R-code for producing Figure 2 from Pedersen et al. (2013)

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This vignette includes the commands to reproduce Fig. 2 from "A kinetic model explains why shorter and less affine enzyme-recruiting oligonucleotides can be more potent". The R-functions from the ASOmodels package are used.

```
> require(devtools)
> #install_github(ASOmodel,username=lykkep)
> require(ASOmodels)
```

Kinetic model figures

Figure 2a: Time-resolved simulation of the model (unsaturated)

Parameters for the model, the initial concentrations and the time-steps for which the simulation is performed:

```
> parms <- c(Et = 1,KdOT = 0.3,kOpT = 0.2,KdOTE = 70,kOTpE = 5,
+            vprod = 0.2,kdegrad = 0.04,alpha=0.1,kcleav = 8)
> init <- c(T=parms[vprod]/parms[kdegrad], OT=0, OTE=0,
+           E=parms[Et], O=0.1, OCE=0, OC=0)
```

Using `vode()` the model is simulated in time. The function `diffASO()` is part of the ASOmodels package.

```
> solASO <- vode(init,0:100,diffASO,parms)
```

The timetraces for the concentrations of $[O]$, $[T]$, $[OT]$, $[OTE]$, and $[E]$ are plotted:

```
> colVAR <- c("black","darkgreen","darkred","orange","green")
> SSvalue <- signif(last(solASO),3)
> SSvalue[c(3:4,6)] <- SSvalue[c(3:4,6)]*1E3
> xtime <- 59; ySS <- c(0.08,0.88,0.83,0.18,0.13)
> uSS <- c(nM,pM,pM,nM,pM)
> labSS=c(T,OT,OTE,E,O)
```

```
> par(mar=c(3.2,3.4,0.1,0.1),bty=n,mgp=c(2,0.7,0),
+     las=1,cex.lab=1.25)
> plot(0,0,ylim=c(0,1),xlim=c(0,xtime+30),type=n,xaxt=n,
+      yaxt=n,ylab=relative concentrations,xlab=minutes)
> axis(2,at=c(0,1),label=c(min,max),las=1)
> axis(1,at=c(seq(0,xtime,by=10),xtime+20),
+      label=c(seq(0,xtime,by=10),))
> axis(1,at=xtime+20,label=steady-\nstate,mgp=c(0,1.6,0))
> for(i in 2:6){
+   par(new=TRUE)
+   plot(solASO[1:(xtime+1),1], solASO[1:(xtime+1),i], xaxt=n,
+        yaxt=n,ylim=range(solASO[,i]),col=colVAR[i-1],
+        type=l,ylab=NA,xlab=NA,xlim=c(0,xtime+30))
+   lines(xtime+5:37,rep(solASO[101,i],33),col=colVAR[(i-1)])
+   y <- diff(par(usr)[3:4])*ySS[i-1]+par(usr)[3]
+   text(xtime+5,y,col=colVAR[i-1],adj=0,cex=0.8,
+        substitute(b==e*l,list(e=SSvalue[i],l=uSS[i-1],b=labSS[i-1]) ))
+ }
```

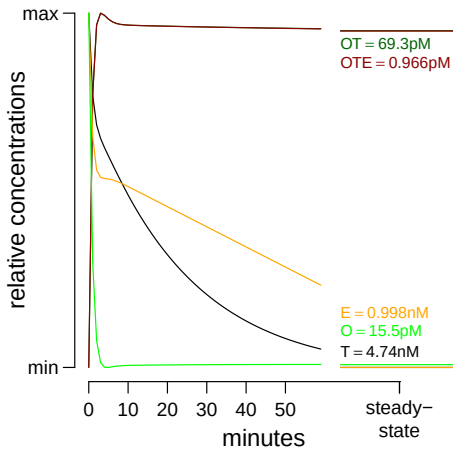

Figure 2a: Time resolved simulation of the relative concentrations of key species.

Figure 2b: Time-resolved simulation of the model (saturated)

The initial oligonucleotide concentration is increased to 100nM.

```
> init <- c(T=parms[vprod]/parms[kdegrad], OT=0, OTE=0,
+           E=parms[Et], O=100, OCE=0, OC=0)
> solASO <- vode(init,0:100,diffASO,parms)
```

The timetraces for the concentrations of $[O]$, $[T]$, $[OT]$, $[OTE]$, and $[E]$ are plotted:

```
> SSvalue <- signif(last(solASO),3)
> SSvalue[c(2,4)] <- SSvalue[c(2,4)]*1E3
> xtime <- 55; ySS <- c(0.06,0.3,0.34,0.26,0.67)
> uSS <- c(pM,nM,pM,rep(nM,2))
> labSS=c(T,OT,OTE,E,O)
> par(mar=c(3.2,3.4,0.1,0.1),bty=n,mgp=c(2,0.7,0),
+     las=1,cex.lab=1.25)
> plot(0,0,ylim=c(0,1),xlim=c(0,xtime+25),type=n,xaxt=n,
+      yaxt=n,ylab=relative concentrations,xlab=minutes)
> axis(2,at=c(0,1),label=c(min,max),las=1)
> axis(1,at=c(seq(0,xtime,by=10),xtime+15),
+      label=c(seq(0,xtime,by=10),))
> axis(1,at=xtime+15,label=steady-\nstate,mgp=c(0,1.6,0))
> for(i in 2:6){
+   par(new=TRUE)
+   plot(solASO[1:(xtime+1),1], solASO[1:(xtime+1),i], xaxt=n,
+        yaxt=n,ylim=range(solASO[,i]),col=colVAR[i-1],
+        type=l,ylab=NA,xlab=NA,xlim=c(0,xtime+25))
+   lines(xtime+5:25,rep(solASO[101,i],21),col=colVAR[(i-1)])
+   y <- diff(par(usr)[3:4])*ySS[i-1]+par(usr)[3]
+   text(xtime+5,y,col=colVAR[i-1],adj=0,cex=0.8,
+        substitute(b==e*l,list(e=SSvalue[i],l=uSS[i-1],b=labSS[i-1])))
+ }
```

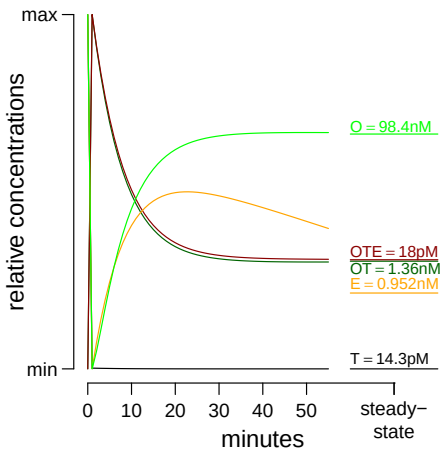

Figure 2b: Time resolved simulation of the relative concentrations of key species.

Figure 2c: Simulated dose-response curve

Given a set of parameters the R-function `Trel()` from the ASOmodels package calculates the relative target concentration as a function of the total concentration of oligonucleotide added to the system.

```
> par(mar=c(3.2,3.4,0.1,0.1),bty=n,mgp=c(2,0.7,0),
+     las=1,cex.lab=1.25)
> curve(Trel,1E-3,5E2,log=x, lwd=2,ylim=c(0,1),
+       ylab=expression(T[rel]),xaxt=n,
+       xlab=Total oligonucleotide conc (nM))
> abline(h=Trel(1E9),lty=2) #Trel,min
> abline(v=EC50(parms[KdOT]),lty=2) #EC50
> axis(1,at=10^c(-3,-1,1,3),
+      labels=pretty10expLP(10^c(-3,-1,1,3),drop.1=T))
> axis(1,at=EC50(parms[KdOT]),label=expression(EC[50]))
> axis(2,at=Trel(1E6),label=expression(T[rel*,*min]),las=1)
```

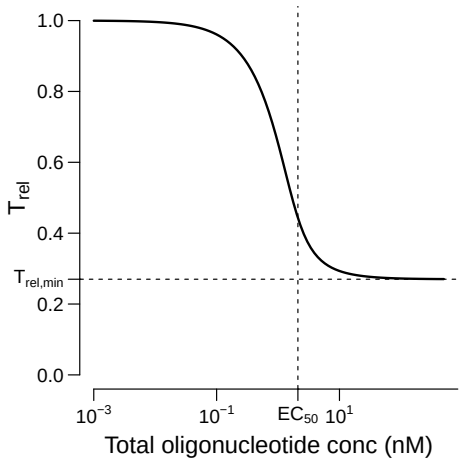

Figure 2c: The relative total target concentration (T_{rel}) is defined as the steady state level of total target in the presence of oligonucleotide divided by the target concentration in the absence of oligonucleotide. Dashed lines indicate 1-efficacy (horizontal) and EC_{50} (vertical).

Figure 2d: An optimal affinity

For a range of affinities `D1_seq` the EC_{50}-values are calculated by use of the R-function `EC50()` from the ASOmodels package:

```
> D1_seq <- 10^seq(-3,3,by=0.25)
> ECfit <- sapply(D1_seq,EC50)
```

When there is no coupling between the off-rates $k_{\mathrm{OT}\to\mathrm{O+T}}$ and $k_{\mathrm{OC}\to\mathrm{O+C}}$ then the value of $k_{\mathrm{OC}\to\mathrm{O+C}}$ is set in the param vector as the entry `'kC'`:

```
> parmsNO <- c(parms,kC=parms[kOpT]*parms[KdOT]/parms[alpha])
> names(parmsNO)[length(parmsNO)] <- kC
> ECfitNO <- sapply(D1_seq,EC50NO) #EC50 without coupling
```

For the range of affinities the corresponding EC_{50}-values are plotted:

```
> par(mar=c(3.2,3.4,0.1,0.1),bty=n,mgp=c(2,0.7,0),
+     las=1,cex.lab=1.25)
> plot(D1_seq,ECfit,log=xy,yaxt=n,type=l,xaxt=n,
+      xlab=expression(K[dOT]~(nM)),
+      ylab=expression(EC[50]~(nM)))
> lines(D1_seq,ECfitNO,lty=2)
> axis(2,at=c(2,20,200),labels=c(2,20,200),las=2)
> axis(1,at=10^pretty(log10(D1_seq)),
+      labels=pretty10expLP(10^pretty(log10(D1_seq)),drop.1=T),)
> legend(topleft,c(Coupling,No coupling),lty=c(1,2),bty=n)
```

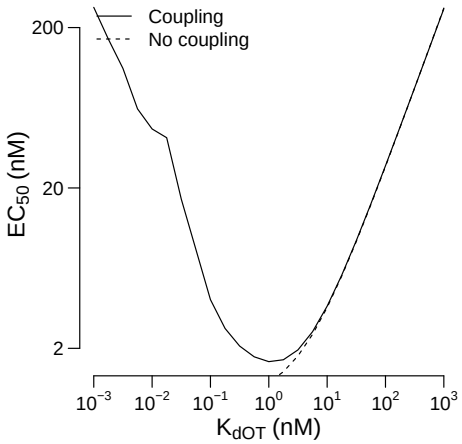

Figure 2d: EC_{50} as a function of the dissociation constant for the OT complex. A low K_{dOT} corresponds to a high affinity binding. Dashed line: no coupling of off-rates. Solid line: coupling of off-rates.

Experimental data figures

Figure 2e: Frieden et al. (2003)

```
> data(gapmers)
> dat <- data.frame(gapmers)
> colL <- c(red,orange,darkgreen,,darkblue,,
```

```
+           purple,,black)
> OLength <- sort(unique(dat$Oligo.length))
> #### We plot the data from Frieden et al, 2003
> dat.F <- dat[dat$Study=="Frieden 2003",]
> Flength <- dat.F$Oligo.length
> par(mar=c(3.2,3.4,0.1,0.1),bty=n,mgp=c(2,0.7,0),
+     las=1,cex.lab=1.25)
> fitpar <- function(x,y){
+   Fit <- lm(y ~ x + I(x^2))
+   coef <- coefficients(Fit)
+   f <- summary(Fit)$fstatistic
+   p <- signif(pf(f[1],f[2],f[3],lower.tail=F),2)
+   xmin <- round(-coef[2]/(2*coef[3]))
+   tmp <- as.expression(substitute(Optimal~T[m]%~~%x*degree*C,list(x=xmin)))
+   return(list(coef=coef,p=p,legend=tmp))
+ }
> Fx <- dat.F$Predicted.Tm; Fy <- dat.F$Dose.2nm
> FitF <- fitpar(Fx,Fy)
> Parfun <- function(x){FitF$coef[1]+FitF$coef[2]*x+FitF$coef[3]*x^2}
> curve(Parfun(x),min(Fx),max(Fx), lwd=1,col=grey,ylim=c(0,110),
+      ylab=activity (% of control),
+      xlab=expression(predicted~T[m]~(*degree*C)))
> legend(diff(par(usr)[1:2])/2+par(usr)[1],100,
+        c(Luciferase,paste(p =,FitF$p),FitF$legend),
+        bty=n,cex=1.1,yjust=0.4,xjust=0.5  )
> points(Fx,Fy,pch=19,cex=2,col=colL[Flength-11])
```

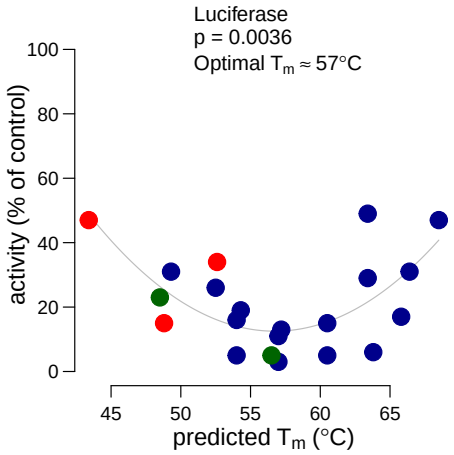

Figure 2e: 21 oligonucleotides targeted against the luciferase firefly gene.

Figure 2f: Stanton et al. (2012)

```
> #### We plot the data from Stanton et al 2012
> dat.S <- dat[dat[,1]=="Stanton 2012",]
> Slength <- dat.S$Oligo.length
> par(mar=c(3.2,3.4,0.1,0.1),bty=n,mgp=c(2,0.7,0),
+     las=1,cex.lab=1.25)
> Sx <- dat.S$Predicted.Tm; Sy <- dat.S$Dose.3nm
> FitS <- fitpar(Sx,Sy)
> Parfun <- function(x){FitS$coef[1]+FitS$coef[2]*x+FitS$coef[3]*x^2}
> curve(Parfun(x),min(Sx),max(Sx), lwd=1,col=grey,,ylim=c(0,110),
+      ylab=mRNA (% of control),
+      xlab=expression(predicted~T[m]~(*degree*C)))
> points(Sx,Sy, pch=19,col=colL[Slength-11],cex=2)
> legend(bottomright,as.character(sort(unique(OLength))),
+        pch=19,col=colL[sort(unique(OLength))-11],bg=white,
+        horiz=T,bty=n,cex=1.1)
> legend(diff(par(usr)[1:2])/2+par(usr)[1],100,
+        c(GR,paste(p =,FitS$p),FitS$legend),
+        bty=n,cex=1.1,yjust=0.4,xjust=0.5  )
```

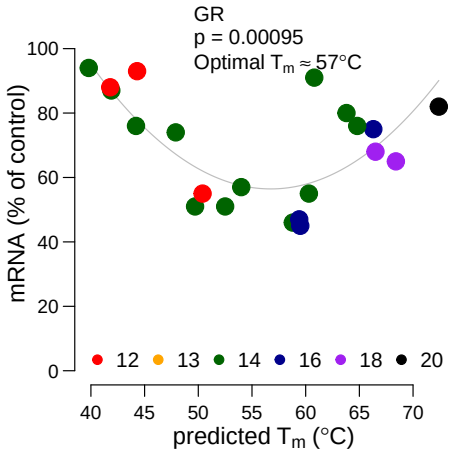

Figure 2f: 21 oligonucleotides targeted against the glucocorticoid receptor.

Figure 2g: Pedersen et al. (2013) (this work)

```
> ### We plot the data from Pedersen et al, 2013
> dat.P <- dat[dat$Study=="Pedersen 2013",]
> Plength <- dat.P$Oligo.length
> par(mar=c(3.2,3.4,0.1,0.1),bty=n,mgp=c(2,0.7,0),
```

```
+     las=1,cex.lab=1.25)
> Px <- dat.P$Predicted.Tm; Py <- dat.P$Dose.1nm
> FitP <- fitpar(Px,Py)
> Parfun <- function(x){FitP$coef[1]+FitP$coef[2]*x+FitP$coef[3]*x^2}
> curve(Parfun(x),min(Px),max(Px), lwd=1,col=grey,
+       xlab=expression(predicted~T[m]~(*degree*C)),
+      ylim=c(0,110),ylab=mRNA (% of control) )
> points(Px,Py,pch=19,cex=2,col=colL[Plength-11],)
> legend(diff(par(usr)[1:2])/2+par(usr)[1],100,
+        c(expression(APOB (*O[t]==1nM)),paste(p =,FitP$p),FitP$legend),
+        bty=n,cex=1.1,yjust=0.4,xjust=0.5 )
```

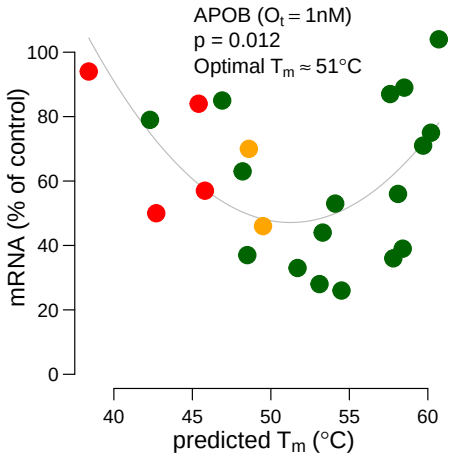

Figure 2g: 23 oligonucleotides targeted against apolipoprotein B.

Figure 2h: Pedersen et al. (2013) (this work)

```
> ### We plot the data from Pedersen et al, 2013
> dat.P <- dat[dat$Study=="Pedersen 2013",]
> Plength <- dat.P$Oligo.length
> par(mar=c(3.2,3.4,0.1,0.1),bty=n,mgp=c(2,0.7,0),
+     las=1,cex.lab=1.25)
> Px <- dat.P$Predicted.Tm; Py <- dat.P$Dose.25nm
> FitP <- fitpar(Px,Py)
> Parfun <- function(x){FitP$coef[1]+FitP$coef[2]*x+FitP$coef[3]*x^2}
> curve(Parfun(x),min(Px),max(Px), lwd=1,col=grey,
+       xlab=expression(predicted~T[m]~(*degree*C)),
+      ylim=c(0,110),ylab=mRNA (% of control) )
> points(Px,Py,pch=19,cex=2,col=colL[Plength-11],)
> legend(diff(par(usr)[1:2])/2+par(usr)[1],100,
```

```
+         c(expression(APOB (*O[t]==25nM)),paste(p =,FitP$p),FitP$legend),
+         bty=n,cex=1.1,yjust=0.4,xjust=0.5 )
```

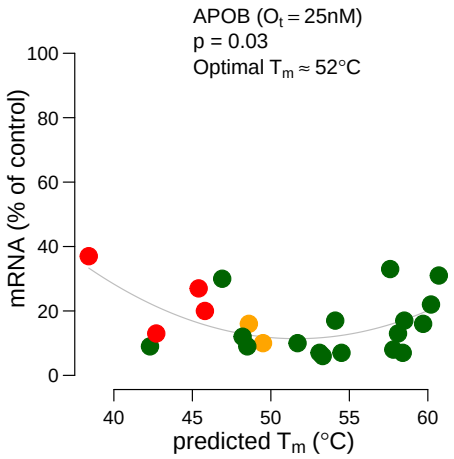

Figure 2h: 23 oligonucleotides targeted against apolipoprotein B.