Supplementary Table 1：For single LD scenarios, including cases of high correlation, low correlation, and unbalanced correlation,

SNP	MAF	r matrix					
1	0.2	1	0.9	0.9	0.9	0.9	0.9
2	0.2		1	0.9	0.9	0.9	0.9
3	0.2			1	0.9	0.9	0.9
4	0.2				1	0.9	0.9
5	0.2					1	0.9
6	0.2						1

SNP	MAF	r matrix					
1	0.2	1	0.3	0.3	0.3	0.3	0.3
2	0.2		1	0.3	0.3	0.3	0.3
3	0.2			1	0.9	0.3	0.3
4	0.2				1	0.3	0.3
5	0.2					1	0.3
6	0.2						1

SNP	MAF	r matrix					
1	0.2	1	0.3	0.9	0.3	0.9	0.3
2	0.2		1	0.3	0.9	0.3	0.9
3	0.2			1	0.3	0.9	0.3
4	0.2				1	0.3	0.9
5	0.2					1	0.3
6	0.2						1

Note: For the number of other SNPs in a single LD block, the expansion is based on the above

Supplementary Table 2**:** For mutiple LD scenarios, including cases of high correlation, low correlation, and unbalanced correlation,

high correlation:

SNP	MAF	r matrix																													
1	0.2	1	0.9	0.9	0.9	0.9	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0.2		1	0.9	0.9	0.9	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0.2			1	0.9	0.9	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0.2				1	0.9	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0.2					1	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0.2						1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0.4							**1**	**0.8**	**0.8**	**0.8**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0.4								**1**	**0.8**	**0.8**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0.4									**1**	**0.8**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.4										**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0.25											1	0.9	0.9	0.9	0.9	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0.25												1	0.9	0.9	0.9	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0.25													1	0.9	0.9	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0.25														1	0.9	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0.25															1	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0.25																1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0.3																	**1**	**0.8**	**0.8**	**0.8**	0	0	0	0	0	0	0	0	0	0	0	0
18	0.3																		**1**	**0.8**	**0.8**	0	0	0	0	0	0	0	0	0	0	0	0
19	0.3																			**1**	**0.8**	0	0	0	0	0	0	0	0	0	0	0	0

20	0.3																					**1**	0	0	0	0	0	0	0	0	0	0
21	0.1																					1	0.9	0.9	0.9	0.9	0.9	0	0	0	0
22	0.1																						1	0.9	0.9	0.9	0.9	0	0	0	0
23	0.1																							1	0.9	0.9	0.9	0	0	0	0
24	0.1																								1	0.9	0.9	0	0	0	0
25	0.1																									1	0.9	0	0	0	0
26	0.1																										1	0	0	0	0
27	0.15																											**1**	**0.8**	**0.8**	**0.8**
28	0.15																												**1**	**0.8**	**0.8**
29	0.15																													**1**	**0.8**
30	0.15																														**1**

Note: The 24-block pattern is made up of 4 identical 6-block patterns and is a high correlated simulation scenario with optional K values experiment.

low correlation:

SNP	**MAF**	**r matrix**																													
1	0.2	1	0.3	0.3	0.3	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0.2		1	0.3	0.3	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0.2			1	0.3	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0.2				1	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0.2					1	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0.2						1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

7	0.4							**1**	**0.5**	**0.5**	**0.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0.4								**1**	**0.5**	**0.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0.4									**1**	**0.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.4										**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0.25											1	0.3	0.3	0.3	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0.25												1	0.3	0.3	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0.25													1	0.3	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0.25														1	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0.25															1	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0.25																1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0.3																	**1**	**0.5**	**0.5**	**0.5**	0	0	0	0	0	0	0	0	0	0	0
18	0.3																		**1**	**0.5**	**0.5**	0	0	0	0	0	0	0	0	0	0	0
19	0.3																			**1**	**0.5**	0	0	0	0	0	0	0	0	0	0	0
20	0.3																				**1**	0	0	0	0	0	0	0	0	0	0	0
21	0.1																					1	0.3	0.3	0.3	0.3	0.3	0	0	0	0	0
22	0.1																						1	0.3	0.3	0.3	0.3	0	0	0	0	0
23	0.1																							1	0.3	0.3	0.3	0	0	0	0	0
24	0.1																								1	0.3	0.3	0	0	0	0	0
25	0.1																									1	0.3	0	0	0	0	0
26	0.1																										1	0	0	0	0	0
27	0.15																											**1**	**0.5**	**0.5**	**0.5**	
28	0.15																												**1**	**0.5**	**0.5**	

29	0.15																													**1**	**0.5**
30	0.15																														**1**

Note: The 24-block pattern is made up of 4 identical 6-block patterns.

unbalanced correlation:

SNP	**MAF**	**r matrix**																													
1	0.2	1	0.3	0.9	0.3	0.9	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0.2		1	0.3	0.9	0.3	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0.2			1	0.3	0.9	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0.2				1	0.3	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0.2					1	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0.2						1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0.4							**1**	**0.5**	**0.8**	**0.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0.4								**1**	**0.5**	**0.8**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0.4									**1**	**0.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0.4										**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0.25											1	0.3	0.9	0.3	0.9	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0.25												1	0.3	0.9	0.3	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0.25													1	0.3	0.9	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0.25														1	0.3	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0.25															1	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0.25																1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

17	0.3																	**1**	**0.5**	**0.8**	**0.5**	0	0	0	0	0	0	0	0	0	0
18	0.3																		**1**	**0.5**	**0.8**	0	0	0	0	0	0	0	0	0	0
19	0.3																			**1**	**0.5**	0	0	0	0	0	0	0	0	0	0
20	0.3																				**1**	0	0	0	0	0	0	0	0	0	0
21	0.1																					1	0.3	0.9	0.3	0.9	0.3	0	0	0	0
22	0.1																						1	0.3	0.9	0.3	0.9	0	0	0	0
23	0.1																							1	0.3	0.9	0.3	0	0	0	0
24	0.1																								1	0.3	0.9	0	0	0	0
25	0.1																									1	0.3	0	0	0	0
26	0.1																										1	0	0	0	0
27	0.15																											**1**	**0.5**	**0.8**	**0.5**
28	0.15																												**1**	**0.5**	**0.8**
29	0.15																													**1**	**0.5**
30	0.15																														**1**

Note: The 24-block pattern is made up of 4 identical 6-block patterns.

Supplementary Table 3: Three complex scenarios for 120SNP

Case1: The structure consists of four modules: six-block patterns from a high correlation scenario(30snps), six-block patterns from a low correlation scenario(30snps), six-block patterns from an unbalanced correlation scenario(30snps), and six-block patterns from another high correlation scenario(30snps). There is zero correlation between the four module groups.

Case2: The structure consists of two sets of combined modules, each formed by a high-correlation 4-block scenario (20 SNPs), a low-correlation 4-block scenario (20 SNPs), and an unbalanced-correlation 4-block scenario (20 SNPs). There is zero correlation between the module groups

Case3: The structure consists of four combined sets, each formed by a high-correlation 2-block scenario (10 SNPs), a low-correlation 2-block scenario (10 SNPs), and an unbalanced-correlation 2-block scenario (10 SNPs), with no correlation between the modules. And it’s also the complex correlated simulation scenario with optional K values experiment.