19. Consider a TM M that works as follows. On input x, M computes the sequence $f(x), f(f(x)), f(f(f(x))), \cdots$, until the sequence hits 1. If it hits 1, M accepts. Even if M runs forever on some input, we can use H to determine in a finite number of steps whether M accepts or not.

Now, consider another TM N that works as follows. On input w, it neglects w and for each natural number i, starting at 1, runs H on $< M, i >$. If H rejects, then N accepts. If H accepts, then N proceeds onto the next natural number. Clearly, N accepts iff there were a counter-example to the $3x + 1$ problem, else it runs forever.

Now, run H on $< N, w >$. If H accepts, then it indicates that there is a counter-example to the $3x+1$ problem; we can now run N confidently and hope to obtain the actual counter-example. If H rejects, then that indicates that no such counter-example exists.