Fitnesses

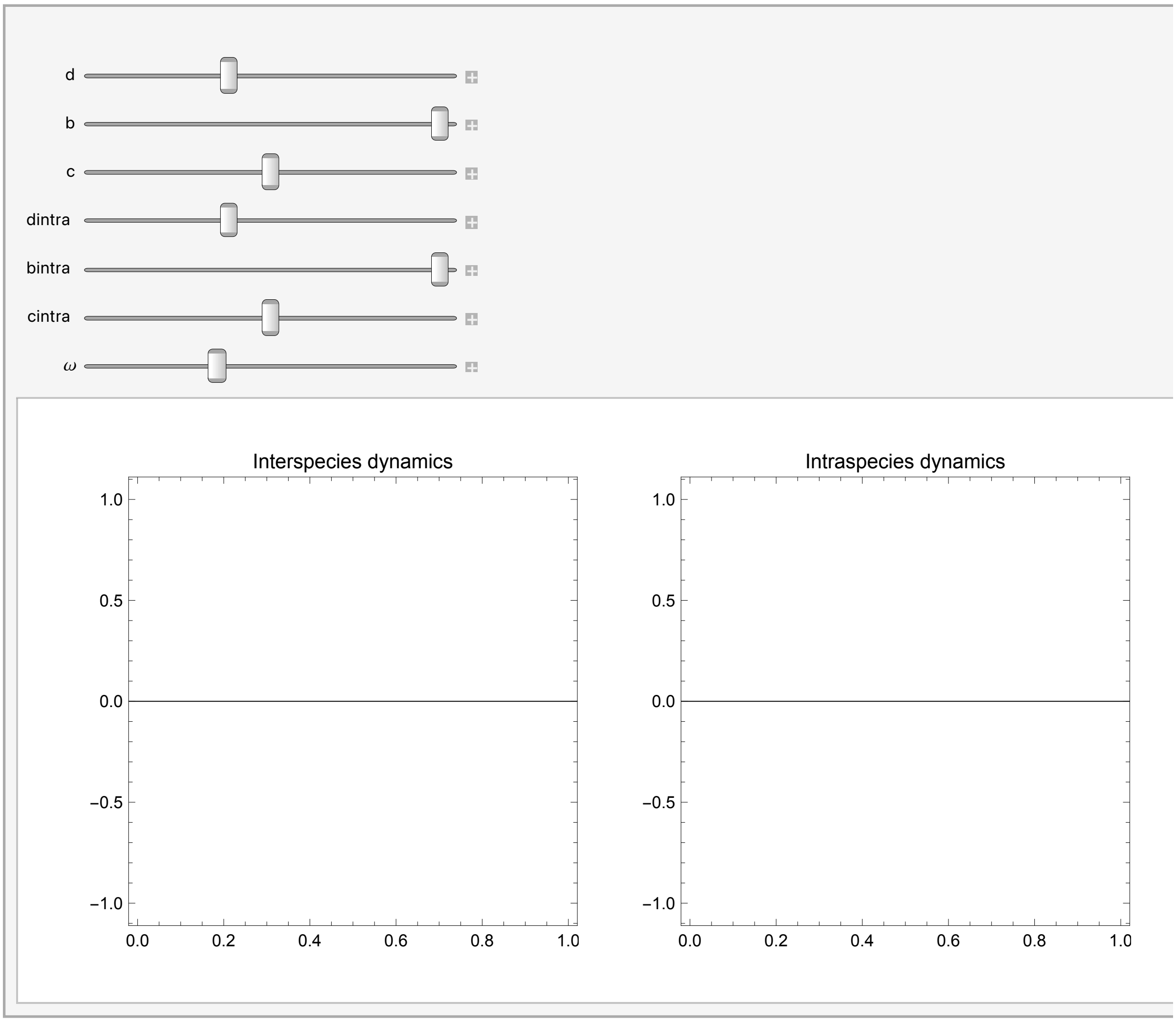
In[ ]:=
```
θ[x_, thresh_] := If[x < thresh, 0, 1];
πD[b_, num_, thresh_] := b θ[num, thresh] + 1;
πC[b_, c_, num_, thresh_] :=
  πD[b, num, thresh] - c/num θ[num, thresh] - c/thresh (1 - θ[num, thresh]);
```

$$\pi\text{intraD}[d\_, b\_, c\_, num\_, \omega\_] := \frac{b}{d}\sum_{i=0}^{num-1}\omega^{i};$$

```
πintraC[d_, b_, c_, num_, ω_] := πintraD[d, b, c, num, ω] - c;
```

In[ ]:=
```
Manipulate[
 GraphicsRow[{Plot[{Sum[(Binomial[d - 1, k] x^k (1 - x)^(d-1-k) πC[b, c, k + 1, 1]), {k, 0, d-1}],
     Sum[(Binomial[d - 1, k] x^k (1 - x)^(d-1-k) πD[b, k, 1]), {k, 0, d-1}]}, {x, 0, 1},
    PlotStyle → {Blue, {Red, Dashed}}, Frame → True, AspectRatio → 1,
    Filling → {1 → {{2}, {Directive[Lighter[Red], Opacity[0.6]], Directive[
          Lighter[Blue], Opacity[0.6]]}}}, PlotLabel → "Interspecies dynamics"],
   Plot[{Sum[(Binomial[dintra - 1, k] y^k (1 - y)^(dintra-1-k) πintraC[dintra,
          bintra, cintra, k + 1, ω]), {k, 0, dintra-1}], Sum[(Binomial[dintra - 1, k] y^k
          (1 - y)^(dintra-1-k) πintraD[dintra, bintra, cintra, k, ω]), {k, 0, dintra-1}]}, {y, 0, 1},
    PlotStyle → {Blue, {Red, Dashed}}, Frame → True, AspectRatio → 1,
    Filling → {1 → {{2}, {Directive[Lighter[Red], Opacity[0.6]],
         Directive[Lighter[Blue], Opacity[0.6]]}}},
    PlotLabel → "Intraspecies dynamics"]}],
 {{d, 5}, 2, 10, 1},
 {{b, 10}, 2, 10},
 {{c, 3}, 1, 5},
 {{dintra, 5}, 2, 10, 1},
 {{bintra, 10}, 2, 10},
 {{cintra, 3}, 1, 5},
 {{ω, 0.75}, 0.1, 2}]
```

Out[∘]=



Dynamics

In[∘]:=

$$\texttt{fD[d\_, dintra\_, x\_, y\_, b\_, c\_, bintra\_, cintra\_, thresh\_, }\omega\texttt{\_, p\_] :=}$$

$$p\left(\sum_{k=0}^{d-1}\left(\text{Binomial}[d-1,k]\,x^k\,(1-x)^{d-1-k}\,\pi D[b,k,\text{thresh}]\right)\right)+$$

$$(1-p)\left(\sum_{k=0}^{\text{dintra}-1}\left(\text{Binomial}[\text{dintra}-1,k]\,y^k\,(1-y)^{\text{dintra}-1-k}\,\pi\text{intraD}[\text{dintra},\text{bintra},\text{cintra},k,\omega]\right)\right);$$

$$\texttt{fC[d\_, dintra\_, x\_, y\_, b\_, c\_, bintra\_, cintra\_, thresh\_, }\omega\texttt{\_, p\_] :=}$$

$$p\left(\sum_{k=0}^{d-1}\left(\text{Binomial}[d-1,k]\,x^k\,(1-x)^{d-1-k}\,\pi C[b,c,k+1,\text{thresh}]\right)\right)+$$

$$(1-p)\left(\sum_{k=0}^{\text{dintra}-1}\left(\text{Binomial}[\text{dintra}-1,k]\,y^k\,(1-y)^{\text{dintra}-1-k}\right.\right.$$

```
        πintraC[dintra, bintra, cintra, k + 1, ω]))];

fbar1[d_, dintra_, x_, y_, b_, c_, bintra_, cintra_, thresh_, ω_, p_] :=
  x fC[d, dintra, y, x, b, c, bintra, cintra, thresh, ω, p] +
   (1 - x) fD[d, dintra, y, x, b, c, bintra, cintra, thresh, ω, p];
fbar2[d_, dintra_, x_, y_, b_, c_, bintra_, cintra_, thresh_, ω_, p_] :=
  y fC[d, dintra, x, y, b, c, bintra, cintra, thresh, ω, p] +
   (1 - y) fD[d, dintra, x, y, b, c, bintra, cintra, thresh, ω, p];
xdot[d_, dintra_, x_, y_, b_, c_, bintra_, cintra_, thresh_, m_, ω_, p_] :=
  m x (1 - x) (fC[d, dintra, y, x, b, c, bintra, cintra, thresh, ω, p] -
     fD[d, dintra, y, x, b, c, bintra, cintra, thresh, ω, p]);
ydot[d_, dintra_, x_, y_, b_, c_, bintra_, cintra_, thresh_, n_, ω_, p_] :=
  n y (1 - y) (fC[d, dintra, x, y, b, c, bintra, cintra, thresh, ω, p] -
     fD[d, dintra, x, y, b, c, bintra, cintra, thresh, ω, p]);
res[p_, q_, lim_] :=
  Quiet[NDSolve[{x'[t] == m x[t] (fC[d1, d1intra, y[t], x[t], b, c, bintraforsp1,
          cintraforsp1, thresh1, ωforsp1, prob] - fbar1[d1, d1intra, x[t],
          y[t], b, c, bintraforsp1, cintraforsp1, thresh1, ωforsp1, prob]),
     y'[t] == n y[t] (fC[d2, d2intra, x[t], y[t], b, c, bintraforsp2,
          cintraforsp2, thresh2, ωforsp2, prob] - fbar2[d2, d2intra, x[t],
          y[t], b, c, bintraforsp2, cintraforsp2, thresh2, ωforsp2, prob]),
     x[0] == p, y[0] == q}, {x, y}, {t, lim}]];
liseval[t_, rep_] := Evaluate[{x[t], y[t]} /. rep];

gamea = {3, 3 / 4};
gameb = {1, 3 / 4};
gamec = {1, 4 / 3};
gamed = {3, 4 / 3};

d1 = 5;
d2 = 5;
d1intra = 5;
d2intra = 5;
thresh1 = 1;
thresh2 = 1;
b = 2;
c = 1;
bintraforsp1 = 10;
cintraforsp1 = gameb[[1]];
ωforsp1 = gameb[[2]] // N;

bintraforsp2 = 10;
cintraforsp2 = gameb[[1]];
ωforsp2 = gameb[[2]] // N;

m = 1 / 8 // N;
n = 1;
```

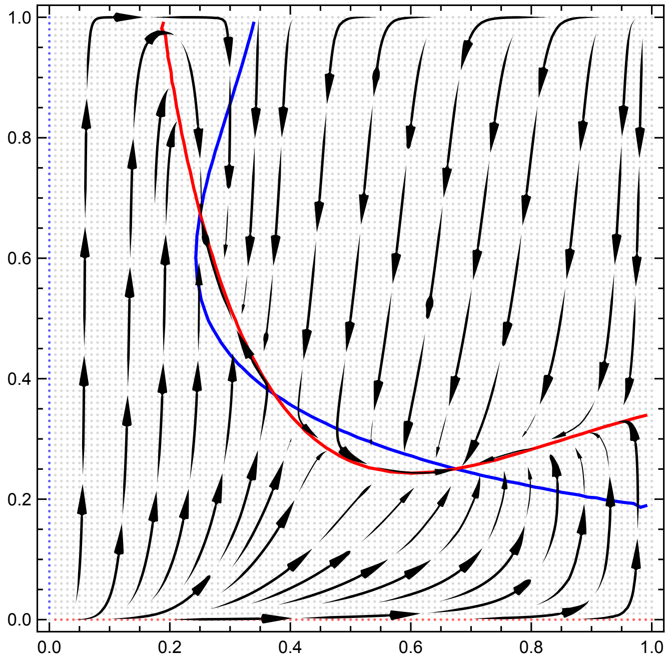
```
prob = 0.666;
lim = 800;
```

In[ ]:=
```
Clear[blue, red, black];
blue = {};
red = {};
black = {};
For[u = 0.0, u ≤ 1.0, u = u + 0.01, For[v = 0.0, v ≤ 1.0, v = v + 0.01,
  If[
    liseval[lim, res[u, v, lim]]⟦1⟧⟦1⟧ > 0.9999 &&
     liseval[lim, res[u, v, lim]]⟦1⟧⟦2⟧ < 0.01,
    AppendTo[red, {u, v}], If[liseval[lim, res[u, v, lim]]⟦1⟧⟦1⟧ < 0.01 &&
      liseval[lim, res[u, v, lim]]⟦1⟧⟦2⟧ > 0.9999,
     AppendTo[blue, {u, v}], AppendTo[black, {u, v}]]];
 ]]

ans = Solve[
   {xdot[d1, d1intra, x, y, b, c, bintraforsp1, cintraforsp1, thresh1, m, ωforsp1,
      prob] == 0, ydot[d2, d2intra, x, y, b, c, bintraforsp2, cintraforsp2, thresh2,
      n, ωforsp2, prob] == 0, xdot[d1, d1intra, x, y, b, c, bintraforsp1,
      cintraforsp1, thresh1, m, ωforsp1, prob] == ydot[d2, d2intra, x, y, b,
      c, bintraforsp2, cintraforsp2, thresh2, n, ωforsp2, prob]}, {x, y}];
xlis = {};
ylis = {};
For[i = 1, i ≤ Length[ans], i++,
 For[j = 1, j ≤ 2, j++,
  If[ans⟦i⟧⟦j⟧⟦1⟧ == x,
   temp = ans⟦i⟧⟦j⟧⟦2⟧ // N;
   If[Head[temp] == Real && temp > 0 && temp < 1, AppendTo[xlis, temp]]
  ];
  If[ans⟦i⟧⟦j⟧⟦1⟧ == y,
   temp = ans⟦i⟧⟦j⟧⟦2⟧ // N;
   If[Head[temp] == Real && temp > 0 && temp < 1, AppendTo[ylis, temp]]
  ]
 ]
]
xlis = Flatten[Union[xlis]];
ylis = Flatten[Union[ylis]];

xplots = Table[ContourPlot[y == ylis⟦z⟧, {x, 0, 1}, {y, 0, 1}, AspectRatio → 1,
    ContourStyle → {Blue, Thickness[0.003]}], {z, 1, Length[ylis]}];
yplots = Table[ContourPlot[x == xlis⟦z⟧, {x, 0, 1}, {y, 0, 1}, AspectRatio → 1,
    ContourStyle → {Red, Thickness[0.003]}], {z, 1, Length[xlis]}];
```

```
In[◦]:= (*(*p1fun[d1_,d2_,b_,c_,thresh1_,thresh2_,m_,n_]:=ContourPlot[
          {ydot[d2,x,y,b,c,thresh2,n]==0,xdot[d1,x,y,b,c,thresh1,m]==0},{y,0,1},
          {x,0,1},ContourStyle→{{Thickness[0.009],Red},{Thickness[0.009],Blue}},
          Axes→False,Frame→True];*)
        p2fun[d1_,d2_,d1intra_,d2intra_,b_,c_,thresh1_,thresh2_,m_,n_]:=StreamPlot[{
           xdot[d1,d1intra,x,y,b,c,bintraforsp1,cintraforsp1,thresh1,m,ωforsp1,prob],
           ydot[d2,d2intra,x,y,b,c,bintraforsp2,cintraforsp2,thresh2,n,ωforsp2,
             prob]},{x,0.0001,1},{y,0.0001,1},StreamScale→0.2,Axes→False,
          StreamPoints→30,StreamStyle→{"PinDart",Directive[Black,Thick]},Frame→True,
          PlotRange→{{-0.01,1.01},{-0.01,1.01}},StreamColorFunction→(Black&)];
        (*diagonal=Plot[1-x,{x,0,1},
          PlotStyle→{Thickness[0.005],Green,Dashed},AspectRatio→1,Frame→True];*)
        (*sep=ContourPlot[ydot[d2,x,y,b,c,thresh2,n]==xdot[d1,x,y,b,c,thresh1,m],
          {x,0,1},{y,0,1},ContourStyle→{Thickness[0.005],Green,Dashed}];*)*)

In[◦]:= p2fun[d1_, d2_, d1intra_, d2intra_,
         b_, c_, thresh1_, thresh2_, m_, n_] := StreamPlot[{
          xdot[d1, d1intra, x, y, b, c, bintraforsp1, cintraforsp1, thresh1,
            m, ωforsp1, prob], ydot[d2, d2intra, x, y, b, c, bintraforsp2,
            cintraforsp2, thresh2, n, ωforsp2, prob]}, {x, 0.0001, 1},
         {y, 0.0001, 1}, StreamScale → 0.2, Axes → False, StreamPoints → 30,
         StreamStyle → {"PinDart", Directive[Black, Thick]}, Frame → True,
         PlotRange → {{-0.01, 1.01}, {-0.01, 1.01}}, StreamColorFunction → (Black &)]

In[◦]:= g1 = ListPlot[{blue, red, black},
          PlotStyle → {Lighter[Blue, 0.4], Lighter[Red, 0.4], Lighter[Gray, 0.7]},
          AspectRatio → 1, Frame → True, PlotRange → {{-0.01, 1.01}, {-0.01, 1.01}}];

In[◦]:= p2fun[d1, d2, d1intra, d2intra, b, c, thresh1, thresh2, m, n]

In[◦]:= p2contour[d1_, d2_, d1intra_, d2intra_,
         b_, c_, thresh1_, thresh2_, m_, n_] := ContourPlot[{
          xdot[d1, d1intra, x, y, b, c,
             bintraforsp1, cintraforsp1, thresh1, m, ωforsp1, prob] == 0.00,
          ydot[d2, d2intra, x, y, b, c, bintraforsp2, cintraforsp2, thresh2,
             n, ωforsp2, prob] == 0.00}, {x, 0.001, 0.99}, {y, 0.001, 0.99},
         ContourStyle → {{Thickness[0.005], Blue}, {Thickness[0.005], Red}}]

In[◦]:= p2contour[d1, d2, d1intra, d2intra, b, c, thresh1, thresh2, m, n]
```

In[ ]:=
```
Show[g1, (*,p1fun[d1,d2,b,c,thresh1,thresh2,m,n],*)
 p2contour[d1, d2, d1intra, d2intra, b, c, thresh1, thresh2, m, n],
 p2fun[d1, d2, d1intra, d2intra, b, c, thresh1, thresh2, m, n](*,
 xplots,yplots*), Frame → True, FrameStyle → Thickness[0.0025],
 ImagePadding → 17, PlotRange → {{-0.02, 1.02}, {-0.02, 1.02}}]
```

Out[ ]=




```
(*Export["Untitled.pdf",%]*)
```