Synthetic Genetic Elements for Improving Recombinant Protein Expression

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Renata Caikauskaite, Cristina Alexandru-Crivac, Ryan Taylor, Molly Smith, Kate Fewkes, Andy Racher, David James
Email: andy.racher@syngensys.com
SynGenSys Ltd, Sheffield, S1 2JE, UK

Abstract

High productivity cell lines are essential for improving the availability of mAb drugs. Recombinant gene transcription ultimately controls the recombinant protein production rate by mammalian cells. Synthetic promoters can significantly increase productivity and facilitate an optimal stoichiometry of recombinant polypeptide co-expression. We describe improved mAb expression in GS-KO CHO cells by using novel transcriptional hubs that utilise an optimal combination of synthetic promoters to further enhance expression without adversely affecting growth

SynGenSys's Third Generation Synthetic Promoters

- Rationally designed using rules formulated by SynGenSys
- Not variations of hCMV-MIE promoter
- Access more of CHO cell transcriptional landscape than hCMV-MIE promoter
- High level of sequence diversity
- Higher productivity, compared to hCMV-MIE, seen for a range of products when transcription driven by a CHO.SET® promoter

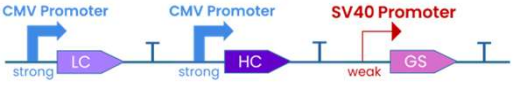
- Transcriptional Hub™ created by combining CHO.SET® promoters with synthetic selectable marker promoters (SMPs) engineered to minimise overlap in TFRE species
- Productivity using Transcriptional Hub™ higher than either CHO.SET® promoters or SMPs in isolation or standard hCMV-MIE/SV40E combination
- Transcriptional Hub™ concept offers approach to increasing selection stringency without the downside of using high concentrations of selective agents

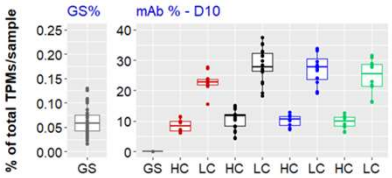
Introduction

The need to overcome limitations in patient access to biologics drives efforts to enhance productivity and reduce costs. In the bioreactor, product concentration is a function of cell specific production rate (Qp), mean viable cell concentration, and process duration. To date, most efforts have focussed upon improving the space-time yield of viable biomass with relatively few efforts focussing upon improving Qp. An assumption is that the widely used hCMV-MIE promoter, used to drive transgene transcription, cannot be improved upon. SynGenSys has formulated rules for designing mammalian promoters can be formulated and used them to build better promoters. These promoters are not variants or combinations of naturally occurring viral or endogenous promoters but true *de novo* designs leading to better Qp values compared to hCMV-MIE. Coupling CHO.SET® promoters with SMPs to minimise promoter interference increases productivity further.

1. The problem with standard promoter set-ups

Layout of typical vector for mAb production





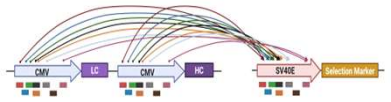
mRNA expression of CMV-driven light chain (LC) and heavy chain (HC) of 4 mAbs, and SV40-driven GS in a GS-KO CHO host cell line.
Fig 3 from Alexandru-Crivac, CN *et al*, 2024
https://doi.org/10.1101/2024.06.27.600995v1

- Low selectable marker (SM) gene expression is potentially growth limiting
- CMV competes with SV40E promoter, a strong promoter in its own right, for transcription factors causing substantial reduction in GS gene transcription
- Fixed transgene and selectable marker expression ratios when using standard CMV-CMV-SV40 set-up
- The need for high levels of selective drugs can cause selection for unwanted phenotypes

2. Transcriptional Hubs™: a route to higher productivities

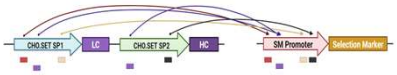
A standard approach to obtaining more productive cell lines is to use higher concentrations of selective drugs to increase selection stringency during CLC. This risks selection for unwanted phenotypes e.g. reduced growth rate or altered cellular redox potential. Increased expression of the selectable marker gene risks damping transgene transcription as both promoters compete for the same transcription factors (TFs). Transcriptional hubs, artificial assemblies of genes whose transcription is driven by distinct promoters, create the possibility of stringent selection using synthetic promoters designed with minimal overlap of TFREs and no increased levels of selective drugs.

High promoter interference
Many TF binding elements shared between CMV and industry relevant SM promoters



- hCMV-MIE and SV40E **promoters interfere** through shared TFREs, significantly dampening SV40E-driven transcription
- Co-located **CMV promoters may compete with each other** but retain activity due to TFRE redundancy
- Low SV40E activity leads to less Selectable Marker protein and **slower outgrowth** of desired cell populations
- This mechanism may favour clones with silenced CMV activity, leading to **low Qp levels**

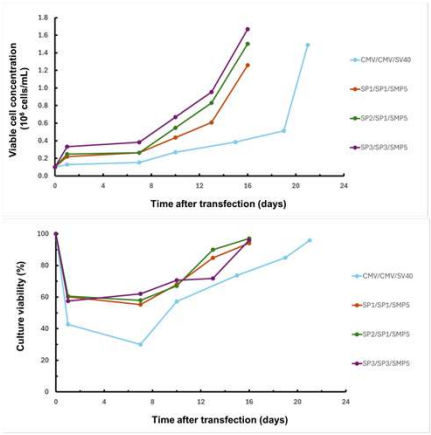
Tunable promoter interference in Transcriptional Hub™
***Fewer** TFREs shared between CHO.SET® and SM promoters*



- Designed with varying compositions of active CHO-specific TFREs
- Transgene and SM promoters are co-optimised for minimal interference and hence **rapid outgrowth of high Qp cells**.
- This increases the likelihood of both improved growth and higher productivity than cells containing the standard vector architecture
- No population dynamic pressure to select for unstable clones with silenced transgene synthetic promoter activity

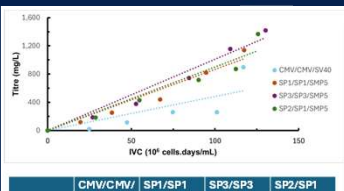
3. Transcriptional Hub™: faster recovery following transfection

- GS-KO CHO host transfected by nucleofection with vector encoding LC and HC genes for trastuzumab plus glutamine synthetase (GS) and allowed to recover according to vendor's guidelines
- Transcription of HC and LC genes driven by hCMV-MIE (CMV) or the CHO.SET promoters SP1, SP2 and SP3
- Transcription of the GS gene driven by either the SV40E promoter (SV40) or a synthetic promoter (SMP5) designed to form a Transcriptional Hub™ when paired with a CHO.SET® promoter
- Data are means of three replicates

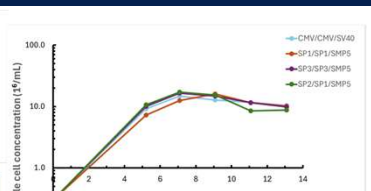


- Cells transfected with Transcriptional Hub™ vector recover faster compared to standard CMV/SV40 vector
- Cell concentration at day 10 0.5-0.7 x 10^6 viable cells/mL for cultures using Transcriptional Hub™ compared to 0.3 x 10^6 viable cells/mL for CMV/SV40 vector, with culture viabilities of about 70% compared to 59% for CMV/SV40
- For Transcriptional Hub™ vectors, cell concentration achieves 10^6/mL between days 13-16 compared to 19-21 for CMV/SV40 vector
- Similar results seen for CHO GS-KO hosts obtained from two different vendors

4. Transcriptional Hubs™: higher productivities



	CMV/CMV/ SV40	SP1/SP1 /SMP5	SP3/SP3 /SMP5	SP2/SP1 /SMP5
Qp (pg/(cell.d))	4.84	9.61	11.17	8.22
Titre (mg/L)	367	1140	1394	1277



- Trastuzumab production by GS-KO CHO host tested in fed-batch culture according to vendor's guidelines
- CHO.SET® promoters and Transcriptional Hub™ designed, through use of more powerful promoters to drive transgene transcription and reduced overlap of TFREs, to improve mAb gene expression of each cell. The expected result of an increase in Qp compared to the standard vector set-up was observed.
- Substantially improved harvest titre compared to the standard vector architecture primarily due to large increase in Qp and not IVC

5. Transcriptional Hubs™: answering the productivity question

- Work done at SynGenSys shows that treating the transgenes and SM gene as parts of a single system, a Transcriptional Hub, can result in substantial improvements in Qp, even over the use of strong synthetic promoters in isolation
  - Lower likelihood of interference between promoters as less competition for TFs
  - Good growth and fewer unwanted phenotypes as high selective agent concentrations are not required