Supplementary file: Co-Training based prediction of multi-label Protein-Protein Interactions

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1 Details of features used in CoMPPI

CoMPPI extracts 9 features from protein sequence, categorized into ordered and nominal features based on the necessity for additional extraction of contextualized information.

1.0.1 Ordered feature

Pre-trained word2vec: word2vec has been a classical embedding model for representation learning of sequence data. Here we use the pre-trained word2vec model that computed by the residue representation process of DeepFE-PPI, which applies skip-gram model and sets the corresponding n-gram as 1 to extract distinct residue interactions. The word2vec model was pre-trained with 558,590 sequences from Swiss-Prot database with various combinations of hyper-parameter values. In this work, we select the model with residue dimension 20 and window value 16.

Amino acid type: The electrostatic interaction and hydrophobic effect are dominant factors for amino acid preferences. Shen et al. calculated the electrostatic and hydrophobic interactions side chain of each amino acid with density-functional theory method B3LYP/6–31G∗ and molecular modeling approach, based on the similarity between this two factors, 26 amino acids can be clustering into eight class. Here, the one-hot-encoding of amino acid type is used as a part of the input features.

Position specific matrix: An abstraction of the alignment result of one sequence against a set of sequences, which reflects the probability of each amino acid at a specific position, each amino acid in the original sequence is represented as vector:

$$V_i = \sum_{j=1}^{20} W_j \times Y(i,j) \tag{1}$$

where i is the position of amino acid, j represents the 20 naturally amino acids, W_j is the weight for the appearance of amino acid j, Y is Dayhoff's matrix. Here we use PSI-blast to compute PSSM, as this alignment process requires an extra database, usage of PSSM feature is optional for PPI prediction.

1.0.2 Nominal feature

Conjoint triad: the combination of k-mer and amino acid type. k-mer denotes the length k substrings within a biological sequence and widely used in the analysis of proteomic and genomic data. During the computation of conjoint triad, the amino acids are divided into 7 classes. As its name indicates, conjoint triad select 3 as k value, each 3-mer is considered as a unit and all 3-mers are classified based on the class of their amino acids, hence there are $7^3 = 343$ entries in the representation of each protein sequence.

Amino acid composition (AAC): the fraction of each amino acid within a protein sequence, that is, each protein is represented as a vector with 20 entries, each entry is the occurrence of one amino acid within a sequence divided by the length of this sequence.

Pseudo-amino acid composition (PAAC): A combination of conventional AAC and discrete sequence correlation factors, for sequence $S = [a_1, a_2, ..., a_L]$, the λ-order correlation factor is defined as:

$$\begin{aligned} \theta_\lambda &= \frac{1}{L-\lambda} \sum_{i=1}^{L-\lambda} O(a_i, a_{i+\lambda}) \\ O(a_i, a_j) &= \frac{1}{3}[(H_1(R_j) - H_1(R_i))^2 \\ &\quad +(H_2(R_j) - H_2(R_i))^2 \\ &\quad +(M(R_j) - M(R_i))^2] \end{aligned} \tag{2}$$

$H_1(a), H_2(a)$ and $M(a)$ denotes the hydrophobicity, hydrophilicity and side-chain mass of a. The sequence is represented as a vector with length $20 + \lambda$:

$$v_i = \begin{cases} \frac{f_i}{\sum_{j=1}^{20} f_j + \omega \sum_{k=1}^{\lambda} \theta_k}, & i <= 20 \\ \frac{\omega \theta_{i-20}}{\sum_{j=1}^{20} f_j + \omega \sum_{k=1}^{\lambda} \theta_k}, & i > 20 \end{cases} \quad (3)$$
$$i \in 1, 2..., (20 + \lambda)$$

f_i denotes the frequency of ith amino acid in sequence. It is clear that λ should be smaller than L, in practice, Chou et al. set λ as 30, we follow the same strategy in this work.

CTDT: The transition descriptor in CTD (Composition, Transition and Distribution). For 13 physicochemical properties of amino acids, the amino acids are divided into three functional groups by each property, and transition (T) is the frequency of dipeptides. Finally, a vector with length 39 is computed by the original sequence.

ProVec1D: A feature derived from ProtVec, in which each 3-mer in protein sequence is mapped to a vector with length 100, ProVec1D sums the 100 components as single numeric value.

Global position information: the sum of position information of each amino acid in protein divided by sequence length, where the position information denotes the relative position of amino acid in corresponding sequence.

2 Statistical Tests

In order to test the whether the performance of each method are statistically significant. We conduct a two-sample t-test on all pairs of methods among CoMPPI, AFTGAN, GNN-PPI(KeAP), PIPR(optimized). The results shows that the improvement between CoMPPI and AFTGAN (pvalue 0.2697) are much larger than AFTGAN and GNN-PPI (pvalue 0.6343).

t-test value	CoMPPI	AFTGAN	GNN-PPI(KeAP)	PIPR(optimized)
CoMPPI	1.000000	0.269745	0.143898	0.004886
AFTGAN	0.269745	1.000000	0.634318	0.019317
GNN-PPI(KeAP)	0.143898	0.634318	1.000000	0.040580
PIPR(optimized)	0.004886	0.019317	0.040580	1.000000

Table S1: Accuracy comparison of models on SHS27K, SYS30K and SYS60K

Dataset	Partition scheme	Method				
		CoMPPI	AFTGAN	GNN-PPI (KEAP)	PIPR (optimized)	PIPR
SHS27K	Random	0.9359	0.9112	0.9121	0.8064	0.7090
	BFS	0.9021	0.8678	0.8700	0.8308	0.6966
	DFS	0.9243	0.8965	0.8961	0.8723	0.7087
SYS30K	Random	0.7988	0.7679	0.7508	0.6583	0.6722
	BFS	0.7904	0.7546	0.7546	0.7008	0.6354
	DFS	0.8585	0.8067	0.7943	0.7626	0.6728
SYS60K	Random	0.8268	0.8135	0.7484	0.7074	0.6923
	BFS	0.8217	0.7566	0.7524	0.7482	0.6347
	DFS	0.8813	0.8476	0.8358	0.7994	0.6671

Table S2: AU-PRC comparison of models on SHS27K, SYS30K and SYS60K

Dataset	Partition scheme	Method				
		CoMPPI	AFTGAN	GNN-PPI (KEAP)	PIPR (optimized)	PIPR
SHS27K	Random	0.9611	0.9382	0.9396	0.7715	0.6647
	BFS	0.9429	0.9196	0.9210	0.8781	0.8321
	DFS	0.958	0.9393	0.9400	0.9107	0.8545
SYS30K	Random	0.7381	0.7058	0.6321	0.4587	0.4792
	BFS	0.8391	0.814	0.814	0.768	0.75
	DFS	0.911	0.8562	0.8441	0.7963	0.7644
SYS60K	Random	0.7653	0.6735	0.623	0.5126	0.484
	BFS	0.8867	0.8396	0.8318	0.8195	0.7802
	DFS	0.9399	0.9158	0.9091	0.8744	0.8425

Table S3: AU-ROC comparison of models on SHS27K, SYS30K and SYS60K

Dataset	Partition scheme	Method				
		CoMPPI	AFTGAN	GNN-PPI (KEAP)	PIPR (optimized)	PIPR
SHS27K	Random	0.9802	0.9643	0.9655	0.8795	0.8382
	BFS	0.9648	0.9417	0.9440	0.9112	0.8919
	DFS	0.9762	0.9600	0.9595	0.9414	0.9169
SYS30K	Random	0.8762	0.8462	0.8210	0.6349	0.6704
	BFS	0.8778	0.8392	0.8392	0.7997	0.7835
	DFS	0.9390	0.8913	0.8767	0.8406	0.8266
SYS60K	Random	0.8982	0.8652	0.8231	0.7283	0.7128
	BFS	0.9099	0.8578	0.8488	0.8359	0.8125
	DFS	0.9572	0.9322	0.9246	0.8947	0.8891

Table S4: Micro-F1 comparison of CoMPPI with different trim length on SHS27K, SYS30K and SYS60K

Dataset	Partition scheme	Length				
		128	256	512	1024	2048
SHS27K	Random	0.9007	0.9019	0.9019	**0.9029**	0.9018
	BFS	0.7198	0.7145	0.7157	**0.7306**	0.7285
	DFS	0.7325	0.7389	**0.7417**	0.7297	0.7389
SYS30K	Random	**0.8803**	0.8779	0.8786	0.8769	0.8746
	BFS	0.7719	0.7652	**0.7692**	0.7712	0.7614
	DFS	0.7936	**0.8013**	0.8011	0.794	0.7947
SYS60K	Random	0.9024	0.9017	**0.9106**	0.9025	0.9077
	BFS	0.8268	**0.8311**	0.8298	0.8281	0.8296
	DFS	0.8561	0.8576	**0.8611**	0.8537	0.8596

Bold text indicates the best result in corresponding case.

Table S5: Ablation study of ordered features

Dataset	Partition scheme	w/o word2vec	w/o amino acid type	w/o PSSM
SHS27K	Random	0.8816	0.8856	0.8843
	BFS	0.7035	0.6960	0.6977
	DFS	0.6888	0.6927	0.6851
SYS30k	Random	0.8601	0.8601	0.8548
	BFS	0.7478	0.7457	0.7501
	DFS	0.7811	0.7797	0.7783
SYS60k	Random	0.8963	0.8935	0.8970
	BFS	0.8080	0.8076	0.8060
	DFS	0.8452	0.8466	0.8411

Table S6: Ablation study of Nominal features

Dataset	w/o Conjoing triad	w/o AAC	w/o PAAC	w/o CTDT
SHS27K	0.7318	0.7343	0.7304	0.7306
	0.5661	0.5624	0.5696	0.5729
	0.6116	0.6099	0.6108	0.6076
SYS30k	0.7816	0.7808	0.7812	0.7813
	0.6497	0.6610	0.6535	0.6641
	0.6817	0.6806	0.6833	0.6791
SYS60k	0.8079	0.8079	0.8092	0.8078
	0.7291	0.7334	0.7264	0.7329
	0.7731	0.7673	0.7687	0.7663

Table S7: The interactions in SYS30k that identified by CoMPPI and challenging for the previous methods

Protein A	Protein B	interaction type
4932.YER025W	4932.YER036C	reaction
4932.YCR011C	4932.YPL150W	expression
4932.YCR011C	4932.YMR139W	expression
4932.YBR103W	4932.YPR119W	inhibition
4932.YNR012W	4932.YPL204W	ptmod
4932.YNL317W	4932.YNR012W	ptmod
4932.YNL098C	4932.YNR012W	inhibition
4932.YNR012W	4932.YPR104C	expression
4932.YGR056W	4932.YPR119W	expression
4932.YGR056W	4932.YKR029C	ptmod
4932.YGR056W	4932.YMR199W	expression
4932.YDL029W	4932.YDL048C	expression
4932.YDL048C	4932.YDR510W	ptmod
4932.YBR229C	4932.YDL048C	inhibition
4932.YDL048C	4932.YPR120C	inhibition
4932.YDL048C	4932.YPR120C	expression
4932.YDL048C	4932.YDR059C	expression
4932.YDL048C	4932.YGR133W	expression
4932.YBR088C	4932.YDL048C	expression
4932.YDL048C	4932.YJL047C	ptmod
4932.YCR051W	4932.YDL048C	inhibition
4932.YCR051W	4932.YDL048C	expression
4932.YDL048C	4932.YHR042W	inhibition
4932.YBR049C	4932.YDL048C	inhibition
4932.YBR049C	4932.YDL048C	expression
4932.YJR127C	4932.YPR119W	expression
4932.YDL056W	4932.YJR127C	expression
4932.YDR177W	4932.YJR127C	expression
4932.YGR252W	4932.YJR127C	ptmod
4932.YGR252W	4932.YJR127C	inhibition
4932.YJR127C	4932.YKL203C	expression
4932.YDR510W	4932.YJR127C	ptmod
4932.YJR127C	4932.YKL161C	inhibition
4932.YJR127C	4932.YKL161C	expression
4932.YDL064W	4932.YJR127C	ptmod
4932.YDL064W	4932.YJR127C	expression
4932.YER024W	4932.YJR127C	inhibition
4932.YBR082C	4932.YJR127C	expression
4932.YJL112W	4932.YJR127C	ptmod

4932.YJR127C	4932.YOR039W	ptmod
4932.YJR127C	4932.YOL111C	activation
4932.YML081W	4932.YMR068W	expression
4932.YML081W	4932.YOR061W	ptmod
4932.YKL166C	4932.YML081W	inhibition
4932.YBR195C	4932.YML081W	inhibition
4932.YJL164C	4932.YML081W	inhibition
4932.YKL029C	4932.YML081W	inhibition
4932.YCR027C	4932.YML081W	expression
4932.YGR109C	4932.YML081W	expression
4932.YML081W	4932.YPL110C	expression
4932.YBR009C	4932.YMR068W	ptmod
4932.YGR052W	4932.YMR068W	inhibition
4932.YDL070W	4932.YMR068W	ptmod
4932.YCR083W	4932.YMR068W	expression
4932.YBR160W	4932.YMR068W	ptmod
4932.YBR009C	4932.YMR139W	ptmod
4932.YBR009C	4932.YMR139W	expression
4932.YBR009C	4932.YIL001W	ptmod
4932.YBR009C	4932.YPL216W	ptmod
4932.YBR009C	4932.YPL256C	ptmod
4932.YBR009C	4932.YKL198C	ptmod
4932.YBR009C	4932.YKL198C	inhibition
4932.YBR009C	4932.YKL198C	expression
4932.YBR009C	4932.YBR195C	inhibition
4932.YBR009C	4932.YBR160W	ptmod
4932.YBR009C	4932.YIL126W	ptmod
4932.YBR009C	4932.YOR233W	inhibition
4932.YBR009C	4932.YOR233W	expression
4932.YBR009C	4932.YGR252W	ptmod
4932.YBR009C	4932.YOL128C	inhibition
4932.YBR009C	4932.YOL128C	expression
4932.YGL242C	4932.YMR139W	expression
4932.YMR139W	4932.YOR267C	ptmod
4932.YMR139W	4932.YPR048W	expression
4932.YLR371W	4932.YMR139W	ptmod
4932.YMR139W	4932.YOL041C	ptmod
4932.YGL097W	4932.YMR139W	inhibition
4932.YLR077W	4932.YMR139W	inhibition
4932.YHL027W	4932.YMR139W	expression
4932.YDL213C	4932.YMR139W	ptmod
4932.YDL213C	4932.YMR139W	expression

4932.YMR139W	4932.YNL055C	ptmod
4932.YMR136W	4932.YMR139W	expression
4932.YLR430W	4932.YMR139W	expression
4932.YGL106W	4932.YGL242C	ptmod
4932.YGL242C	4932.YPL038W	expression
4932.YGL242C	4932.YLR210W	expression
4932.YGL242C	4932.YPL026C	expression
4932.YGL242C	4932.YOR061W	ptmod
4932.YER028C	4932.YPL021W	expression
4932.YGL194C	4932.YPL021W	expression
4932.YDR043C	4932.YPL021W	expression
4932.YPL021W	4932.YPR186C	expression
4932.YER130C	4932.YLR399C	inhibition
4932.YLR399C	4932.YOR194C	reaction
4932.YGL254W	4932.YLR399C	inhibition
4932.YBR219C	4932.YCR065W	ptmod
4932.YCR065W	4932.YDL155W	expression
4932.YCR065W	4932.YIL001W	expression
4932.YGR233C	4932.YHR082C	inhibition
4932.YDR216W	4932.YGR233C	inhibition
4932.YGR233C	4932.YPR200C	expression
4932.YGL008C	4932.YGR233C	expression
4932.YGR233C	4932.YNL167C	inhibition
4932.YER045C	4932.YGR233C	inhibition
4932.YER111C	4932.YML027W	expression
4932.YER111C	4932.YLR375W	expression
4932.YER111C	4932.YKL062W	expression
4932.YER111C	4932.YMR136W	expression
4932.YDR129C	4932.YER111C	expression
4932.YBR089C-A	4932.YPR013C	expression
4932.YBR066C	4932.YBR089C-A	expression
4932.YIL001W	4932.YKL198C	expression
4932.YHR205W	4932.YKL198C	inhibition
4932.YBR049C	4932.YKL198C	inhibition
4932.YIL001W	4932.YNL030W	ptmod
4932.YIL001W	4932.YKR090W	ptmod
4932.YDR096W	4932.YIL001W	inhibition
4932.YDR096W	4932.YIL001W	expression
4932.YGR109C	4932.YIL001W	ptmod
4932.YGR109C	4932.YIL001W	expression
4932.YIL001W	4932.YMR104C	expression
4932.YIL001W	4932.YPL213W	expression

4932.YHR102W	4932.YIL001W	ptmod
4932.YER045C	4932.YIL001W	expression
4932.YIL001W	4932.YNL068C	expression
4932.YNL030W	4932.YPL141C	expression
4932.YCR051W	4932.YMR136W	expression
4932.YCR051W	4932.YGL209W	expression
4932.YBR276C	4932.YCR051W	expression
4932.YCR051W	4932.YEL009C	expression
4932.YCR051W	4932.YGL106W	ptmod
4932.YAL040C	4932.YCR051W	expression
4932.YCR051W	4932.YPL038W	inhibition
4932.YCR051W	4932.YPL038W	expression
4932.YCR051W	4932.YMR213W	expression
4932.YBR066C	4932.YCR051W	expression
4932.YCR051W	4932.YDR039C	expression
4932.YCR051W	4932.YKL126W	inhibition
4932.YCR051W	4932.YKL190W	inhibition
4932.YJL105W	4932.YMR136W	ptmod
4932.YJL105W	4932.YMR136W	expression
4932.YMR136W	4932.YMR182C	expression
4932.YLR131C	4932.YMR136W	expression
4932.YKR008W	4932.YMR136W	ptmod
4932.YMR042W	4932.YMR136W	expression
4932.YGR232W	4932.YMR136W	ptmod
4932.YGR232W	4932.YMR136W	expression
4932.YHR079C	4932.YMR136W	expression
4932.YDL070W	4932.YJL105W	ptmod
4932.YHR128W	4932.YJL105W	expression
4932.YIL036W	4932.YJL105W	expression
4932.YEL009C	4932.YOR113W	inhibition
4932.YLR113W	4932.YOR113W	inhibition
4932.YBR229C	4932.YOR113W	inhibition
4932.YHR030C	4932.YOR113W	inhibition
4932.YDR139C	4932.YNL031C	activation
4932.YJR059W	4932.YOR133W	ptmod
4932.YDR247W	4932.YOR133W	ptmod
4932.YGR203W	4932.YIL061C	expression
4932.YIL061C	4932.YJL225C	activation
4932.YIL061C	4932.YJL225C	inhibition
4932.YDR545W	4932.YIL061C	activation
4932.YIL061C	4932.YPL283C	activation
4932.YIL061C	4932.YPL283C	inhibition

4932.YIL061C	4932.YJL138C	activation
4932.YIL061C	4932.YJL138C	inhibition
4932.YHR079C	4932.YIL061C	expression
4932.YGR296W	4932.YIL061C	activation
4932.YIL061C	4932.YOR233W	ptmod
4932.YEL009C	4932.YPL213W	expression
4932.YJL014W	4932.YPL213W	activation
4932.YNL307C	4932.YPL213W	inhibition
4932.YKL161C	4932.YPL213W	expression
4932.YNL128W	4932.YPL213W	expression
4932.YKL074C	4932.YPL213W	activation
4932.YNL093W	4932.YPL213W	ptmod
4932.YPL213W	4932.YPL239W	ptmod
4932.YDR098C	4932.YEL030W	expression
4932.YDL213C	4932.YLL067C	activation
4932.YDL213C	4932.YLL067C	inhibition
4932.YBR028C	4932.YBR119W	ptmod
4932.YBL056W	4932.YBR028C	inhibition
4932.YBR028C	4932.YJL095W	catalysis
4932.YBR028C	4932.YGR052W	inhibition
4932.YBR028C	4932.YDR490C	reaction
4932.YBR028C	4932.YHL027W	inhibition
4932.YBR028C	4932.YHL027W	expression
4932.YBR028C	4932.YHR086W	ptmod
4932.YMR182C	4932.YMR250W	expression
4932.YDL064W	4932.YMR182C	ptmod
4932.YMR182C	4932.YPL216W	inhibition
4932.YDR174W	4932.YMR182C	expression
4932.YKL092C	4932.YMR182C	inhibition
4932.YKL161C	4932.YMR182C	inhibition
4932.YBR082C	4932.YMR182C	expression
4932.YMR182C	4932.YPR120C	inhibition
4932.YEL037C	4932.YMR182C	activation
4932.YJL164C	4932.YMR182C	inhibition
4932.YCL024W	4932.YNL154C	catalysis
4932.YNL154C	4932.YOL128C	catalysis
4932.YCL024W	4932.YLR077W	inhibition
4932.YCL024W	4932.YPR022C	expression
4932.YCL024W	4932.YHR084W	expression
4932.YCL024W	4932.YER075C	inhibition
4932.YCL024W	4932.YMR116C	ptmod
4932.YCL024W	4932.YMR116C	activation

4932.YBR010W	4932.YCL024W	ptmod
4932.YCL024W	4932.YLR466W	activation
4932.YAL007C	4932.YCL024W	reaction
4932.YCL024W	4932.YOR107W	inhibition
4932.YCL024W	4932.YML027W	expression
4932.YCL024W	4932.YHR206W	ptmod
4932.YCL024W	4932.YLL001W	ptmod
4932.YCL024W	4932.YLL001W	inhibition
4932.YCL024W	4932.YHR086W	ptmod
4932.YCL024W	4932.YHR086W	expression
4932.YCL024W	4932.YPR048W	expression
4932.YCL024W	4932.YPR186C	expression
4932.YIL126W	4932.YNL167C	inhibition
4932.YIL126W	4932.YNL167C	expression
4932.YER028C	4932.YIL126W	inhibition
4932.YHL035C	4932.YIL126W	expression
4932.YOR107W	4932.YOR233W	inhibition
4932.YKL124W	4932.YOR233W	expression
4932.YJL164C	4932.YOR233W	inhibition
4932.YMR036C	4932.YOR233W	expression
4932.YAL007C	4932.YOR233W	reaction
4932.YAL007C	4932.YOR233W	inhibition
4932.YAL007C	4932.YOR233W	catalysis
4932.YBR276C	4932.YOR233W	expression
4932.YLR113W	4932.YOR233W	inhibition
4932.YDL006W	4932.YOR233W	inhibition
4932.YCR018C	4932.YHL027W	expression
4932.YHR030C	4932.YPL141C	inhibition
4932.YBR023C	4932.YPL141C	expression
4932.YKL193C	4932.YPL141C	expression
4932.YDR456W	4932.YPL141C	expression
4932.YGL097W	4932.YPL141C	inhibition
4932.YKR099W	4932.YPL141C	inhibition
4932.YGR232W	4932.YPL141C	inhibition
4932.YKL124W	4932.YPL141C	expression
4932.YDR096W	4932.YPL141C	expression
4932.YOR208W	4932.YPL141C	inhibition
4932.YOR016C	4932.YPL141C	inhibition
4932.YLR371W	4932.YPL141C	ptmod
4932.YNL180C	4932.YPL141C	inhibition
4932.YDR177W	4932.YNL250W	activation
4932.YDR177W	4932.YPR022C	expression

4932.YDR177W	4932.YMR224C	activation
4932.YDR177W	4932.YLR182W	ptmod
4932.YDR177W	4932.YHR205W	expression
4932.YNL021W	4932.YPR022C	inhibition
4932.YDR216W	4932.YNL021W	inhibition
4932.YNL021W	4932.YOR351C	inhibition
4932.YGL104C	4932.YNL021W	inhibition
4932.YGL104C	4932.YNL021W	expression
4932.YNL021W	4932.YNL027W	inhibition
4932.YHR128W	4932.YNL021W	inhibition
4932.YBR097W	4932.YJR066W	reaction
4932.YBR241C	4932.YJR066W	expression
4932.YGR052W	4932.YJR066W	inhibition
4932.YIL121W	4932.YJR066W	expression
4932.YGL049C	4932.YJR066W	ptmod
4932.YJL098W	4932.YJR066W	ptmod
4932.YDR247W	4932.YJR066W	inhibition
4932.YJR066W	4932.YMR284W	ptmod
4932.YJR066W	4932.YMR080C	ptmod
4932.YJR066W	4932.YMR080C	activation
4932.YBR241C	4932.YMR042W	expression
4932.YBR241C	4932.YLR305C	expression
4932.YBR241C	4932.YPL249C	inhibition
4932.YBR241C	4932.YPL249C	expression
4932.YBR241C	4932.YLR240W	expression
4932.YBR164C	4932.YHR064C	expression
4932.YBR164C	4932.YKL126W	inhibition
4932.YBR164C	4932.YFR019W	ptmod
4932.YBR164C	4932.YLR113W	inhibition
4932.YDL079C	4932.YKL193C	expression
4932.YBR212W	4932.YDL079C	ptmod
4932.YDL079C	4932.YDR466W	catalysis
4932.YBR110W	4932.YDL079C	ptmod
4932.YBR110W	4932.YDL079C	inhibition
4932.YDL079C	4932.YOR090C	ptmod
4932.YDL006W	4932.YDL079C	inhibition
4932.YDL079C	4932.YDR477W	ptmod
4932.YDL079C	4932.YDR096W	expression
4932.YDL079C	4932.YMR213W	ptmod
4932.YDL079C	4932.YMR213W	expression
4932.YDL079C	4932.YJR060W	expression
4932.YDL079C	4932.YKR001C	ptmod

4932.YDL079C	4932.YKR001C	inhibition
4932.YDL079C	4932.YDR099W	ptmod
4932.YDL079C	4932.YKR029C	ptmod
4932.YBR038W	4932.YDL079C	expression
4932.YBR066C	4932.YDL079C	expression
4932.YER103W	4932.YMR186W	expression
4932.YER103W	4932.YMR120C	expression
4932.YLR090W	4932.YPL106C	inhibition
4932.YCR083W	4932.YPL106C	expression
4932.YPL106C	4932.YPR165W	expression
4932.YDR389W	4932.YNL098C	inhibition
4932.YDL145C	4932.YNL098C	inhibition
4932.YGR100W	4932.YNL098C	inhibition
4932.YNL098C	4932.YOR089C	ptmod
4932.YKR014C	4932.YNL098C	ptmod
4932.YDR524C	4932.YNL098C	inhibition
4932.YKL092C	4932.YNL098C	inhibition
4932.YML059C	4932.YNL098C	expression
4932.YIL118W	4932.YLR093C	activation
4932.YIL118W	4932.YPL204W	ptmod
4932.YBR264C	4932.YIL118W	ptmod
4932.YIL118W	4932.YKL161C	inhibition
4932.YIL118W	4932.YOL101C	inhibition
4932.YHR023W	4932.YIL118W	ptmod
4932.YBL105C	4932.YGR252W	inhibition
4932.YBR160W	4932.YGR252W	ptmod
4932.YBR160W	4932.YGR252W	expression
4932.YGR252W	4932.YPR186C	ptmod
4932.YGR252W	4932.YPR186C	inhibition
4932.YGR232W	4932.YGR252W	ptmod
4932.YGR252W	4932.YNL031C	ptmod
4932.YGR252W	4932.YLR240W	ptmod
4932.YGR252W	4932.YOL012C	ptmod
4932.YDR253C	4932.YGR252W	inhibition
4932.YBR160W	4932.YDL132W	ptmod
4932.YBR160W	4932.YKL092C	ptmod
4932.YBR160W	4932.YNL298W	ptmod
4932.YBR160W	4932.YNL167C	inhibition
4932.YBR160W	4932.YJL006C	ptmod
4932.YBR160W	4932.YIL036W	inhibition
4932.YBR160W	4932.YOL012C	ptmod
4932.YBR160W	4932.YOL068C	ptmod

4932.YBR160W	4932.YBR234C	ptmod
4932.YBR160W	4932.YGL003C	ptmod
4932.YBR160W	4932.YGL019W	ptmod
4932.YBR160W	4932.YLR357W	ptmod
4932.YBR160W	4932.YLR357W	expression
4932.YBL084C	4932.YBR160W	ptmod
4932.YBL021C	4932.YNL261W	activation
4932.YBL021C	4932.YMR176W	activation
4932.YBL021C	4932.YHR119W	ptmod
4932.YBL021C	4932.YHR119W	activation
4932.YBL021C	4932.YDL056W	ptmod
4932.YBL021C	4932.YBR133C	ptmod
4932.YBL021C	4932.YHR079C	expression
4932.YAL017W	4932.YPR013C	expression
4932.YAL017W	4932.YDL155W	expression
4932.YER031C	4932.YML059C	expression
4932.YDR036C	4932.YDR216W	inhibition
4932.YDR216W	4932.YGR232W	inhibition
4932.YDR216W	4932.YOR122C	expression
4932.YDR216W	4932.YPR034W	expression
4932.YBR245C	4932.YER148W	activation
4932.YBR044C	4932.YDR247W	ptmod
4932.YLL024C	4932.YML064C	expression
4932.YDR026C	4932.YLL024C	activation
4932.YLL024C	4932.YLR028C	activation
4932.YLL024C	4932.YLR028C	expression
4932.YHR084W	4932.YKR055W	expression
4932.YKL126W	4932.YNL307C	inhibition
4932.YDR270W	4932.YNL307C	expression
4932.YNL307C	4932.YPL203W	inhibition
4932.YGL227W	4932.YNL307C	expression
4932.YKL124W	4932.YNL307C	expression
4932.YJL187C	4932.YNL307C	inhibition
4932.YDL213C	4932.YNL307C	ptmod
4932.YDR432W	4932.YNL307C	ptmod
4932.YNL307C	4932.YOR211C	inhibition
4932.YAL007C	4932.YNL307C	reaction
4932.YAL007C	4932.YNL307C	inhibition
4932.YAL007C	4932.YNL307C	catalysis
4932.YNL307C	4932.YOR107W	inhibition
4932.YLR138W	4932.YNL307C	expression
4932.YBR038W	4932.YNL307C	expression

4932.YJR009C	4932.YJR040W	expression
4932.YHR086W	4932.YPR010C	activation
4932.YHR086W	4932.YPR152C	inhibition
4932.YER107C	4932.YHR086W	activation
4932.YHR086W	4932.YIL177C	activation
4932.YHR086W	4932.YLR467W	activation