Required packages

```
library(deSolve)
```

Ordinary differential equations

Determinate inflorescence

Write the ordinary differential equations for determinate inflorescences.

```
controlDeterminate=function(t,y,parms,controlFunction) {
  P=y[1]; V=y[2]; I=y[3]; L=y[4];

  beta1=parms[1];
  beta2=parms[2];

  pt = controlFunction(t)

  derivs[1]=2*beta1*pt*P - beta1*pt*P - (1-pt)*beta1*P;
  derivs[2]=beta1*pt*P + (1-pt)*beta1*P;
  derivs[3]=(1-pt)*beta1*P;
  derivs[4]=(1-pt)*beta1*P + beta2*I;
  return(list(derivs));
}
```

Indeterminate inflorescence

Write the ordinary differential equations for indeterminate inflorescences.

```
controlIndeterminate=function(t,y,parms,controlFunction) {
  P=y[1]; V=y[2]; I=y[3]; L=y[4];

  beta1=parms[1];
  beta2=parms[2];

    pt = controlFunction(t)[1]
    qt = controlFunction(t)[2]

  derivs[1]= 2*beta1*(pt-qt)*P - beta1*(pt-qt)*P - beta1*qt*P;
  derivs[2]= beta1*(pt-qt)*P + beta1*(1-pt-qt)*P + beta1*qt*P ;
  derivs[3]= beta1*(1-pt-qt)*P+2*qt*beta1*P
  derivs[4]= beta2*I;
  return(list(derivs));
}
```

Initial conditions

```
# Vector to hold the derivatives
derivs=numeric(4);
```

```
# starting values of both state variables
y0=c(P=0.5,V=0,I=0,L=0);
# time sequence
times=seq(0,8,length=200)
# controls
parms=c( beta1=1,
         beta2=1);
```

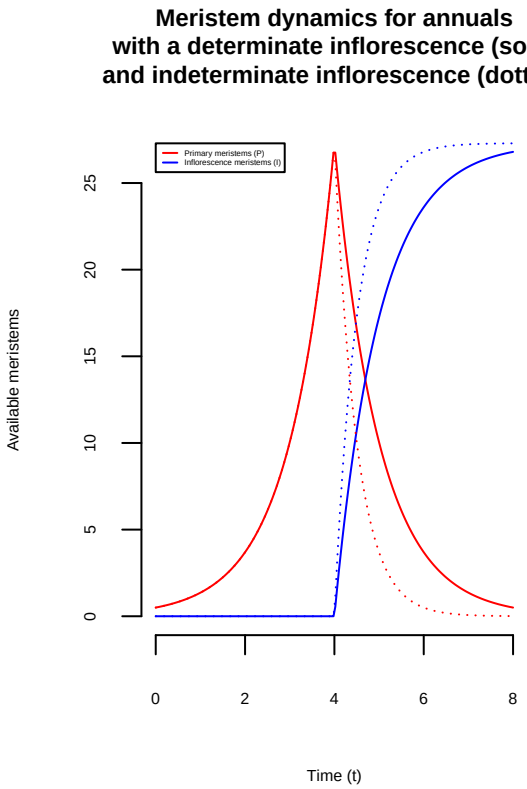
Function to plot solutions

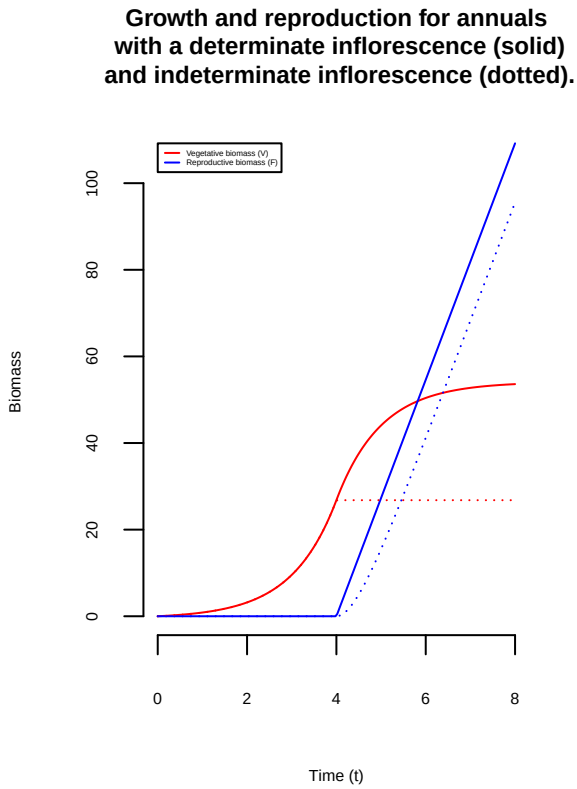
```
plotSolutions = function(ode1=odeSolutionDeterminate,ode2=odeSolutionIndeterminate){

par(mfrow=c(1,2))

# plot(ode1$time,ifelse(ode1$time<4,1,0),type="l",col="black",bty="n",
#      main="Optimal growth and reproduction for an annual\n with a determinate inflorescence.",
#      xlab="Time (t)",
#      ylab="Control",
#      ylim=c(0,1))

plot(ode1$time,ode1$P,type="l",col="red",bty="n",
     main="Meristem dynamics for annuals\n with a determinate inflorescence (solid)\n and indeterminate
     xlab="Time (t)",
     ylab="Available meristems",
     ylim=c(0,max(ode1$I,ode2$I)  ),
     cex.lab=.5, cex.axis=.5, cex.main=.75, cex.sub=.5)

lines(ode1$time,ode1$I,col="blue")
lines(ode2$time,ode2$I,col="blue",lty='dotted')
lines(ode2$time,ode2$P,col="red",lty='dotted')

legend(x = 0, y = max(ode1$I,ode2$I) ,
       legend = c("Primary meristems (P)", "Inflorescence meristems (I)"),
       col = c('red', 'blue') ,
       lty = c(1,1),
       cex = .25)

plot(ode1$time,ode1$V,type="l",col="red",bty="n",
     main="Growth and reproduction for annuals\n with a determinate inflorescence (solid)\n and indeter
     xlab="Time (t)",
     ylab="Biomass ",
     ylim=c(0,max(ode1$L,ode2$L)) ,
     cex.lab=.5, cex.axis=.5, cex.main=.75, cex.sub=.5)

lines(ode1$time,ode1$L,col="blue")

lines(ode2$time,ode2$V,col="red",lty='dotted')
lines(ode2$time,ode2$L,col="blue",lty='dotted')

legend(x = 0, y = max(ode1$L,ode2$L),
       legend = c("Vegetative biomass (V)", "Reproductive biomass (F)"),
```

```
       col = c('red', 'blue') ,
       lty = c(1,1),
       cex = .25)
}
```

Instantaneous switch

```
instantSwitch = function(t){
  if ( t <= 4)
    tmp <- 1
  else
    tmp <- 0

  return(tmp)
  }

odeSolutionDeterminate=ode(y0,times,controlDeterminate,parms,controlFunction=instantSwitch);
odeSolutionDeterminate = data.frame(odeSolutionDeterminate);

instantSwitch = function(t){

  tmp = c() # tmp[1] = pt, tmp[2] = qt

  if ( t <= 4)
    {tmp[1] <- 1
    tmp[2] <- 0}
  else
  {tmp[1] <- 0
   tmp[2] <- 1}

  return(tmp)
  }

odeSolutionIndeterminate=ode(y0,times,controlIndeterminate,parms,controlFunction=instantSwitch);
odeSolutionIndeterminate = data.frame(odeSolutionIndeterminate)

plotSolutions(odeSolutionDeterminate,odeSolutionIndeterminate)
```



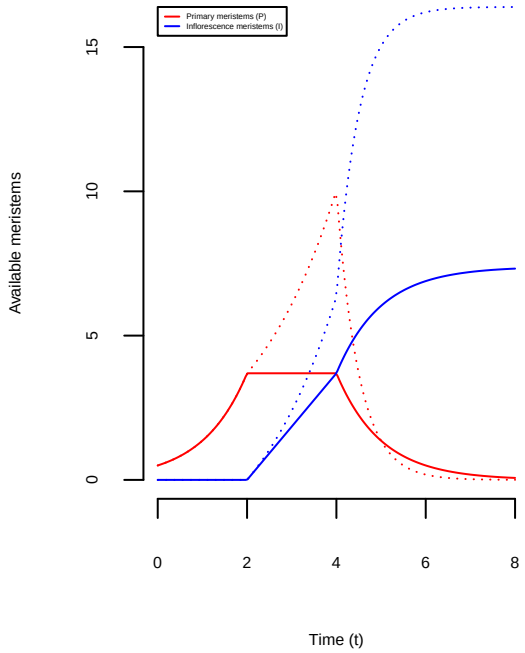


Graded switch

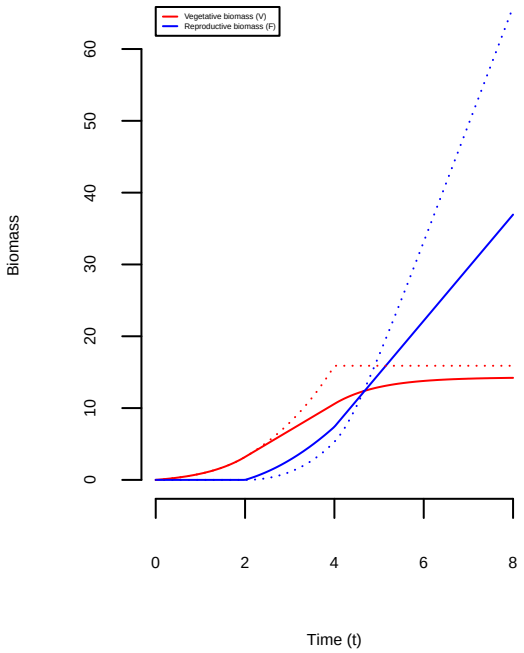
```
gradedSwitch = function(t){
  if ( t <= 2)
    tmp <- 1
  else if (t <= 4)
    tmp <- .5
  else
    tmp <- 0

  return(tmp)
  }

odeSolutionDeterminate=ode(y0,times,controlDeterminate,parms,controlFunction=gradedSwitch);
odeSolutionDeterminate = data.frame(odeSolutionDeterminate);

gradedSwitch = function(t){

  tmp = c() # tmp[1] = pt, tmp[2] = qt

  if ( t <= 2)
    {tmp[1] <- 1
    tmp[2] <- 0}
  else if ( t <= 4)
  {tmp[1] <- .5
    tmp[2] <- 0}
```

```
  else
  {tmp[1] <- 0
   tmp[2] <- 1}

  return(tmp)
  }

odeSolutionIndeterminate=ode(y0,times,controlIndeterminate,parms,controlFunction=gradedSwitch);
odeSolutionIndeterminate = data.frame(odeSolutionIndeterminate)

plotSolutions(odeSolutionDeterminate,odeSolutionIndeterminate)
```

Meristem dynamics for annuals with a determinate inflorescence (solid) and indeterminate inflorescence (dotted).



Growth and reproduction for annuals with a determinate inflorescence (solid) and indeterminate inflorescence (dotted).

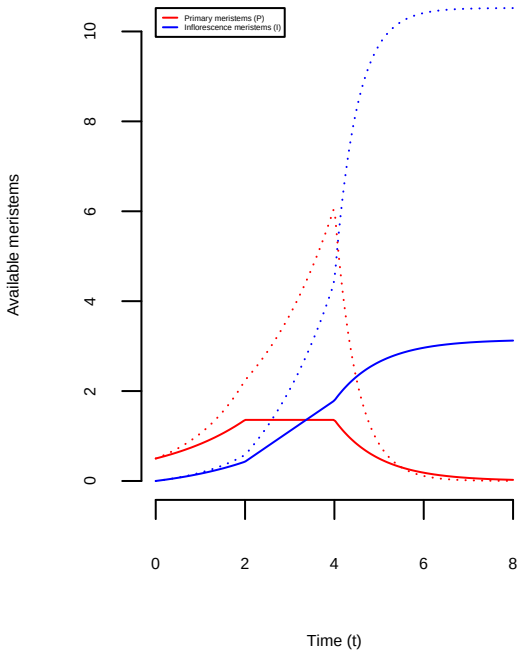


Graded switch

```
gradedSwitch = function(t){
  if ( t <= 2)
    tmp <- .75
  else if (t <= 4)
    tmp <- .5
  else
    tmp <- 0

  return(tmp)
  }

odeSolutionDeterminate=ode(y0,times,controlDeterminate,parms,controlFunction=gradedSwitch);
```

```
odeSolutionDeterminate = data.frame(odeSolutionDeterminate);

gradedSwitch = function(t){

  tmp = c() # tmp[1] = pt, tmp[2] = qt

  if ( t <= 2)
    {tmp[1] <- .75
    tmp[2] <- 0}
  else if ( t <= 4)
  {tmp[1] <- .5
    tmp[2] <- 0}
  else
  {tmp[1] <- 0
   tmp[2] <- 1}

  return(tmp)
  }

odeSolutionIndeterminate=ode(y0,times,controlIndeterminate,parms,controlFunction=gradedSwitch);
odeSolutionIndeterminate = data.frame(odeSolutionIndeterminate)

plotSolutions(odeSolutionDeterminate,odeSolutionIndeterminate)
```

Meristem dynamics for annuals with a determinate inflorescence (solid) and indeterminate inflorescence (dotted).



Growth and reproduction for annuals with a determinate inflorescence (solid) and indeterminate inflorescence (dotted).