Functions

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]);
πintraD[d_, b_, c_, num_, ω_] := b/d Sum[ω^i, {i, 0, num-1}];
πintraC[d_, b_, c_, num_, ω_] := πintraD[d, b, c, num, ω] - c;
fD[d_, dintra_, x_, y_, b_, c_, bintra_, cintra_, thresh_, ω_, p_] :=
  p (Sum[(Binomial[d - 1, k] x^k (1 - x)^(d-1-k) πD[b, k, thresh]), {k, 0, d-1}]) + (1 - p)
    (Sum[(Binomial[d - 1, k] y^k (1 - y)^(d-1-k) πintraD[dintra, bintra, cintra, k, ω]), {k, 0, d-1}]);
fC[d_, dintra_, x_, y_, b_, c_, bintra_, cintra_, thresh_, ω_, p_] :=
  p (Sum[(Binomial[d - 1, k] x^k (1 - x)^(d-1-k) πC[b, c, k + 1, thresh]), {k, 0, d-1}]) + (1 - p)
    (Sum[(Binomial[d - 1, k] y^k (1 - y)^(d-1-k) πintraC[dintra, bintra, cintra, k + 1, ω]), {k, 0, d-1}]);
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]);
```

In[ ]:=
```
checkinternal[point_] :=
  If[point[[1]] > 0 && point[[1]] < 1 && point[[2]] > 0 && point[[2]] < 1, 1, 0];
```

In[ ]:=
```
plotrange = {{-0.02, 1.02}, {-0.02, 1.02}};
```

Parameters

In[ ]:=
```
ClearAll[n, ω, ω1, ω2, r1, r2, d, p]
```

In[ ]:=
```
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;
lim = 100;
```

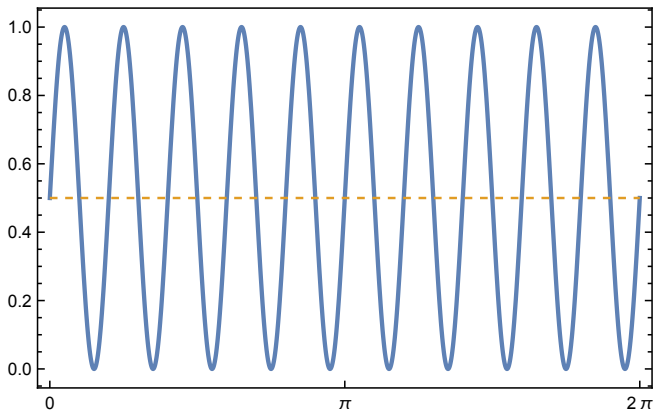
Functions for fluctuations

```
a = 10;
diff = 0;
num[t_] := (Sin[a t - diff] + 1) / 2;(*If[Sin[a t]>0,1/(1+A Sin[a t]),1-A Sin[a t]]*)
mean = Mean[Table[num[t], {t, 0, 20 π, 0.0001}]];
(*geomean=GeometricMean[Table[num[t],{t,0,20 π,0.0001}]]*)
```

Out[ ]=
```
0.5
```

In[•]:=
```
Plot[{num[t], mean}, {t, 0, 2 π}, PlotStyle →
  {{Thickness[0.007]}, {Thickness[0.004], Dashed}, {Thickness[0.004]}},
 PlotRange → {Automatic, Automatic}, Frame → True, FrameStyle → Thickness[0.0025],
 FrameTicks → {{Automatic, Automatic}, {{0, Pi, 2 Pi, 15 Pi, 20 Pi}, None}},
 ImagePadding → 20]
```

Out[•]=



Analysis

In[•]:=
```
plotlis = {};
plotdata = {};
tlim = 100;
For[i = 0.1, i ≤ 0.9, i = i + 0.1,
 For[j = 0.1, j ≤ 0.9, j = j + 0.1,
  sinlistcheck = {};
  s = Quiet[NDSolve[{
       x'[t] == m x[t] (fC[d1, d1intra, y[t], x[t], b, c, bintraforsp1, cintraforsp1,
            thresh1, ωforsp1, num[t]] - fbar1[d1, d1intra, x[t], y[t], b,
            c, bintraforsp1, cintraforsp1, thresh1, ωforsp1, num[t]]),
       y'[t] == n y[t] (fC[d2, d2intra, x[t], y[t], b, c, bintraforsp2,
            cintraforsp2, thresh2, ωforsp2, num[t]] - fbar2[d2, d2intra, x[t],
            y[t], b, c, bintraforsp2, cintraforsp2, thresh2, ωforsp2, num[t]]),
       x[0] == i, y[0] == j}, {x, y}, {t, 0, tlim}, MaxStepSize → 0.005]];
  tabsin = Table[{Evaluate[x[t] /. s][[1]], Evaluate[y[t] /. s][[1]]}, {t, 0, tlim}];
  AppendTo[plotdata, tabsin];
 ]
]
```

In[ ]:=
```
res[p_, q_, lim_] :=
  Quiet[NDSolve[{x'[t] == m x[t] (fC[d1, d1intra, y[t], x[t], b, c, bintraforsp1,
          cintraforsp1, thresh1, ωforsp1, num[t]] - fbar1[d1, d1intra, x[t],
          y[t], b, c, bintraforsp1, cintraforsp1, thresh1, ωforsp1, num[t]]),
     y'[t] == n y[t] (fC[d2, d2intra, x[t], y[t], b, c, bintraforsp2,
          cintraforsp2, thresh2, ωforsp2, num[t]] - fbar2[d2, d2intra, x[t],
          y[t], b, c, bintraforsp2, cintraforsp2, thresh2, ωforsp2, num[t]]),
     x[0] == p, y[0] == q}, {x, y}, {t, lim}]];
liseval[t_, rep_] := Evaluate[{x[t], y[t]} /. rep];
```

ReplaceAll : {rep} is neither a list of replacement rules nor a valid dispatch table, and so cannot be used for replacing.

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]] < 0.001,
    AppendTo[red, {u, v}], If[liseval[lim, res[u, v, lim]][[1]][[1]] < 0.001 &&
      liseval[lim, res[u, v, lim]][[1]][[2]] > 0.9999,
     AppendTo[blue, {u, v}], AppendTo[black, {u, v}]]];
 ]]
```

In[ ]:=
```
g1 = ListPlot[{blue, red, black},
    PlotStyle → {Lighter[Blue, 0.8], Lighter[Red, 0.4], Lighter[Gray, 0.7]},
    AspectRatio → 1, Frame → True, PlotRange → {{-0.01, 1.01}, {-0.01, 1.01}}];

plotcolors = {};
For[i = 1, i ≤ Length[plotdata], i++,
 If[Last[plotdata[[i]]][[1]] ≥ 0.99 && Last[plotdata[[i]]][[2]] ≤ 0.01,
    AppendTo[plotcolors, {Darker[Red], Thickness[0.003]}],
    If[Last[plotdata[[i]]][[2]] ≥ 0.99 && Last[plotdata[[i]]][[1]] ≤ 0.01,
     AppendTo[plotcolors, {Darker[Blue], Thickness[0.003]}],
     AppendTo[plotcolors, {Black, Thickness[0.003]}]
    ]
  ];
]
Show[g1,
 ListPlot[{blue, red}, PlotStyle → {Lighter[Blue, 0.8], Lighter[Red, 0.8]},
  AspectRatio → 1, Frame → True, PlotRange → plotrange],
 ListPlot[plotdata, Joined → True, InterpolationOrder → 2, AspectRatio → 1,
  PlotRange → plotrange, PlotStyle → plotcolors, Frame → True],
 Frame → True, FrameStyle → Thickness[0.0025], ImagePadding → 17]
```

Out[ ]=