Czech
Technical University
in Prague

F3

Faculty of Electrical Engineering
Department of Cybernetics

Named Entity Recognition in Czech

Bachelor's Thesis of
Radek Štulc

Supervisor: **Ing. Herbert Ullrich**
Study program: **Open Informatics**
Specialization: **Artificial Intelligence and Computer Science**
May 2024

BACHELOR'S THESIS ASSIGNMENT

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Department / Institute: **Department of Cybernetics**

Study program: **Open Informatics**

Specialisation: **Artificial Intelligence and Computer Science**

II. Bachelor's thesis details

Bachelor's thesis title in English:

Named Entity Recognition in Czech

Bachelor's thesis title in Czech:

Rozpoznávání pojmenovaných entit v českém jazyce

Guidelines:

The overall task of this thesis is to research the Natural-Language-Processing challenge of Named Entity Recognition, its solutions based on Language Models with Transformer architecture and their application to Czech training data to obtain and publish a re-useable solver for the task.
1) Explore state-of-the-art machine learning methods dealing with the task of Named Entity Recognition and other related NLP tasks in Czech language and in English (with the focus on their reproducibility in Czech and other Slavonic languages).
2) Perform a comparatory analysis of the availabe data and solution architectures.
3) Based on the findings, train multiple classifiers for the task and compare their performance.
4) Perform an empirical analysis of how your best-performing solution performs on general real-world data (such as news articles), describe your findings, and propose how to address possible issues.
5) Release the model publicly for a streamlined open usage.

Bibliography / sources:

[1] Jana Straková, Milan Straka, and Jan Hajic: "Neural Architectures for Nested NER through Linearization". In Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics
[2] Ikuyi Yamada et al.: "LUKE: Deep Contextualized Entity Representations with Entity-aware Self-attention" (2020). Proceedings of the 2020 Conference on Empirical Methods in Natural Language Processing (EMNLP)
[3] Besnik Fetahu, Sudipta Kar, Zhiyu Chen, Oleg Rokhlenko, and Shervin Malmasi. 2023. "SemEval-2023 Task 2: Fine-grained Multilingual Named Entity Recognition (MultiCoNER 2)". In Proceedings of the 17th International Workshop on Semantic Evaluation (SemEval-2023)

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Date of bachelor's thesis assignment: **19.01.2024** Deadline for bachelor thesis submission: **24.05.2024**

Assignment valid until: **21.09.2025**

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III. Assignment receipt

The student acknowledges that the bachelor's thesis is an individual work. The student must produce his thesis without the assistance of others, with the exception of provided consultations. Within the bachelor's thesis, the author must state the names of consultants and include a list of references.

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Acknowledgements

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Declaration

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Abstract

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Abstrakt

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Tables

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Chapter 1
Introduction

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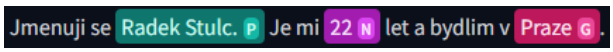

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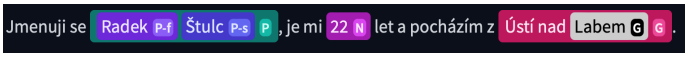

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1.1 Motivations

^j §nL9´¸ °n}eLJ 9ehn § 0®0}´nj0 _ Hnj j0H§0L §\}n«X\ §\0 ^j§0}j0§ 9jL « 0 _§ L9_e´ §n X9§\0} _jTn}h9§_nju in nj0 °n«eL @0 «}q}_ 0L §\9§ jn§ 9ee §_ _jTn}h9§_nj _ T9H§«9ee´ Hn}}0H§J H}09§_jX h_ _jTn}h9§_nj 9jL §\0 L9jX0} nT q}09L_jX «H\ h_ _jTn}h9§_nju ¦n Hnh@9§ §_ J h9j´ an«}j9e_ § @0X9j §n T9H§]H\0Hc He9_h J j0° q9q0} 9}§_He0 J n} ®_L0n u ¦\0 idp §09h 9§ §\0 8}§_»H_9e ^j§0ee_X0jH0 G0j§0}º e0L @´ `9j K}H\9e L0H_L0L §n \0eq §\0h @´ H}09§_jX 9j 9«§nh9§0L T9H§]H\0Hc_jX qe9§Tn}h EK}H\9e 0§ 9euJ ©·©¨Fu ¦_ qe9§Tn}h }0x«_}0 0®0}9e §}njX He9 _»0} §n «jL0} §9jL §\0 Hnj§0²§ nT _jTn}h9§_njJ _jHe«L_jX §\0 j9h0L 0j§_§´ He9 _»0}u i9h0¦9X © n¸0} «H\ 9 He9 _»0}J @«§ 9 §9§0L 9@n®0J §_ hnL0e _ §}9_j0L « _jX j0 §0L 0j§_§_0 u ¦_ h9´ 00h e_c0 9 §}_®_9e q}n@e0hJ @«§ _§ H9j H9« 0 h9an} n@ §9He0 J 9 §\0 0h@0LL_jX H9j X}n° x«_Hce´ 9jL nh0 0j§_§_0 h9´ q}n®0 §n @0 hn}0 HnjT« _jX §\9j \0eqT«eJ Tn} 0²9hqe0J _j §\0 j9h0 nT §n°j ōœ §ϑ j9L d9@0hŸ §\0 }_®0} 0j§_§´ ōd9@0hŸ h9´ jn§ @0 §\9§ _hqn}§9j§ Tn} §\0 «jL0} §9jL_jX nT §\0 0j§_}0 0j§0jH0u 8 §\0 hnL0e Tn} G¶0H\ iN| °0}0 0_§\0} jn§ q«@e_He´ 9®9_e9@e0 n} ne®0L j0 §0L iN|J ^ °9 §9 c0L °_§\ H}09§_jX 9 L9§9 0§ §\9§ Hnj§9_j §\0 9h0 L9§9 9 §\0 GiNG L9§9 0§ @«§ Ln0 jn§ Hnj§9_j j0 §0L 0j§_§_0 J 9jL H}09§_jX 9 h9H_j0 e09}j_jX hnL0e §\9§ q}nL«H0 j09}]\«h9j }0 «e§ »j0]§«j0L _j §_ L9§9 0§u

1.2 Main Challenges

¦\0 h9_j H\9ee0jX0 nT §_ §\0 _ 9}0 §\0 9e}09L´ h0j§_nj0L H}09§_nj nT 9 L9§9 0§ Hnj] §9_j_jX nje´ ¼9§ 0j§_§_0 9jL §\0 H}09§_nj nT 9 h9H_j0 e09}j_jX hnL0e ne®_jX iN|u 8ee 9®9_e9@e0 ne«§_nj 9 nT jn° Tn} G¶0H\ 9}0 Hnhqe0² 9}H_§0H§«}0 Hnh@_j_jX §\0 ¦}9j] Tn}h0} 9}H_§0H§«}0 °_§\ n§\0} j0«}9e j0§°n}c u ^ TnH« 0L nj H}09§_jX 9 q«@e_He´ 9®9_e9@e0 hnL0e « _jX [«XX_jX S9H0 e_@}9}_0 © « _jX §\0_} §}9_j_jX 8p^ 9jL ne®_jX §\0 iN| q}n@] e0h _j 9 °9´ §\9§ _ 09 _e´ }0qe_H9@e0 9jL « _jX 9 _jXe0 hnL0e @9 0L nj §\0 ¦}9j Tn}h0} 9}H_§0H§«}0u

[«XX_jX S9H0 _ 9 e9}X0 h9H_j0 e09}j_jX 9jL L9§9 H_0jH0 Hnee9@n}9§_nj qe9§Tn}h §\9§ \0eq « 0} @«_eLJ L0qen´J 9jL §}9_j h9H_j0 e09}j_jX hnL0e u ¦\0 H}09§_nj nT 9 Hnhqe0² §}9_j_jX ennq Tn} iN| Hn«eL @0 9 §nq_H Tn} 9 °\ne0 §\0 _ J 9jL °0 Hn«eL §_ee jn§ @0 9 0¹H_0j§ 9jL 0¸0H§_®0 9 « _jX 9 §}9_j_jX ennq n¸0}0L @´ §\0 [«XX_jX S9H0 Hnh h«j_§´ §\9§ _ Hnj»X«}0L 9jL nq§_h_¶0L Tn} §\0 @0 § }0 «e§ u ¦n 9H_0®0 §\0 @0 § }0 «e§ J ^ L0H_L0L §n « 0 §_ qe9§Tn}h 9jL 9ee hnL0e 9jL L9§9 0§ °0}0 h9L0 q«@e_He´ 9®9_e9@e0u

¦\0 n¸0}0L ne«§_nj \n«eL «}q9 §\0 9®9_e9@e0 §9§0]nT]§\0]9}§ }0 «e§ J 9jL §\0 hnL0e \n«eL §}9j e9§0 °0ee _j§n }09e]°n}eL _§«9§_nj J 9 §0 §_»0L @´ 9j 0hq_}_H9e 9j9e´ _u

^j 9LL_§_nj §n §\0 iN| He9 _»0}J ^ 9e n L0H_L0L §n §}9_j 9 hnL0e H9q9@e0 nT Hnhq}0] \0jL_jX j0 §0L 0j§_§_0 §n 9Hx«_}0 9 L00q0} «jL0} §9jL_jX nT §\0 iN| q}n@e0hu

1.3 Introduction to Transformers

^j §\0 q9 §J Lnh_j9j§ hnL0e ne®_jX idp §9 c °0}0 @9 0L nj Hnhqe0² }0H«}}0j§ n} Hnj®ne«§_nj9e j0«}9e j0§°n}c _j 9j 0jHnL0}]L0HnL0} Hnj»X«}9§_nju ¦\0 @0 §]q0}Tn}h_jX hnL0e °n«eL 9e n Hnj j0H§ §\0 0jHnL0} 9jL L0HnL0} §\}n«X\ 9j 9§§0j§_nj h0H\9j_ hu ^j §\0 E-9 °9j_0§ 9euJ ©·o¢F q9q0}J 9 j0° _hqe0 j0§°n}c 9}H_§0H§«}0 °9 _j§}nL«H0LJ 9@e0

[o] \§§q I¤¤°°°u9_HuT0euH®«§uH¶¤

[©] \§§q I¤¤\«XX_jXT9H0uHn¤

§n ne®0 0x«0jH0]§n] 0x«0jH0 q}n@e0h @9 0L ne0e´ nj 9§§0j§_nj h0H\9j_ h J L_ q0j _jX §\0 }0H«}}0j§ 9jL Hnj®ne«§_nj9e j0§°n}c Hnh qe0§0e´¡ §\0 ¦}9j Tn}h0} u ¦_ \9 @00j 9 h9an} @}09c§\}n«X\ _j §\0 »0eL 9jL X9®0 @_}§\ §n T9h n« hnL0e «H\ 9 ?N|¦ EK0®e_j 0§ 9euJ ©·okFJ Nd g m Ep0§0} 0§ 9euJ ©·oPF n} Wp¦]¨ E?}n° j 0§ 9euJ ©·©·FJ °_H\ x«_Hce´ n«§q0}Tn}h0L n§\0} hnL0e J 9jL }0H0j§ }0 09}H\ @«_e§ nj §\0 0 hnL0e q« \0L H«}}0j§ §9§0]nT]§\0]9}§ j09} n} 0®0j n«§q0}Tn}h_jX \«h9j }0 «e§ J 9jL §_ }0 09}H\ °_ee « 0 §\0 ¦}9j Tn}h0} 9}H_§0H§«}0 9 °0eeJ n ^ »jL 9qq}nq}_9§0 §n L0 H}_@0 §_ 9}H_§0H§«}0u

¦\0 9§§0j§_nj h0H\9j_ h _ 9 h0§\nL §\9§ _h«e9§0 \n° \«h9j 9§§0j§_nj °n}c @´ 9 _Xj_jX ®9}´_jX e0®0e nT _hqn}§9jH0 §n L_¸0}0j§ °n}L _j 9 0j§0jH0u 8§§0j§_nj 9 _Xj _hqn}§9jH0 §n 09H\ °n}L @´ H9eH«e9§_jX °0_X\§ Tn} §\0 °n}L¸ 0h@0LL_jX °_§_j 9 q0H_»H 0j§0jH0 0H§_nj H9ee0L §\0 Hnj§0²§ °_jLn° §n L0§0}h_j0 _§ _Xj_»H9jH0u ¦\0 0 °0_X\§ H9j 9L9q§ 9jL H\9jX0 °_§\ 09H\ §}9_j_jXu

¦_ 9}H_§0H§«}0 n¸0} h9j´ 9L®9j§9X0 n®0} n§\0} ne«§_nj u ¦\0 @_XX0 § _ §\0 _j] H}09 0 _j q0}Tn}h9jH0 _j h9j´ idp §9 c _jHe«L_jX iN|u 8jn§\0} @_X 9L®9j§9X0 _ §\0 9®9_e9@e0 « 0 nT q9}9ee0e_ hJ9 §\0 ne«§_nj Ln0 jn§ §}09§ §\0 _jq«§ §0q @´ §0qJ 9jL §_ 9}H_§0H§«}0 @9§§e0 nj0 nT §\0 @_XX0 § L_ 9L®9j§9X0 nT }0H«}}0j§ j0«}9e j0§°n}c J °_H\ q}_n}_§_¶0 hn}0 }0H0j§ _jTn}h9§_nj n®0} §\0 neLu

g9 c0L d9jX«9X0 gnL0e_jX rgdgs_ 9 h0§\nL §\9§ §}9_j 9§§0j§_nj @´ h9 c_jX nh0 q9}§ nT 9 0j§0jH0 9jL Tn}H_jX §\0 hnL0e §n L0q0jL nj n§\0} °n}L §n q}0L_H§ §\0 h9 c0L nj0 9jL h9c_jX §\0 hnL0e « _jX 9§§0j§_nj @0§§0} «jL0} §9jL 0j§0jH0 @9 0L nj §\0 Hnj§0²§u

¦\0 ¦}9j Tn}h0} 9}H_§0H§«}0 _ L0q_H§0L _j S_X«}0 ouVu

1.4 Thesis outline

g´ §\0 _ _ L_®_L0L _j§n £ H\9q§0} u 8 «HH_jH§ L0 H}_q§_nj nT 09H\ H\9q§0} H9j @0 00j @0en°I

- G\9q§0} o _j§}nL«H0 §\0 §\0 _ J _§ hn§_®9§_njJ h9_j Xn9e J 9jL H\9ee0jX0
- G\9q§0} © 0²qen}0 §9§0]nT]§\0]9}§ h0§\nL Tn} iN| 9jL L0 H}_@0 §\0 q}0]§}9_j0L hnL0e §n @0 « 0Lu
- G\9q§0} ¨ 0²qe9_j §\0 G iNG L9§9 0§ « 0L Tn} »j0]§«j_jX 9jL §\0 q}n@e0h j9h0L j0 §0L iN| °_H\ °_ee 9e n @0 }0 09}H\0Lu
- G\9q§0} V Hnj§9_j L0§9_e nj §\0 §}9_j_jX 9jL 0®9e«9§_nj nT §\0 q}0]§}9_j0L hnL0e u
- G\9q§0} U n¸0} 9j 0hq_}_H9e 9j9e´ _ nT §\0 §°n @0 § q0}Tn}h_jX hnL0e
- G\9q§0} £ HnjHe«L0 §\0 §\0 _ u

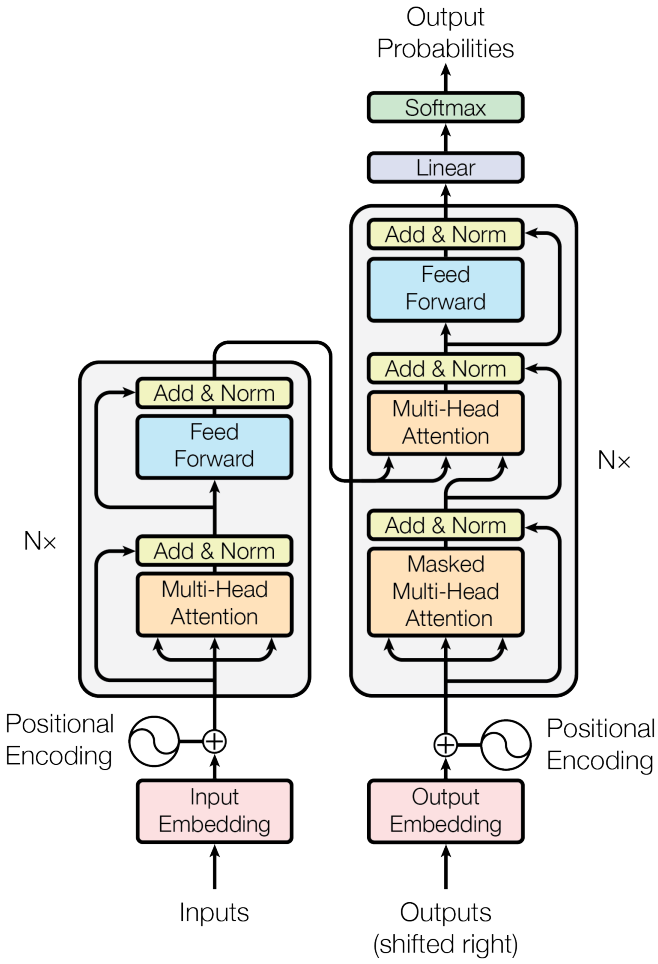

Figure 1.4: 8 j 9}H_§OH§«}O nT §\O ¦}9j Tn}hO} hnLOe r}Oq}_j§OL T}nh E-9 °9j_ O§ 9euJ ©·o¢Fs

Chapter 2
State-of-the-Art Overview

¦_ H\9q§0} 0²qen}0 H«}}0j§ §9§0]nT]§\0]9}§ h0§\nL « 0L _j i9h0L Nj§_§´ |0HnXj_§_nj _j NjXe_ \ 9jL G¶0H\u ^§ _j§}nL«H0 9jL L0 H}_@0 q}0]§}9_j0L hnL0e « 0L _j §_ §\0 _ Tn} »j0]§«j_jX _j G¶0H\u d9 §e´J ^ 0²qe9_j §\0 h0§}_H « 0L Tn} §\0 n@ 0}®9§_nj nT §\0 hnL0e q0}Tn} h9j H0u

2.1 Named Entity Recognition in English

i9h0L Nj§_§´ |0HnXj_§_nj _j NjXe_ \ _ 9e}09L´ 9 °0ee]}0 09}H\0L §nq_H °_§\ h9j´ »j0]§«j0L hnL0e 0²H00L_jX k· t F_1 Hn}0u ¦\0 9qqe_H9§_nj nT L00q e09}j_jX h0§\nL _j idp °9 h9L0 qn _@e0 @´ §\0 _j§}nL«H§_nj nT °n}L 0h@0LL_jX Eg_cnen® 0§ 9euJ ©·o¨FJ °_H\ }0q}0 0j§ °n}L 9 ®0H§n} _j 9 en°]L_h0j _nj9e Hnj§_j«n« q9H0J H9q§«}_jX §\0_} 0h9j] §_H9e }0e9§_nj u [n°0®0}J 9 q}n@e0h nHH«}}0LI L0q0jL_jX nj §\0 Hnj§0²§J nj0 °n}L Hn«eL \9®0 hn}0 h09j_jX u ¦_ °n}L °n«eL \9®0 §\0 9h0 0h@0LL_jX Tn} 9ee \nhnj´h u K00q j0«}9e hnL0e @9 0L nj dnjX ~\n}§]¦0}h g0hn}´rd~¦ gs E[nH\}0_§0} 9jL ~H\h_L\«@0}J okk¢F 9jL ¦}9j Tn}h0} E-9 °9j_ 0§ 9euJ ©·o¢F 9}H_§0H§«}0J «H\ 9 Ndgn Ep0§0} 0§ 9euJ ©·oPF 9jL ?N|¦ EK0®e_j 0§ 9euJ ©·okF \9®0 _j§}nL«H0L Hnj§0²§«9e_¶0L °n}L }0q}0 0j§9] §_nj rG¯ |sr9e n cjn°j 9 Hnj§0²§«9e_¶0L 0h@0LL_jX sJ h9c_jX °n}L ®0H§n} 0j _§_®0 §n Hnj§0²§u ¦_ 9een°0L §\0 H}09§_nj nT h9j´ e9jX«9X0 hnL0e §}9_j0L « _jX 9 §9 c 0x«_®] 9e0j§ §n n} _h_e9} §n gdgJ °_H\ Hn«eL @0 « 0L Tn} 9 °_L0 }9jX0 nT Ln°j §}09h idp §9 c J j9h0e´J §\0 iN| §9 cJ °\0}0 §\0 0 hnL0e 9H_0®0 §\0 So Hn}0 h0j§_nj0Lu ¦\0 ¦}9j Tn}h0} 9}H_§0H§«}0 _ @}_0¼´ 0²qe9_j0L _j ~0H§_nj ou¨u

g9j´ hnL0e « 0 L_¸0}0j§ h0§\nL §n @nn § §\0 So Hn}0 9 _X\ 9 qn _@e0 9jL @09§ n§\0} hnL0e u 8j _j§0}0 §_jX hnL0e _ dª bN E³9h9L9 0§ 9euJ ©·©·FJ °_H\ §}09§ jn§ nje´ °n}L r _h_e9} §n 0²_ §_jX G¯ | hnL0e s @«§ 9e n 0j§_§_0 9 _jL0q0jL0j§ §nc0j n §\9§ §\0 0j§_§_0 °n«eL \9®0 §°n 0h@0LL_jX J nj0 9 §nc0j 0h@0LL_jX 9jL §\0 n§\0} 9j 0j§_§´ 0h@0LL_jXu

|0H0j§ °n}c 9e n Tn«jL @0§§0} °n}L }0q}0 0j§9§_nj @´ HnjH9§0j9§_jX L_¸0}0j§ §´q0 nT 0h@0LL_jX u E¯9jX 0§ 9euJ ©·©oF q}nqn 0L 9j 8«§nh9§0L GnjH9§0j9§_nj nT Nh@0LL_jX r8GNs §n 9«§nh9§0 §\0 q}nH0 nT »jL_jX 9 @0§§0} HnjH9§0j9§_nj nT 0h@0LL_jX u

2.2 Named Entity Recognition in Czech

^j G¶0H\J i9h0L Nj§_§´ |0HnXj_§_nj _ 9 e0 }0 09}H\0L §9 c §\9j _j NjXe_ \J 9jL §\0 hnL0e Ln jn§ }09H\ «H\ _X\ So Hn}0 u ^j ©·©VJ §\0 §9§0]nT]§\0]9}§ _ i9h0¦9X © E~§}9cn®¾ 0§ 9euJ ©·okFJ °_H\ °_ee @0 h´ @0jH\h9}c Tn} h´ »j0]§«j0L hnL0e J 9jL _§ Hn}0 H9j @0 00j _j ¦9@e0 VuUu S«}§\0}hn}0J E~_Ln 0§ 9euJ ©·©oF §}9_j0L §\0 »} § G¶0H\

KQMQHBM;m H H M;m2`;i# kQ//2QHM i?2 `+?Bi2+im`2bHQB7M"1_hH(X-
kyR)NM/ G"1_hG(M 2i HX)-Uk3ykXb+Q`2 QMEQ?M2F(QH 2i )HpX2-`kyRQ9M
Q7L1*RXR/ i ba2BVQ(2i HX)-HkykQR+QKT `2/i?2B` KQ/2H-2mpBHBMK"1_h(
2i HX-)kyNR/NaH pB+"1F_?hB(TQp 2i)HX-h?2RHNbi KQ/2H- A ? p2 7QmM/-
+?B2p2b bi i2@Q7@i?_2Q@#2*ix2+(am`HFb 2Bib HX)-Uk3ydkXR3k+Q`2 QM
*L1*RXRVX
JQ`2Qp2`- `2+2MiH `;2#2`i@HBF2KQ/2sHG-J@B_Q?"BM(HQM@2b *x2+?
M2 m 2i HX)X kykGy@_Q"1_h Bb H `;2 KmHiBHBM;m H H M;m ;2 K
_Q"1_hG(Bm 2i HX)-`k+?BN2+im`2X h?Bb KQ/2H + M #2i` BM2/mbBM;
/i b2i/2b+`B#2/BM;X*? Ti2`
/2i BH2/ /2b+`BTiBQM Q7 2 +? KQ/2H A rBHH }M2@imM2 M/ 2p H
7QHHQrBM;bm#b2+iBQMbX

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L K2h ; k(ai` FQp€ 2i H)XBbkyRMN2m` H M2irQ`F `+?Bi2+imX`2 7Q` M2
L K2i ; k Bb /BpB/2/BMiQ irQ /Bz2`2Mi M2m` H KQ/2Hb,

h?2 }`bi KQ/2H mb2b bi M/ `GGkaTH@?2i 6H)X`+k?BRie2+im`2-r?2`2
i?2 BMTmi-r?B+? Bb +QM+ i2M iBQM Q7 KmHiBTH2 H #2Hb Q7
MGahJM2m` H M2irQ`F M/ i?2M +2+QMQ/B2i/B#QM H ` M/_QMX}2H/ U
Hi?Qm;?i?Bb TT`Q +? Bb bBKTH2 M/ 2z2+iBp2-i?2 Q#pBQmb /
BM+`2 bBM; MmK#2` Q7 M K2/ 2MiBiB2b-r?B+? K F2b i?Bb KQ/2
T`Q#H2K Q7LM2Xbi2/

AM i?2 b2+QM/ KQ/2H-i?2 M2bi2/ 2MiBiB2b `2 `2T`2b2Mi2/ b
i bF bb2[m2M+2@iQ@2b[2k[bM2a[M+b2F2Up2` 2i)HiXbFkyRN9?2 KQbi
TQTmH ` `+?Bi2+im`2 mb2/ 7Q` i?Bb i bF Bb i?2 2M+Q/2`@/2+Q/2
2M+Q/2` Bb #B/Gà2J(fmQM2iHX)-MyFRN2 /2+Q/2GabbX M?2
iQF2Mb `2 pB2r2/ b i?2 BMTmib2[m2M+2 M/ i?2 2M+Q/2/H #2H
QM2 #v i?2 /2+Q/2` mMiBH i?2 /2+Q/2` QmiTmib i?2 óI2Qr=ô U2M
KQp2b iQ i?2 M2ti iQF2MX

h?2 M2irQ`F r b i` BM2/mbBM; p `B MEQ7;K KQ/TiB-kBykR9+(?
QMHv mT/ i2b i?2 ++mKmH iQ`b 7Q` i?2 p `B #H2b-i?Bii?TT2@` BM +
` K2i2`b= 0:9 M/2= 0:98X h?2v mb2/ KBMB@# i+?2b Q7 bBx2 3X 6Q` `2
i?2v TTHB2/ /`QTQmi` i2Q7 yX8 M/i?2 rQ`//`QTQmi`2TH +2b ky
FMQrMiQF2MiQ 7Q`+2 i?2 M2irQ`F iQ `2Hv KQ`2 QM +QMi2tiX h?2v
2K#2//BM;b 7`QKS2iG2JQ2(i H)X-"1_yR2pHBM 2i H-X-Mk/y6RHNFB#B(F
2i HX-)kyQR3Q`/@ M/+? ` +i2`@H2p2H 2K#2//BM;biQ`2 +? 2p2M 7m

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b K2MiBQ*Mx2/i(aB/Q 2i HX)-Bkoyk?R2 }`bi *x2+? KQMQHBM;m H H M;m
`2b2Mi iBQM KQ/2H # b2/ .2MHB2"1_hH(X-MkykGN1_hG(M 2i HX-
kyk)y `+?Bi2+im`2bX b bi i2X-B"M1_a2BbBQKMQ/2H # b2/ QM h` Mb7Q`K
`+?Bi2+im`2 rBi? irQ T`2@J`bBFM2/BQM;M;bmFb2, JQJ/2HMB M/LU2ti
a2Mi2M+2 S`2LBa-SXBQM U?2 Q`B;BM2pHHTBM22`i( HX?2kyRN?Q` Tm#@
HBb?2/"1_h M/"1_h_:1 r?2`2"1_Gh_:1 +QMi BMb jiBK2b i?2 T` K2i2`b

[R] ?iiTb,ffrrrXi2MbQ`~QrXQ`;f //QMbfimiQ`B HbfQTiBKBx2`bnH xv / K

Q7 "1_h X G i2`- G"1_hM(2i HX)-TkyQTQb2/ r v iQ mb2 i?2 T ` K2i2`
KQ`2 2z2+iBp2Hv M/ `2/m+2 i?2B` MmK#2` r?BH2 K BMi BMBM; bB
HbQ /BpB/BM; BMiQ- GG"1_hb _:1- G"1_hG _:1- G"1_hsG _:1X
*x2`i HbQ 7QHHQr2/ i?Bb +QMp2MiBQM M/ +`2 i2/ irQ KQ/2Hb,

- *x2`i@Bb p2`v bBKBH `iQ i?2 bi M/ X/ G"1_h
- *x2`i@Bb +QM};m`2/ 2t +iHy X b "1_h

"Qi? Q7 i?2 KQ/2Hb `2 i` BM2/ QM i2ti +Q`Tmb +QMbBbiBM; Q7,

- auL p9E(ü2M 2i HX)- kyHR`e,2 +Q`Tmb Q7 +QMi2KTQ` `v r`Bii2M *x2-
  iQF2MbX
- *x2bM(iQMvKQmb- kyQRH2+iBQM Q7 *x2+? M2rbT T2` M/K ; xBM2
  iQF2MbX
- SH BM i2tib 2ti` +i2/ 7`QK i?2 *x2+? qBFBT2/B /miKT/mBbBM; qBFB
  kyR)8 RkjJ iQF2MbX

"Qi? KQ/2Hb `2 i` BM2/ rBi? H2 10`4MBM;H`BM2 Q7/2+ v mbBM; i?2 / K
QTiBKBEx2M(K M/ " -)XyR9
6Q` Kv 2tT2`BK2Mib- A }M2@imM2/ QMHv *x2`i@" M/ aH pB+"1_
/ i b2i 7`QK *?j-Ti2b`i?2v T2`7Q`K i?2 #2bi b b?QmB/BQM2i?2HX-T2` (
kyk)RX

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aH pB+"1(_hF?BTQp 2i)HXb kyR2V QM KmHiBHBM;m H p22k@BQM Q7 i?
pHBM 2i H)X-Qk/2HN7Q+mb2/ QM 7Qm` aH pB+ H M;m ;2b, _mbbB M-"
*x2+?X h?2 Q`B;BM H "1_h 2K#2//2` Bb H`2 /v i` BM2/ QM Ry9 H M
i?2 7Qm` H M;m ;2b- i?2v /B/ MQi M22/ i?2 2MiB`2 BMp2MiQ`v Q7 Km
i?2 Q`B;BM H qQ`/SB2+2 iQF2MBx iBQM K v H +F aH pB+@bT2+B}+
BM HQM;2` BMTmi b2[m2M+2X >2M+2- i?2v `2i` BM2/ "1_h BM i?2
*x2+?- SQHBb?- M/ "mH; `B M- M/ L2rb / i 7Q` _mbbB MX h?2v BM
i?2 KmHiBHBM;m H "1_h- b i` BMBM; 7`QK b+` i+? rQmH/ #2 2ti`2K2
T2MbBp2X
7i2` T`2@i` BMBM; M/ }M2@imMBM; QM /QrMbi`2 K / i b2i- i?2
KmHiBHBM;m H "1_h- M7_#6vH/ 2BM;i?2 KQ/2H Bb +?B2pBM; 2p2M #2
7Q`K M+2X

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_Q#2*x2(a?` F 2i HX)-Bkyk Rx2+? +QMi2tim HBx2/H M;m ;2 `2T`2b2M
b2/ QM i?2 h` Mb7Q`K2` `+?Bi2+im`2 i` BM2/ bQH2Hv QM *x2+? /
++m` i2Hv *x2+? KQMQHBM;m HQ2mb2BiQMX- 7`QM1b_hH(QTiBKBx2/
"1_h T`2@i` BMBM; TT`Q +?X _Q#2*x2+? r b i` BM2/ QM 7Qm` Tm
h?`22 Q7 i?2K `2 i?2 b K2 b 7Q` *x2`i /2Xk-XR#2/M2M/a2+,iBQM

- .Q+mK2Mib rBi? iH2 bi 9yy iQF2Mb 7`QK i?2 *x2+? T `@Q7 i?2 qk*
  DHB --JkyDRHB M/ ‡ #QF`)bRw-JkyQFH2Mb

lbBM;i?2 +QM+ i2M i2/ +Q`Tmb- _Q"1_h r b i` BM2/ 7`QK b+` i+? mb
`2H2 b2/ BM i?2 6 B[k]Xb 2[/ HKBr#b `mvb2/ b M QTiBK[1]B=xQ:9 rBMi/?
[2]=0:98- i?2 # i+? bBx2 Bb 3-RNk M/ i?2 H2 `MBM;` i2 Bb / Ti2/ mbB
/2+ v b+?2K rBi? Ry-yyy r `K@mT mT/ i2b M/ i?2 K t7B1Km[4]K H2 `MBM;
h?2 i` BMBM;iQQF TT`QtBK i2Hv i?`22 KQMi?bX
h?2v bi i2/ i? i 7kQ1_i?`2Q#H2K- i?2v `2T`Q/m+2/ i?2 +m``2Mi bi i2@
`+?Bi2+am``2FQp€ 2i H)X/-2k+RBN#2/ BMkX2+XHBmQ MB/ MQi b? `2 +Q/2
`2TQbBiQ`v Q` i` BM2/ r2B;?ibX

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sGJ@_Q"1_hBb+`Qbb@HBM;m H H sMG;Jm G2KKTQH/22HMU *QMM)2 m- kyRN
b2/ QM _Q"1G_Bm(2i HX-- rk?yER+N? Bb- b b B/kBXN+Xa9"1_Bm@M# b2/
KQ/2H rBi? M QTiBKBx2/ i` jBXMsBGJ;@T_Q"+12/m`r2b i` BM2/ BM QM2 ?mM
H M;m ;2b- mbBM; kX8 i2` #vi2b Q7 }Hi2`2/*QQMKK2QM *2irHHX-ikXykAyM (
T T2`- i?2v /Bb+mmbb2iQ27 KmHi,BJHQB`M2;HmMH;Bmiv,2b H2 /iQ #2ii2` +`Qbb@
T2`7Q`K M+2 BM HQr@`2bQm`+2 H M;m ;2b mT iQ TQBMi- 7i2` r?B
QM KQMQHBM;m H M/ +`Qbb@HBM;m H #2M+?K `Fb /2;` /2bX h?Bb
BM+`2 bBM; i?2 KQ/2H + T +Biv- i? i Bb r?v i?2 mi?Q`b K /2irQ KQ/
H `;2c sGJ@_Q"1rBi? kdyJ T ` K2i2`b M/ sGJ@_Q"1_h88yJ
T ` K2i2`b- r?B+? Bb- 7Q` 2t KTH2- Qp2` 9 iBK2b i?2 bkBXkX9 7 _Q#2*
sGJ@_Q"1_h bB;MB}+ MiHv QmiT2`7Q`Kb Qi?2` KmHiBHBM;m H K
r2HH +QKT `2/ iQ Qi?2` *x2+? KQMQHBM;m H KQa2`HB- 2b bH?X-rM BM
kyk-RB/Q 2i HX-Mv7RQ` i?Bb `2 bQM- A rBHH HbQ 2tT2`BK2MirBi? i?

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AM i?Bb a2+iBQM- A rBHH 2tTH BM HH T`BK `v K2i`B+b mb2/ iQ 2p

++m` +Bvb i?2 # b2 K2i`B+ mb2/ 7Q` KQ/2H 2p Hm iBQM- r?B+? /2
Q7 +Q``2+i T`2/B+iBQMb Qp2` HH T`2/B+iBQMb,

$$\frac{LmK\#2`\ Q7\ *Q``2+i\ S`2/B+iBQMb}{LmK\#2`\ Q7\ HH\ S`2/B+iBQMb}$$

S`2+BbBQM K2 bm`2 Q7 ?Qr K Mv Q7 i?2 TQbBiBp2 T`2/B+iBQMb
TQbBiBp2bV,

$$\frac{h`m2\ TQbBiBp2b}{h`m2\ SQbBiBp2b\ Y\ 6\ Hb2\ SQbBiBp2b}$$

_2+ HBH K2 bm`2 Q7 ?Qr K Mv Q7 i?2 TQbBiBp2 + b2b i?2 +H bbB}
Qp2` HH i?2 TQbBiBp2 + b2b BM i?2 / i ,

$$\frac{h`m2\ SQbBiBp2b}{h`m2\ SQbBiBp2b\ Y\ 6\ Hb2\ L2;\ iBp2b}$$

F_1 b+QB2b K2 bm`2 +QK#BMBM; T`2+BbBQM M/ `2+ HHX AiBb ;2M
? `KQMB+ K2`M2(- RKQj7Ri?2 irQ,

$$2\ \frac{S`2+BbB2Q+MHH}{S`2+BbBQM\ Y\ _2+\ HH}$$

[k] ?iiTb,ff;Bi?m#X+QKf7 +2#QQF`2b2 `+?f7 B`b2[fi`22fK BMf2t KTH2bf`Q#2`i
[j] 6Q` 2t KTH2- _Q"1_h mb2/ 6Q` 2t KQMHv

h?Z $_1$ b+Q`2 Bb bT2+B H+b+bQ2`Q-7ri??Z2b2 TQbBiBp2`2 H 7 +iQ`- +?Q
bQ i? i`2+ HH Bb +iQ`BMB2B/2b`2/KTQ`i Mi bT`2+BbBQM Bb,

$$(1+\ ^2)\ \frac{S`2+Bb\ \underline{B2Q+}MHH}{(\ ^2\ S`2+B)b\ B_Q2M\ HH}$$

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h?Bb +? Ti2`/2b+`B#2bi?2/ i b2imb2/7Q`}M2@imMBM; M/?Qri?2
/Bz2`2Mi p2`bBQMb- BMi`Q/m+2b T`Q1#_H2K/`2Q ri2/`2HQb2HMiiQ2
T`Q#H2K 7Q`i?2 T`2@i` BM2/ KQ/2HbX

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6Q` i?2 *x2 1?- i?2 H `;2bi Tm#HB+ /*ix2 2? LbK2/2 1MiBiv *Q`@
Tmk(2pÍQFQp€ 2i)HXXh?kyyd i b2i +QMi BMb M2bi2/ 2MiBiB2b- r?B+?
T`Q#H2K Q7LM1_bi2Hi?Qm;? i?2 K BM T`Q#H2K Q7 i?Bb i?2bBb Bb i?2
L1_T`Q#H2K- A /2+B/2/iQ }M2@imM2 KQ/2Hb QM i?Bb / i b2i M/ +`2
i?2 M2bLi2/X L2biL21/_Bb /2b+`B#2/ BjMXaX+HHQpM2`bBQMb `2 p BH #H2
/QrMHQ /7`QK i?2B` Q{+2pÍHQFQ#pB22 (HXX- kyyd#
h?2*L1*/ i b2i Bb /BpB/2/ BMiQ /Bz2`2Mi p2`bBQMb,

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h?Bb Bb i?2 Q`B;BM H p2`bBQM Q7 i?2 +Q`TmbX h?Bb p2`bBQM Bb Q
r2#bBi2 Q7 i?2 +Q`Tmb pÍQFQpB22M (HXX-Mkyyd Bb ?B;?Hv `2+QKK2M/2/
mb2 i?2 p2`bBQM /2b+`BX#2XrB2M+a?2+QBMQ BMb i?2 b K2/ i #miQz2`b }

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h?2*L1* RXR Bb +Q`Tmb Q7 83e3 *x2+? b2Mi2M+2b rBi? jjeek *x2
K Mm HHv MMQi i2/- +H bbB}2/ ++Q`/BM; iQ irQ@H2p2H ?B2` `+
jXRVXjQ7 ek irQ@H2ii2` M K2/ 2MiBiB2b M/ Ry QM2@H2jXR` bmT2`iv
h?Bb Bb KBMQ`mT/ i2 iQ Bib T`2pBQmb p2`bBQMX
h?2 /Bz2`2M+2 *#L21 r2RXy *ML/1* RXR `2 i?2 7QHHQrBM;,

- }t2/ bQK2 KBb MMQi i2/ 2MiBiB2b M/ ivTQb
- K F2 HH 7Q`K ib +QMi BM i?2 b K2/ i
- `2TH +2/ iKi 7Q`K i #v i`22t 7Q`K i
- bTHBi HH 7Q`K ib BMiQ i` BM- /i2bi- M/ 2i2bi
- HH / i r2`2 +`2 i2/ M/ MMQi i2/2pÍQFQp€ 2M (HXX-i?kyyd T`Q+2@

/m`2,

#´¬óã¡ì*ê7 RXR M K2/ 2MiBiB2b ivT2 ?B2` `+2pvÍQ F2QTp`€BMii2HX-Qk y(d

a2Mi2M+2b r2`2 ` M/QKHv b2H2+i2/ 7`QK i?2 *x2+? L iBQM H *Q`[R]

h?2/ i ? p2 #22M K Mm HHv MMQi i2/ #v irQ MMQi iQ`b BM T ` I
MMQi i2/ BMbi M+2b ? p2 #22M +?2+F2/ M/[k]X2+B/2/ #v i?B`/ T2

h?2/ i ? p2 #22M /BpB/2/ BMiQ i` BMBM;-/2p2HQTK2Mi i2bi- M/
BM i?2 3,R,R ` iBQX

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h?Bb Bb i?2 KQbi `2+2Mi p2`bBQM Q7 i?2 +Q`TmbX Ai +QMi BMb 3NN
*x2+? M K2/ 2MiBiB2b K Mm HHv MMQi i2/X Ai Bb K DQ`2tT MbBQ

[R] ?iiTb,ffm+MFX77X+mMBX+xf+bf
[k] J ;/ 2pÍQFQp€-w/2MÿF ‡ #QF`ibFw- M/ PH/üB+? E`ix

h?2 +Q`Tmb mb2b 9e irQ@H2ii2` M K2/ 2MiBiv ivT2b- r?B+? + M #2 M2bi21 _T`Q#H2Kc 2X;X- i?2 `Bp2` M K2 + M #2 T `i Q7 i?2 M K2 Q7 I;m 8biQ M / I;? G>#2K

h?2`2 `2 HbQ 9 M K2/ 2MiBiv +QMi BM2`b, irQ Q` KQ`2 M K2/ 2M M K2/ 2MiBiv +QMi BM2`- bm+? b BM, IS IT7 C M=ITb L>Qp€F

*QMi BM2`b `2 K `F2/ rBi? + TBi H QM2@H2ii2` i ;X HH ivT2b Q b22M BM 6XB+?m?2`2 + M HbQ #2 b22M QM2@H2ii2` i ;b- r?B+? `2 MQ + HH2/ bmT2`ivT2b M/ `2 Km+? KQ`2 ;2M2` H- b QTTQb2/ iQ i?2 } ivT2bX

h?2 +? M;2b 7`QK i?2 T`2pBQmb p2`bBQM `2 bi i2/ QM i?2 Q{+B bBQ 2Mp(IQFQp€ 2i)H,X- kyR9#

- Qp2`? mH i?2 MmK#2` 2MiBiB2b- bQK2 2MiBiB2b r2`2 K2`;2/- KQp
- M2r 2MiBiB2b 7Q` 2K BH r b //2/
- Qi?2` 2MiBiB2b i? i b?Qr2/ bBKBH `BiB2b Q` r2`2 iQQ }M2@;` BM
- M2r / i r b MMQi i2/ M/ //2/- K BMHv 7Q` i?2 +Q`Tmb iQ #2ii2 /2MbBiv Q7 M K2/ 2MiBiB2b- bQ HQi Q7 b2Mi2M+2b rBi? MQ M K

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AMi?2 E2Q(MFQH M/EQM)QTTQ2F`--ky?2j mi?Q`b BMi`Q/m+2/i?2 *QLGG@# b
Q7L1*X EQMFQH M/EQMQTQF ? p2i F2M #Qi? p2`bBQMb-`2KQp2/i
H #2H2/ HH 2MiBiB2b iQ`jQXMhPBb bmTi2`MvT2Q`K2/i?2 T`Q#H2K Q7
L1_BMiQ i?2 T`Q#H2K1QX7 ~ i

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h?2 / i b2i- b 2tTH BM2j/XBMX+ja2M+#B2QM#2//2/X h?Bb H2 /b iQ i?2 T`Q
Q7 M2bi12_/X >Qr2p2`-r2 + M HbQ i` Mb7Q`K i?2L1_iTBQM#Q2iK-i Q7
b b?QrM-7Q`2t KTH2XBXM9Q2?iTBQM#H2Kb Kmbi #2 `2T`2b2Mi2/7Q`i
iQ mM/2`bi M/i?2 / i b2i M/i` BM Bib2H7 QM BiX b i?2 K BM +? H
i?2L1_T`Q#H2K- A /2+B/2/iQ +QMp2`i 2p2M i?2XpR2XMBXQMX7`QK a2+
7`QK M2bi12_/Q ~ Li1_ M/+`2 i2 KQ/B}2//i b2i +QMi BMBM;i?2 b K2
+?B2p2 2p2M bi`QM;2` M//Bp2`b2 +H bbB}2`b-r?B+? +QmH/?2HT

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6B`bi-r2 M22/iQ HQQF i?Qr i?2 / i b2i Bb `2T`2b2Mi2/ M/?Qr r2
h?2 / i b2i Bb b p2/BM h`22t 7Q`K iX q2rQmH/HBF2iQ i` Mb7Q`K i?
`2 / #H2 *QMGG 7Q`K iX hQ +?B2p2 i?Bb- A KQi/BF2Q/p€S2i`HHX+`BTi
kyRyeT T2`X
h`22t 7Q`K i}H2 Bb M sJG}H2 rBi?bT2+B}+`mH2b-K FBM;Bi TQ
M/+QMp2`i i?Bb}H2 iQ Qi?2` 7Q`K ibX h`22t 7Q`K i+ M #2 b22M BM

```
R XXX
k     I#mM/H2b=
j        IGJ B/4]bR]=
9           XXX Qi?2` i ;b M/ `mH2b
8           IGJ B/4] ni`22XXX]=
e              I7Q`K= bBBIf7Q`K=
d              IH2KK = bB2nc:IfH2KK =
3              Ii ;=LL6ae@@@@@ @@@@Ifi ;=
N              IQ`/=RNIfQ`/=
Ry          IfGJ=
RR          XXX
Rk       IMni`22 B/4]XXX]=
Rj          XXX
R9          IGJ B/4]XXX]=
R8             IM2nivT2=;iIfM2nivT2=
Re             IMQ`K HBx2/nM K2= bBBIfMQ`K HBx2/nM K2=
Rd          I X`7= ni`22XXXIf X`7=
R3          IfGJ=
RN          XXX
ky       IfGJ=
kRXXX
```

<´çî´Ì¬ì`êMZ2t KTH2 Q7 i?2 / i `2T`2b2Mi2/BM h`22t 7Q`K i

---

[j] q?B+? `2 i?2 bmT2`ivT2b b?jQXrjM BM 6B;m`2

h?2 b+`BTii` Mb7Q`Kb i?2 }H2 BMiQ i?2 *QLGG 7Q`K i-r?B+?Bb KQ`
2t KTH2 Bb b?QrM #2HQr,

```
R XXX
k CB?Qpm+?Q/ML DB?Qpm+?Q/ML   6ae@@@@R @@@@ P
j  bBB      bB2nc:  LL6ae@@@@@ @@@@@ "@;i
9           @R      C @@@@@@@@@@@@@@ P
8 vQm      i2M      S.6ad@@@@@@@@@@@ P
e XXX
```

<´çî´Ì¬ì`MZ2t KTH2 Q7 i?2 / i BM *QLGG 7Q`K i 7Q`~ i 2MiBiB2b

h?2 }`bi +QHmKM +QMi BMb rQ`/b- BM+Hm/BM; TmM+im iBQM- i?2 b
K b Q7 i?2b2 rQ`/b- i?2 i?B`/ +QHmKM +QMi BMb KQ`T?QHQ;B+ H i
+QHmKM +QMi BMb L1bX
6Q` i?2 M2bi2/ 2MiBiB2b- Bi ? b i?2 b K2 bi`m+im`2 rBi? M //2/ 2M

```
R XXX
k DK2MmD2 DK2MQp in,hn,q o"@a@@@jS@  @@@ P
j b22    b2n Uxp`Xnx{DK2MQ%^È{biB+2^V Sd@s9@@@@@@@@@@@
9 MM     MMncu            LL6as@@@@@ @@@@@ "@S%"@T7
8 am#    am#              s!@@@@@@@@@@@@@@ A@S%"@Tb
e X      X                w,@@@@@@@@@@@@@@ P
d XXX
```

<´çî´Ì¬ì`MZ2t KTH2 Q7 i?2 / i BM *QLGG 7Q`K i 7Q` M2bi2/ 2MiBiB

q2 + M Q#b2`p2 i?2 mA M,2 BQ/ 7 @?Q mib B/ A2 @V#2 ;;BXMAMBi?2 b BMbi M+2- i?
mb ;2 Q7 i?2 AP"ki ;;BM; Bb b?QrMX h?Bb 7Q`K i Q7 iK;bBM; r b T`2b2
M/ J `+mb-)RTNT2` M/ Bb +QKKQMHv mb2/ 7Q` i ;;BM; iQF2MbX h?2
/2b+`B#2/ b,

- A@ T`2}t BM/B+ i2b i? i i?2 iQF2M Bb BMbB/2 M 2MiBiv
- "@ T`2}t BM/B+ i2b i? i i?2 iQF2M Bb i?2 #2;BMMBM; Q7 M 2MiBi
- P BM/B+ i2b i? i i?Bb iQF2M Bb MQi T `i Q7 Mv 2MiBiv

h?2 /Bz2`2M+2 #2ir22M AP" M/ AP"k@Tb2-}BMbAmb-/?QMHv 7i2` MQi?
iQF2M i? i Bb MQiH ;;2/ b

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PMHv ? pBM; i?2 }H2 i` Mb7Q`K2/ BMiQ i?2 *QLGG 7Q`K i rBHH MQi #
iQ mM/2`bi M/ i?2 BMTmiX >m;;BM; 6 +2 KQ/2Hb Kmbi ? p2 2 +? 2Mi
iQ Bib +Q``2bTQM/BM; A. MmK#2`X 1t KTH2ô;BqB2HH ?Mp2 MiBAv H #2
Q7 X h? MFb iQ i?2 >m;;BM; 6 +2 HB#` `v- A r b #H2 iQ +`2 i2 bBK
7QHHQrBM; i2KTH i2 7`Q-KB>Mmr;?BM; A +2M T`2T `2 HH i?2 72 im`2b
/ i b2i b?QmH/ ? p2c A rBHH 2tTH BM i?Bb b+9BXXXkQ22HBQM/B2M;BH BM
b+`BTiHQ /b i?2 / i b2i BMiQ . i b2i.B+ic i?Bb . i b2i.B+i +QMbBbib
`2T`2b2MiBM; i?2 i` BM- p HB/ iBQM- M/ i2bi bTHBiX
1 +? bTHBi ? b 72 im`2 iQ F2BM? M2`ni ;b^ nQF2M b2^rQ`/b- 7`QK
2 +? b2Mi2M+2`Mi/ ;b`2 i ;b- 7Q` 2 +? iQF2M BM i?2 A. 7Q`KX aBKTH

[9] ?iiTb,ff?m;;BM;7 +2X+Qf/Q+bf/ i b2ibf/ i b2inb+`BTi

```
R &^iQF2Mb^, (^o2/2^- ^DB^- ^~2M ^- ^-^- ^DK2MmD2^- ^b2^- ^ MM
    !  ^)-
k ^M2`ni ;b^, (y- y- y- y- y- y- d8- 3R- y)'
j ^^^
9 d8, ^"@T7^ UT2`bQM^b 7B`bi M K2V
8 3R, ^"@Tb^ UT2`bQM^b bm`M K2V
e ^^^
```

<´çî´Ì¬ì`M2t KTH2 Q7 i?2 H #2HBM; 7Q` ~ i2MiBiB2b

h?Bb 2t KTH2 Bb 7Q` i?2 Q`#H2K- 7Q` L1_ T`Q#H2K- A }M2@imM2/ `ni ;b^, ((y)- (y)- (y)- (y)- (y)- (y)- (R- 3j)- (k- 3N)- (y))' bQQF bHB;?iHv /Bz2`2Mi- b i?2 MQrQ2Mb irQ H #2HbX

```
R &^iQF2Mb^, (^o2/2^- ^DB^- ^~2M ^- ^-^- ^DK2MmD2^- ^b2^- ^ MM
    !  ^)-
k ^M2`ni ;b^, ((y)- (y)- (y)- (y)- (y)- (y)- (R- 3j)- (k- 3N)- (y))'
j ^^^
9 R, ^"@S^-
8 k, ^A@S^-
e 3j, ^"@T7^-
d 3N, ^"@Tb^
3 ^^^
```

<´çî´Ì¬ì`M2t KTH2 Q7 i?2 H #2HBM; 7Q` M2bi2/ 2MiBiB2b

q2 + M b22 i? i 7Q` i?2 L1_ T`Q#H2K- A }M2@imM2/ 2tT2+i HH p `B #H2b iQ #2 i?2 b K2 ivT2X

h?2 MmK#2` Q7 2MiBiB2b `2T`2b2Mi2/ BM i?2 +Q/2 7Q` i?2 KQ/2H /2 p2`bBQM mb2/ 7Q` }M2@imMBM; M/ i?2 ivT2 Q7 T`Q#H2K r2 `2 i`vE MQr MQi2/ i? i i?2 MmK#2` Q7 2MiBiB2b 7Q` i?2 b K2 p2`bBQM 7Q` }M2@imMBM; M/ i?2 MmK#2` Q rBi? .`X ai`[8] FQp€b BM 7Q`K2/ i? i i?2 2p Hm iBQM 7Q` i?2 kyy)dT T2`QMr `/r2`2 +?B2p2/QM QMHv 9k M K2/ 2MiBiB2b M/ /m2 iQ # +Fr `/ +QKT iB#BHBiv- HH `2bmHib 7Q` i?Bb p2`bBQM 2MiBiB2bX Ai b?QmH/ MQr #2 2tTH BM2/ r? i MmK#2` Q7 2MiBiB2b A

6Q` i?2 p2`bBQM 7`QM KXiR-XE9Q2M+FBQHMM/ EQM)QmTbQ7-dkbymRT2`ivT2b- 7`QK i?2 Q`B;BM H bmT2`ivT2b bQ M?2M/ 2[X+Hm/2/,

6Q` i?2 p2`bBQM 7`jQ R-XaR2+BiB?QbMQHp2/ i?2 L1_ T`Q#H2K- A }M2@im KQ/2H QM 9k ivT2b- r?B+? + M #2Xb 2mMi?2M K6B`2n-`A }M2@imM2/ M 2p Hm i2/ i?2 KQ/2H QMHv QM bmT2`ivT2b- r?B+? MQr mb2/ HH i?2 2t+Hm/2/ 2MiBiB2b- b 2t+Hm/BM; bmT2`ivT2b MQr rQmH/ K p2`bBQM 7`QM KXaR2X+9B?QM bQHpBM; L1_ T`Q#H2K- 9 +QMi BM2`b `2 //2/- b b?QrM BM; mF B2M; i?2 iQi H MmK#2` Q7 2MiBiB2b 9eX

6Q` i?2 p2`bBQM 7`jQ R-Xa2+BiB?QbMQHM#2` Q7 ivT2b M/ bmT2`ivT2b K i+ QM2 mb2/ 7Q` }M2@imMBM;- r?B+? Bb 9e ivT2b M/ L1_ T`Q#H2K- A 9 +QMi BM2`b `2 //2/- K FBM; i?2 iQi H 8yX

[8] ai` FQp€- T2`bQM H +QKKmMB+ iBQM- J `+? Rk- kyk9

#´¬óã¡ì*ìZ1* RXR M K2/ 2MiBiB2b ivT2 ?B2` `+?v 2t+Hm/BM; mMmb2/ 2MiB
2/Bi2/ 7`Q2kpÍQ FQp€ 2i)MX- kyyd

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BÓ•¡Å îã‰´Ì´Ì¬

h?Bb +? Ti2` +QMi BMb HH i?2 /2i BHb QM i?2 i` BMBM; M/ 2p Hm
mb2/ 7Q` }M2@imMLBM/ QM i?2 b+`B#2/ BMX*AMTi2Bb +? Ti2`- A HbQ
/2b+`B#2 i?2 / i T`2T`Q+2bbBM; `2[mB`2/ #27Q`2 2p2`v i` BMBM;X h
T`2T`Q+2bbBM; K v p `v /2T2M/BM; QM r?2 i?2 Q`iM2 bQ/ mBQM Bb 7Q
A rBHH 2tTH BM #Qi? bQHmiBQMb i? i A mb2/ b2T ` i2HvX HH MQi2
BM i?2 2M+HQb2/ `2TQbBiQ`v 2t"TXH BM2/ BM TT2M/Bt

í`ê ‰î‰ Vã¡àãÓ—¡çç´Ì¬

Cmbi? pBM; / i b2i Bb MQi 2MQm;? iQ }M2@imM2 i?2 b2H2+i2/ KQ/2
? p2 /Bz2`2Mi iQF2MBx2`b i? i 2tT2+i i?2 / i iQ #2 BM bmBi #H2 7Q
KQ/2HX AM a2+iBQM- A r
bi2Tb KQ`2 i?Q`Qm;?HvX

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AM a2+iBQM- A r ?Qr2/ ?Qr i?2 ` r / i Bb `2T`2bb2/ BMQ BQ2MB;QM2/
S2`H b+`BTib 7FQ`+QMp2`bBQM M/QM2 # b?
h?2`2 `2BMiQi H 7Qm` S2`H b+`BTib 7Q` +QMp2`bBQM M/QM2 # b?
i?2 ` r / i BMiQ i?2 `2bmHiBM; *QLGG 7Q`K ii2/ }H2 M/ /Bz2`2Mi p2`
i?2 `;mK2Mib `2+2Bp2/ 7Q` i?2 # b? b+`BTiX

- i`22tk+QMHHkyyjnM+2QMp2`Tib i?2 }H2 rBi? HH ivT2b M/ ~ i2MiBiB2b-
  #2 b22M BMjXX2bbiBM;
- i`22tk+QMHHbmT2`nMQ2Mp2`Tib i?2 }H2- #mi QMHv rBi? bmT2`ivT2b M/
- i`22tk+QMHHkyyjnM+2QMp2`Tib i?2 }H2 ; BM rBi? HH ivT2b- #mi 7
  2MiBiB2b- i?2 `2bmHi + M #2Xb22M BM GBbiBM;
- i`22tk+QMHHbmT2`nMQ2Mp2`Tib i?2 }H2 iQ bmT2`ivT2b M/ M2bi2/ 2

1 +? b+`BTi ? b ? b?K T 7Q` HH i?2 H #2Hb 7Q` #Qi? p2`bBQMb-
/2T2M/b QM i?2 `;mK2Mib T bb2/ BMiQ i?2 b+`BTi- bQ 2 +? b+`BTi +
*L1*RXR M/ kXyX HH p2`bBQMb r2`2 Q`; MBx2/ BM i?2B `}H2b 7Q` 2
b ` r / i BMiQ i` BM- i2bi- M/ p HB/ iBQM bTHBibX

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h?2 / i Kmbi #2 i ;;2/ M/ bTHBi BMiQ iQF2Mb iQ i F2 /p Mi ;2 Q7
>m;;BM; 6 +2 HB#` `B2b Qz2`X A K2 [illegible]
#2 b22M BM [illegible]
A +`2 i2/ HQ /BM; b+`BTib 7QHH [illegible]
7Q` i?2 ;2M2` iBQM Q7 b KTH2b- r?2`2 2 +? b KTH2 ? b 72 im`2b i? i
^M2`ni ;b^ /^iQF2Mb^

h? MFb iQ i?2 *QLGG 7Q`K i Q7 i?2 / i - A + M bTHBi 2 +? `Qr BMiQ
}`bi +QHmKM Bb mb2/ b iQF2M- i?2 M2ti irQ +QHmKMb `2 B;MQ`2/
7Q` bQHp [illegible]
i ; i?2 iQF2MX h?Bb i ; ? b iQ #2 +QMp2`i2/ 7`QK i?2 H #2H iQ i?2
E22TBM; BM KBM/ i? i [illegible]
MQr ? p2 H #2H 7Q` i?2 #2;BMMBM; Q7 M 2MiBiv M/ BMbB/2 Q7 M
i?2 MQM2MiBiv ivT2X

h?2`2 Bb bK HH /Bz2`2M+2 BM i?2 HQ /BM; b+`BTib 7Q` M2bi2/
2MiBiB2b- A M2 [illegible]
+QHmKM [illegible]
`2 M `` vX h?Bb #2? pBQ` Bb M22/2/- b i?2 >m;;BM; 6 +2 HB#` `v
72 im`2 iQ #2 Q7 QM2 T`2/2i2`KBM2/ [illegible]
b2[m2M+2b i? i ?QH/ BMi2;2`bX

h?2 r?QH2 Tm`TQb2 Q7 i?2 HQ /BM; b+`BTi Bb iQ HQ / i?2 / i b2i
. i b2i.B+i- r?2`2 2 +? bTHBi Bb `2T`2b2Mi2/ b i?2 >m;;BM; 6 +2 . i
#2 mb2/ M/ 2 bBHv ++2bb2/ #v Qi?2` K2i?Q/b 7`QK >m;;BM; 6 +2 H
Q7 i?2 HQ /2/ / i b2i + M #2 b22M #2HQr,

```
R . i b2i.B+iU&
k     i` BM, . i b2iU&
j        72 im`2b, (^iQF2Mb^- ^M2`ni ;b^)-
9        MmKn`Qrb, 9eN8
8     'V
e     p HB/ iBQM, . i b2iU&
d        72 im`2b, (^iQF2Mb^- ^M2`ni ;b^)-
3        MmKn`Qrb, 83d
N     'V
Ry    i2bi, . i b2iU&
RR       72 im`2b, (^iQF2Mb^- ^M2`ni ;b^)-
Rk       MmKn`Qrb, 83e
Rj    'V
R9'V
```

<´çî´Ì¬í`ê`ë2t KTH2 Q7 i?2 >m;;BM; 6 +2 . i b2i.B+iX h?2 2t KTH2 Bb *L

A Tmb?2/ HH / i b2ib +`2 i2/ 7`QK i?2b2 b+`BTQb#2Q >m;;BM; 6 +2 >
rBi? +`2/Bi iQ i?2 Q`B;BM H mi?Q`b- BM i?2 bi M/ `/ 7Q`K KQbi >m;
L1_ `2 M/ 7Q` 2 bv HQ /BM; rBi? i?2 >m;;BM; 6 +2 imH+` /f/bL K2]V
7mM+iBQMX

[R] ?iiTb,ff?m;;BM;7 +2X+Qf/Q+bf/ i b2ibf/ i b2inb+`BTi
[k] ?iiTb,ff?m;;BM;7 +2X+QfbimH+` /

í`ê`ì cÓÃ¡Ì´ ¡‰Ì• Å´¬Ì

6Q`i?2 KQ/2Hb iQ K F2 b2Mb2 Q7 i?2 BMTmi- i?2 iQF2Mb Kmbi #2 +Q
KQ/2Hb ? p2 i?2B`iQF2MBx2` SA- r?B+? /Q2b i?Bb DQ# bQ i? i i?2 K
iQF2M A. # b2/ QM T`2/2}M2/ pQ+ #mH `vX q2 ? p2 i?2 iQF2Mb H`2
H2i i?2 iQF2MBx2` 7m`i?2` iQF2MBx2 i?2 BMTmi- b b?QrM BM i?2 2t

```
R    (^A^- ^b^- ^.m#2MFQm^- ^-^- ^M ^- ^Fi2`Qm^- ^l^- ^iv;` ^- ^i2/
     !  KvbHLK^- ^X^- ^X^- ^X^)
k    (^(*Ga)^- ^A^- ^b^- ^.m#^- ^OO2MFQ^- ^OOm^- ^-^- ^M ^- ^Fi2
     !   ^iv;^- ^OO` ^- ^i2/^- ^KvbHLK^- ^X^- ^X^- ^X^- ^(a1S)^)
j    (k- 98- 3d- Rj3kN- kkNjy- Ryk8- Re- RNjN- k3Nd- 8d- k3k83- R
     !  j9ey- 8d9d- R3- R3- R3- j)
```

<´çî´Ì¬í`MZ2t KTH2 Q7 T`2@iQF2MBx2/ BMTmib- iQF2MBx2/ BMTmib M/ i

b r2 + M b22- i?2 iQF2MBx2` //b bT2+B H iQF2Mb mb(*Ga) KQ/2Hb
M/ i i?2 2(a1S) M/ rQ`/b i? i r2`2 MQi iQF2MBx2/ iQ i?2 /2bB`2/ 7Q`K
iQF2MBx2/ BMiQ bm#rQ`/b b r2m+#2MbF2Q`mB2M KQ`H2X h?Bb BMi`Q/m+2
KBbK i+? #2ir22M Qm` BMTmiM2`/ni?2b H?#22Hb?2 HBbi Q7 H #2Hb ? b
2H2K2Mib- r?2`2 b Qm` M2r BMTmi ? b R3 iQF2MbX q2 MQr M22/iQ H
rBi? i?2 iQF2MBx2/ BMTmiX h?2 iQF2MBx2`b + M 2 bBHv K T 2 +? iQ
rBi?Q`/nB-/bM/ Bi + M #2 b22M ?Qr i?2v9rXQk`h?2M v BM2r?B+? A HB;M
i?2 H #2Hb /Bz2`b ?2`2- /2T2M/BM; QM L1_ Q`2M 22Li1/X;M iQ ~ i

#Å‰î C Y

6Q` ~Li1_- i?2 K BM +? HH2M;2 Q7 i?Bb i?2bBb- i?Bb T`Q+2bb Bb KQ
2 +? iQF2M rBHH ? p2 2t +iHv QM2 H #2HX h?2 }`bi `mH2 A TTHB2/
rBi? @RyyX h? i Bb #2+ mb2- #v /27 mHi- @Ryy Bb M BM/2t B;MQ`
r?B+? i?2 i` BMBM; mb2bX h?2M- 2 +? iQF2M ;2ib i?2 b K2 H #2H b
i?2 rQ`/ bBM+2 i?2v `2 T `i Q7 i?2 b K2 2"@ QA@ Q`Dm?2b i?2 QM 22MbX
h?Bb T`Q+2bb b?Qrb ?Qr i?2 T`2@iQ F2MBx2/ Q`2 Tim/i BMi Q #?2iQF2MB
M/ HB;M2/ BMTmiXkM h #H2

hQF2Mb	A	b	.m#2MFQm
L1_ i ;b	P	P	"@S

c‰–Å¡ íSêZ@iQF2MBx2/ H #2H2/ BMTmi

hQF2Mb(*Ga)	A	b	.m#	OO2MFQ	OOm	(a1S)
qQ`/ B/b	LQM2	y	R	k	k	k	j
L1_ i ;b	LQM2	P	P	"@S	A@S	A@S	LQM2
G #2Hb @Ryy	y	y	R8	Re	Re	@Ryy

c‰–Å¡ íìQ`F2MBx2/ M/ HB;M2/ BMTmi

C¡çÎ¡•C Y

6Q` M2bLi2/- HB;MBM; H #2Hb rBi? iQF2Mb Bb #Bi KQ`2 +QKTHB+
Bb i? i QM2 iQF2M + M ? p2 KQ`2 i? M QM2 H #2HX Jv }`bi i?Qm;?
bQHmiBQM 7Q` ~ i L1_- #mi ; BM- Tmi HH H #2Hb BMiQ `` vb bQ i
ivT2X >Qr2p2`- i?Bb +`2 i2/ BM+QMbBbi2M+B2b- b i?2 >m;;BM; 6
H #2Hb iQ #2 b2[m2M+2 Q7 BMi2;2`b- r?B+? r b MQr M BKTQbbB#
/Bz2`2Mi TT`Q +? iQ bQHpBM; i?2 M2bi2/ L1_- r?2`2 A rBHH 2tTH BI
BM a2+9X QXXk?2 +`Qbb@2Mi`QTv HQbb*r1 b B2?TGHQ+ 2/ bM?bQ }i
i?Bb HQbb- A M22/ iQ QM2@?Qi 2M+Q/2 Kv H #2HbX
PM2@?Qi 2M+Q/BM; Bb i2+?MB[m2 mb2/ iQ `2T`2b2Mi + i2;Q`B+
p Hm2bX AM Qm`+ b2- 2 +? iQF2M Bb i`2 i2/ b2T ` i2Hv- M/ i?2 H #2
RX p2`v bBKTH2 2t KTH2 Q7 QM2 iQF2M óG #2ô- rBi? QMHv i?`22 i
HQ+ iBQM- M/ BMbiBimiBQMV 9X jm? 2 `22 bB2i2BMbBMBmpH-2#mi BM M 2M
ó>QbiBM2+ m G #2ô Bi Bb T `i Q7 M BMbiBimiBQMX

P	"@S	A@S	"@:	A@:	"@A	A@A
y	y	y	R	y	y	R

c‰–Å¡í`MZ2t KTH2 Q7 QM2@?Qi 2M+Q/2/ H #2H 7Q` QM2 iQF2M

aT2+B H iQF2Mb rBHH ? p2 i HH BM/2t2b @Ryy- bQ i?2v + M #2 B

í`ë cã‰´Ì´Ì¬<ÓÓà

7i2` Qm` / i Bb T`QT2`Hv T`2T `2/- i?2 M2ti bi2T Bb i?2 +im H i` B
i?2 / i X >2`2- i?2 K2i?Q/b mb2/ iQ bQHp2 2 +? T`Q#H2K ; BM /Bz2`
BM i?2B` `2bT2+iBp2 b2+iBQMbX

í`ë`ê#Å‰îC Y

h?2 >m;;BM; 6 +2 +QKKmMB ivB+M2+ H2/bb i? i ;Q2b ? M/ BM ? M/ rBi?
h` BMBM; `;mK2Mib M/ iQ;2i?2` i?2v T`QpB/2 +QKTH2i2 i` BMBM
mb2 iQ i` BM i?2 KQ/2Hb 7Q` ~ i L1_X
h?2h` BM2H bb Bb M H`2 /v T`2T `2/ i` BMBM; HQQT- r?B+? Bb
+Q``2+iHv M/ 2{+B2MiHv rBi? >m;;BM; 6 +2 h` Mb7Q`K2`b KQ/2Hb
BM a2+RXQ M BM; i?2 BMBM; `;mK2Mib- A + M 7m`i?2` ir2 F /Bz2`2Mi
T ` K2i2`b- bm+? b # i+? bBx2- H2 `MBM; ` i2- r2B;?i /2+ v- MmK#2
2 +? KQ/2H- A /2+B/2/ iQ }M/ i?2 #2bi K2i T ` K2i2`b mbBM; i?2 i`B
i? i K tBKBx2 i?2 `2X A KQbiHv TH v2/ rBi? # i+? bBx2b- i`vBM; i?2
3- 9- M/ kX h?2 bi `iBM; H2 `MBM; ` i2 `2K BM2/2i 2 bc k2Q 7Q` HH K
r2B;?i /2+ v- A +?Qb2 #2ir22M yXyR M/ yXyyR- M/ i?2 MmK#2` Q7 2
3 M/ ky 2TQ+?bX h?2 `2 bQMBM; #2?BM/ i?Bb Bb i? i 2p2M i?Qm;?
r2HH rBi? +2`i BM K2i T ` K2i2`b- i?2 Qi?2` KQ/2H + M T2`7Q`K #2i
;mK2Mib XBM2`b2b M / KQ(b?+?BHQp M/ >mQiT2 BKBxR2N- r?B+? Bb M

[j] ?iiTb,ffTviQ`+?XQ`;f/Q+bfbi #H2f;2M2` i2/fiQ`+?XMMX"*1qBi?GQ;BibGQbbX?i
[9] ?iiTb,ff?m;;BM;7 +2X+Qf/Q+bfi` Mb7Q`K2`bfK BMn+H bb2bfi` BM2`
[8] ?iiTb,ff?m;;BM;7 +2X+Qf/Q+bfi` Mb7Q`K2`bfp9X9yXkf2MfK BMn+H bb2bfi` BM2
h` BMBM; `;mK2Mib