Consider the following translation key:

P _ : _ is a pelican

Q _ : _ is a bird

R _ : _ is a mammal

S _ _ : _ flies higher than _

a: Petros

b: Polly

1. Match the sentences in English to their translation in predicate logic given the translation key above:

- Petros is a bird.
- Petros is not a mammal.
- Every pelican is a bird.
- No mammal is a pelican.
- Some birds are pelicans.
- Polly flies higher than Petros
- $\neg\exists x(Rx \wedge Px)$
- Sba
- $\neg Ra$
- $\exists x(Qx \wedge Px)$
- $\forall x(Px \rightarrow Qx)$
- Qa

2. Determine which of the following are atomic formulas, non-atomic formulas, or neither:

(a) $\forall x \forall y Rxy$

(b) $\forall y_1 QRy_1$

(c) Px

(d) $\exists x(Qa \rightarrow Pf)$

(e) $\forall(Px \rightarrow T_2x)$

(f) $\forall x(Px \rightarrow \exists y Tx)$

3. Mark the free variables in the following formulas:

   (a) $\exists x(Py \vee Qy)$

   (b) $\forall y \exists x Txyza$

   (c) $\forall z \forall x_1(Rx_1z \rightarrow \exists x Txz)$

   (d) $\exists z_1 \forall x(Tx \supset S_4z_1) \rightarrow \exists x(T_1x \wedge S_4z_1)$

4. Which of the above are open formulas? Which are closed?

5. Translate the following sentences given the key above:

   (a) Every pelican is a bird but not every bird is a pelican.

   (b) Unless Petros is a mammal, all pelicans are birds.

   (c) Something flies higher than something else.

   (d) Nothing flies higher than itself.

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