(Q1[,c(12,8,3,4)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,

names=c(expression(alpha[S]^M),expression(eta[CG]^M),expression(epsilon[1]),express
ion(epsilon[2])),
        main=expression(paste("Major Sensitivity on"," ",
C[M])),cex.axis=1.2,cex.main=1.7)

########################################
# 2. C_F
########################################
name_order[Par_rankx[,2]]
sig_par[[2]];
Par_rankx+2;
boxplot(Q2[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q2)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", C[F])),cex.axis=1.2)

boxplot(Q2[,c(13,9,3,4)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,

names=c(expression(alpha[S]^F),expression(eta[CG]^F),expression(epsilon[1]),expressi
on(epsilon[2])),
        main=expression(paste("Major Sensitivity on"," ", C[F])),cex.axis=1.2,cex.main=1.7)

########################################
# 3. S_M
########################################
name_order[Par_rankx[,3]]
sig_par[[3]];
Par_rankx+2;

boxplot(Q3[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q3)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", S[M])),cex.axis=1.2)
```

```
boxplot(Q3[,c(12,8,3,4)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,

names=c(expression(alpha[S]^M),expression(eta[CG]^M),expression(epsilon[1]),express
ion(epsilon[2])),
        main=expression(paste("Major Sensitivity on"," ",
S[M])),cex.axis=1.2,cex.main=1.7)

#####################################
# 4. S_F
#####################################
name_order[Par_rankx[,4]]
sig_par[[4]];
Par_rankx+2;
boxplot(Q4[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q4)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", S[F])),cex.axis=1.2)
boxplot(Q4[,c(13,11,3,4)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,

names=c(expression(alpha[S]^F),expression(eta[CG]^F),expression(epsilon[1]),expressi
on(epsilon[2])),
        main=expression(paste("Major Sensitivity on"," ", S[F])),cex.axis=1.2,cex.main=1.7)


#####################################
# 5. T_M
#####################################
name_order[Par_rankx[,5]]
sig_par[[5]];
Par_rankx+2;
boxplot(Q5[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q5)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", T[M])),cex.axis=1.2)
boxplot(Q5[,c(4,6,8,5,3)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,

names=c(expression(epsilon[2]),expression(eta[T]^M),expression(eta[CG]^M),expressio
n(nu),expression(epsilon[1])),
        main=expression(paste("Major Sensitivity on"," ", T[M])),cex.axis=1.2,cex.main=1.7)
```

```
boxplot(Q5[,c(8,5,3)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set2"),outline=FALSE, las=2,
        names=c(expression(eta[CG]^M),expression(nu),expression(epsilon[1])),
        cex.axis=1.7,cex.main=1.7)


######################################
# 6. T_F
######################################
name_order[Par_rankx[,6]]
sig_par[[6]];
Par_rankx+2;
boxplot(Q6[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q6)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", T[F])),cex.axis=1.2)
boxplot(Q6[,c(4,7,9,5,3)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,

names=c(expression(epsilon[2]),expression(eta[T]^F),expression(eta[CG]^F),expression
(nu),expression(epsilon[1])),
        main=expression(paste("Major Sensitivity on"," ", T[F])),cex.axis=1.2,cex.main=1.7)


boxplot(Q6[,c(9,5,3)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=c(expression(eta[CG]^F),expression(nu),expression(epsilon[1])),
        cex.axis=1.2,cex.main=1.7)


######################################
# 7. U1
######################################
name_order[Par_rankx[,7]]
sig_par[[7]];
Par_rankx+2;
boxplot(Q7[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q7)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", U[1])),cex.axis=1.2)
boxplot(Q7[,c(3,12,13,9,8)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
```

```
names=c(expression(epsilon[1]),expression(alpha[M]^S),expression(alpha[F]^S),express
ion(eta[CG]^F),expression(eta[CG]^M)),
       main=expression(paste("Major Sensitivity on","
",U[1],sep="")),cex.axis=1.2,cex.main=1.7)


######################################
# 8. U2
######################################
name_order[Par_rankx[,8]]
sig_par[[8]];
Par_rankx+2;
boxplot(Q8[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
       names=names(Q8)[-c(1:2)],
       main=expression(paste("Major Sensitivity on"," ", U[2])),cex.axis=1.2)
boxplot(Q8[,c(4,3,13,12,9,8)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,

names=c(expression(epsilon[2]),expression(epsilon[1]),expression(alpha[M]^S),expressi
on(alpha[F]^S),expression(eta[CG]^F),expression(eta[CG]^M)),
       main=expression(paste("Major Sensitivity on"," ", U[2])),cex.axis=1.2,cex.main=1.7)


######################################
# 9. U3
######################################
name_order[Par_rankx[,9]]
sig_par[[9]];
Par_rankx+2;
boxplot(Q9[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
       names=names(Q9)[-c(1:2)],
       main=expression(paste("Major Sensitivity on"," ", U[3])),cex.axis=1.2)
boxplot(Q9[,c(4,3,12,9,5,8)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,

names=c(expression(epsilon[2]),expression(alpha[F]^S),expression(alpha[M]^S),express
ion(eta[CG]^F),expression(nu),expression(eta[CG]^M)),
       main=expression(paste("Major Sensitivity on"," ", U[3])),cex.axis=1.2,cex.main=1.7)
```

```
boxplot(Q9[,c(3,12,9,5,8)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set2"),outline=FALSE, las=2,

names=c(expression(alpha[F]^S),expression(alpha[M]^S),expression(eta[CG]^F),expres
sion(nu),expression(eta[CG]^M)),
        cex.axis=1.7,cex.main=1.7)

######################################
# 10. G_M
######################################
name_order[Par_rankx[,10]]
sig_par[[10]];
Par_rankx+2;
boxplot(Q10[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q10)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", G[M])),cex.axis=1.2)
boxplot(Q10[,c(10,3,4)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=c(expression(gamma[M]),expression(epsilon[1]),expression(epsilon[2])),
        main=expression(paste("Major Sensitivity on"," ",
G[M])),cex.axis=1.2,cex.main=1.7)

######################################
# 11. G_F
######################################
name_order[Par_rankx[,11]]
sig_par[[11]];
Par_rankx+2;
boxplot(Q11[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q11)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", G[F])),cex.axis=1.2)
boxplot(Q11[,c(11,3,4)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=c(expression(gamma[F]),expression(epsilon[1]),expression(epsilon[2])),
        main=expression(paste("Major Sensitivity on"," ", G[F])),cex.axis=1.2,cex.main=1.7)

######################################
# 12. G_CM
######################################
name_order[Par_rankx[,12]]
sig_par[[12]];
Par_rankx+2;
```

```
boxplot(Q12[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q12)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", G[M]^C)),cex.axis=1.2)
boxplot(Q12[,c(3,4)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=c(expression(epsilon[1]),expression(epsilon[2])),
        cex.axis=1.2,cex.main=1.7)


boxplot(Q12[,c(10,3,4)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=c(expression(gamma[M]),expression(epsilon[1]),expression(epsilon[2])),
        main=expression(paste("Major Sensitivity on"," ",
G[M]^C)),cex.axis=1.2,cex.main=1.7)

#######################################
# 13. G_CF
#######################################
name_order[Par_rankx[,13]]
sig_par[[13]];
Par_rankx+2;
boxplot(Q13[,-c(1:2)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=names(Q13)[-c(1:2)],
        main=expression(paste("Major Sensitivity on"," ", G[F]^C)),cex.axis=1.2)
boxplot(Q13[,c(11,3,4)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=c(expression(gamma[F]),expression(epsilon[1]),expression(epsilon[2])),
        main=expression(paste("Major Sensitivity on"," ", G[F])),cex.axis=1.2,cex.main=1.7)


boxplot(Q13[,c(3,4)],horizontal=TRUE,col =
brewer.pal(n=8,name="Set1"),outline=FALSE, las=2,
        names=c(expression(epsilon[1]),expression(epsilon[2])),
        cex.axis=1.2,cex.main=1.7)
```