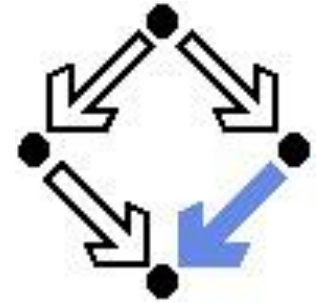# Algebraic and Discrete Methods in Biology

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First Order Logic

Exercises

Find free variables in the following formulae

1. $\forall x.(p(x) \rightarrow \exists y.\neg q(f(x), y, f(y)))$

2. $\forall x(\exists y.r(x, f(y)) \rightarrow r(x, y))$

3. $\forall z.(p(z) \rightarrow \exists y.(\exists x.q(x, y, z) \vee q(z, y, x)))$

4. $\forall z \exists u \exists y.(q(z, u, g(u, y)) \vee r(u, g(z, u)))$

5. $\forall z \exists x \exists y(q(z, u, g(u, y)) \vee r(u, g(z, u)))$

Which of the following formulae is a formalization of the sentence: "There is a computer which is not used by any student"

$$\exists x.(Computer(x) \land \forall y.(\neg Student(y) \land \neg Uses(y, x)))$$

$$\exists x.(Computer(x) \rightarrow \forall y.(Student(y) \rightarrow \neg Uses(y, x)))$$

$$\exists x.(Computer(x) \land \forall y.(Student(y) \rightarrow \neg Uses(y, x)))$$

Define an appropriate language and formalize the following sentences

1. All Students are smart.

2. There exists a student.

3. There exists a smart student.

4. Every student loves some student.

5. Every student loves some other student.

6. There is a student who is loved by every other student.

Define an appropriate language and formalize the following sentences

someone likes Mary.

nobody likes Mary.

nobody loves Bob but Bob loves Mary.

if David loves someone, then he loves Mary.

if someone loves David, then he (someone) loves also Mary.

everybody loves David or Mary.