

< Y`ZYb`G]Y`5`]W]U.`H]Yf\Y]a`B ØfbVYf[
gi W\h`]YVYj c``Yg`Ni \Ui gY`ZØf
GW ÅZYf\ØbX]b

8]Y`Y]b`Å\ f][Y`GW ÅZYf\ØbX]b`5`]W]U`gi W\h`Xf]b [YbX`Y]b
bYi Yg`Ni \Ui gY`]a`H]Yf\Y]a`B ØfbVYf[ž`bUWXYa`] \f
6Yg]hnYf`g]Y`b]W\h`a`Y \f`j`Yfgcf [Yb`_cbbhY"

8]Y`Gi W\Y`bUW`Y]bYa`bYi Yb`Ni \Ui gY`ZØf`X]Y`GW ÅZYf\ØbX]b
5`]W]U`\Uh`X]Y`<YfnYb`j`]Y`Yf`H]Yf`]YV\UVYf`VYfØ\fh"8]Y`Yfgh]j`cf
_i`fnYa`Y]b`Å\ f][Y`<ØbX]b`_Ua`]`bg`B ØfbVYf[Yf`H]Yf\Y]a`ž
bUWXYa`] \f`6Yg]hnYf`b]W\h`a`Y \f`b`XYf`@U[Y`k`Ufž`g]W\`i`a`g]Y`ni
_Øa`a`Yfb"8]YgY`hfUi`f][Y`K`YbXi`b [`ghY`h`b]W\h`bi`f`ZØf`5`]W]U`Y]bY
<YfUi`gZc`fXYfi`b [`XUfž`gcbXYfb`k`]fZh`Ui`W\`Y]b`@]W\h`Ui`Z`X]Y
DfcV`Ya`Yž`X]Y`j`]Y`Y`<Ui`gh]YfVYg]hnYf`]b`gW\k`]Yf][Yb`@YVYbg`U[Yb
Yf`YVYb"

5`]W]U`a`i`gghY`]a`GhfU»Yb`YVYb`ni`fYW\h`_ca`a`Ybž`VYj`cf`g]Y`bi`b
Y]b`bYi`Yg`Ni` \Ui`gY`gi`W\h`Ni` [Ub [`ni`Y]bYa`k`Ufa`Ybž`g]W\YfYb
i`bX``]YVYj`c``Yb`i`a`ZY`X`]gh`ZØf`]\fY`9b`hk`]W`_i`b [`j`cb
Yb`hgW\Y]XYbXYf`6YXYi`hi`b [``5`]W]U`]gh`Y]bY`YW\h`Y`K`UggYffUhhY
i`bX``]YVh`Ygž`]b`DZØ`hnYb`ni`d`UbgW\Yb`ž`VYhc`bh`XUg`H]Yf\Y]a`]b
]\fYa` :`UW`Vcc`_!`Dcgh]b [`ØVYf`X]Y`<ØbX]b" `G]Y`]gh [YgY`][ž`_ca`a`h
[i`h`a`]h`UbXYfYb`<i`bXYb`Ui`gi`bX`Ui`W\`?`]bXYf`\`Å`h`Y`g]Y`[Yfb`]b
]\fYa`bYi`Yb`Ni` \Ui`gY"

9]b` \Yfn`]W\Yf`7` \UfU`_hYf

⇒a`H]Yf\Y]a`k`]fX`X]Y`†`b [Y`GW ÅZYf\ØbX]b`U`g``]YVYbgk`ØfX][`i`bX
j`YfgW`a`i`gh`VYgW`f]YVYb" `A`]h`]\fYf`ZFYi`bX`]W\Yb`5`fh`]gh`Yg`_Y]b
K`i`bXYfž`XUgg`g]Y`g]W\`gW`bY``]b`X]Y`<YfnYb`XYf`A`]hUfVY]hYf
Y]b [YgW`]W\Yb`\Uh"5`]W]U`nY][h [`fc» Y`@YfbVYfY]hgW`UZh`i`bX`]gh

gWbY`b`XYf`@U[Yž`bYi Y`9fn)Y\i b[g_ca a UbXcg`ni `Yf`YfbYb"
8]YgYg`HU`Ybh`Àggh`XUfUi Z`gW`jY» Ybž`XUgg`g)Y`a Ò[`]WYfk Y]gY
bUW`Y]bYf`9]b[Yk Ò\bi b[gnY]h`Ui W`U`Y]bY`V`Y]VYb`_Ubb" `9g`]gh
k]W]h][`ni `k]ggYbž`XUgg`g)Y`UbZUb[g`k U\fgWY]b`]W`Yhk Ug`NY]h
VfUi W`hž`i a `g]W`Ub`XUg`@YVYb`ja `<Ui g`ni `[Yk Ò\biYbž`UVYf`k]f
g]bX`ni j Yfg]W]h]W`ž`XUgg`g)Y`g]W`UbdUggYb`k]fX`ž`Yf`_`ÀfYb`X]Y
H]Yf\Y]a a]hUfVY]hYf`k Y]hYf"

8 Ug`B`ØfbVYf[Yf`H]Yf\Y]a ž`k c`5`]W]U`XYfnY]h`i bhYf[YVfUW]h]ghž
V]YhYh`b]W]h`bi f`ZØf`g]Yž`gcbXYfb`Ui W`ZØf`j]Y`Y`UbXYfY`H]YfY`X]Y
A Ò[`]W`_Y]hž`Y]b`bYi Yg`Ni \Ui gY`ni `Z]bXYb" `BYVYb`5`]W]U`k UfhYh
Ui W`XYf`? Ub[U`5`Z]Ui Z`Y]bY`7\UbW" `GY]bY`J`cf[YgW]W]hY`Ui g
gW`YW]hYf`<U`hi b[`j YfXYi h]W]hž`k]Y`k]W]h][`Yg`]ghž`H]YfYb`]b`B`ch
Y]bY`nk Y]hY`7\UbW`ni `V]YhYb" `8 Ug`H]Yf\Y]a `]ghY]b`C`fh`XYf
<c`Zbi b[`ZØf`j]Y`Y`J]YfVY]bYfž`X]Y`Xi fW`]\fY`I`a`gh`AbXY`]b`Y]bY
B`ch`U[Y`[YfUhYb`g]bXž`i bX`X]Y`5bb`U`a`Yž`XUgg`j]Y`Y`j`cb`]bYb
XUfUi Z`\c`ZYbž`YbX`]W`Y]b`]YVYj`c`Yg`Ni \Ui gY`ni `Z]bXYbž`]gh
Xi fW`k Y[`ZØ`\`VUf"

8]Y`<`YfUi`gZcfXYfi`b[`XYf`H]Yfj`Yfa`]hh`i`b[

8]Y`H]Yfj`Yfa`]hh`i`b[`_Ubb`c`Zh`Y]bY`\`YfUi`gZcfXYfbXY`5i`Z[`UVY`gY]b"
8]Y`A`]hUfVY]hYf`XYg`H]Yf\Y]a`g`g]bX`VYa`Ø\hž`X]Y`VYghYb
6YX]b[`i`b[Yb`ZØf`X]Y`H]YfY`ni`g`W]UZZYbž`k`À\`fYbX`g]Y`[`Y]W]nY]h][
dchYbn]Y`Y`5XcdhUbhYb`ØVYf`X]Y`6YXØfZb]ggY`XYf`Yk`Y`][Yb
<Ui`gh]YfY`]bZcfa`]YfYb" `K`]f`a`ÒW]hYb`g]W]YfghY`Ybž`XUgg`5`]W]U
XUg`Ni` \Ui`gY`Z]bXYhž`XUg`g]Y`j`YfX]Ybh" `8Yg`U`V`ZØ\`fYb`k`]f
dYfg`Òb`]W]Y`;`Ygd`f`ÀW]Y`a`]h`XYb`æ`hYfYggYbhYb`i`bX`j`Yf`gi`W]Ybž
X]Y`dUggYbXYb`:`Ua`]Yb`ni`Z]bXYb`ž`gW]`XYfb`X]Y`A`]hUfVY]hYf`XYg
B`ØfbVYf[Yf`H]Yf\Y]a`g`]fY`J`YfUbhk`cfhi`b["

8 Yf`:`UW`Vcc`!`6Y]hfU[`ØVYf`5`]W]U`\`Uh`VYfY]hg`j`]Y`Y
_ca`a`Ybh]YfYbXY`H]YfZfYi`bXY`Ub]a`]Yfhž`g]W]`a`]h`XYf`G]hi`Uh]cb`XYf
<ØbX]b`ni`VY`ZUggYb`i`bX`g]Y`ni`i`bhYfgh`ØhnYb" `9g`]gh`Y]b`NY]W]Yb
XUZØfž`k`]Y`gY`\`f`X]Y`;`Ya`Y]bgW]UZh`Ub`XYa`K`c`\`XYf`H]YfY
]bhYfYgg]Yfh]`gh" `9g`]gh]a`a`Yf`k`]YXYf`Yf[`fY]ZYbX`ni`gY`Ybž`k`]Y
gc`W]Y`5i`Zfi`ZY`ZØf`H]YfY`]b`B`ch]b`XYf`²`ZYbh`]W]_Y]h`F`Ygcb`Ubn
Z]bXYb"

: Øf`U`Yž`X]Y`Ub`Y]bYf`5Xcdh]cb`]bhYfYgg]Yfh'g]bX`cXYf`a`Y`f`ØVYf`
5`]W]U`i`bX`UbXYfY`<i`bXY`]a`H]Yf\Y]a`YfZU\fyb`a`ØW`hYbž`]gh`XUg`
B`ØfbVYf[`Yf`H]Yf\Y]a`c`ZYb`ZØf` ; Ygdf`ÅW`Y`i`bX` : fU[`Yb`"9g`]gh`X]Y`
 ; Y`Y[`Yb\Y]h`ZØf`H]YfZfYi`bXYž`g]W`U`_h]`VY]`XYf`J`YfVYggYfi`b[`XYg`
@YVYbg`Y]bYg`VYXØfZh][`Yb`H]YfYg`ni`Yb[`U[`]YfYb`"K`Yf`k`Y]»`ž`
j`j`Y`Y]W`h`k`]fX`5`]W]U`V`U`X`]\`f`bYi`Yg`Ni` \Ui`gY`Z]bXYb`i`bX`XUa`]h`
Y]b`?`Ud]hY`"b`]\`fYa`@YVYb`VY[`]bbYbž`XUg`j`cb`@YVY`i`bX`
G]W`Yf\Y]h`[`Ydf`Å[`h`]gh`"

8`Ug`H]Yf\Y]a`B`ØfbVYf[`]gh`b]W`h`b`i`f`Y]b`Ni`Zi`W`hgc`fh`ZØf`5`]W]Už`
gcbXYfb`V]YhYh`Ui`W`j`]Y`Yb`UbXYfYb`H]YfYb`X]Y`A`Ò[`]W`_Y]hž`Y]b`
bYi`Yg`Ni` \Ui`gY`ni`Z]bXYb`"`ϕ`8Yi`hgW`U`bX`[`]Vh`Yg`ØVYf`)`\$\$`
fY[`]ghf]YfhY`H]Yf\Y]a`Yž`X]Y`g]W`i`a`X]Y`5i`ZbU`a`Y`i`bX`
J`Yfa`]h`i`b[`]j`cb`H]YfYb`_Øa`a`Yfbž`X]Y`Ui`g`XYb`
i`bhYfgW`]YX`]W`ghYb` ; fØbXYb`UV[`Y[`YVYb`k`YfXYb`a`ØggYb`"8]YgY`
 ; fØbXY`fY]W`Yb`j`cb`Z]bUb]Y`Y`Yb`GW`k`]Yf][`_Y]hYb`ØVYf`
J`Yf\U`hYbgdfcV`Ya`Y`V]g`\]b`ni`d`Øh`n]W`Yb`@YVYbgj`Yf`ÅbXYfi`b[`Yb`
XYf`6Yg]hnYf`"

Gcn]U`Y`ϕ`b]h]Uh]j`Yb`ni`f`l`bhYfghØhni`b[`]j`cb`
H]YfgW`i`hn`

8`Ug`H\Ya`U`H]YfgW`i`hn`\Uh]b`XYb`Y`h`hYb`ϕ`U`fYb`Ub`6YXYi`hi`b[`
[`Yk`cbbYbž`i`bX`nU`\`fY]W`Y`C`f[`]Ub]gUh]cbYb`gYhnYb`g]W`ZØf`X]YgY`
H]YfY`Y]b`"J`]Y`Y`H]Yf\Y]a`Y`]b`8Yi`hgW`U`bXž`k`]Y`XUg`H]Yf\Y]a`
B`ØfbVYf[`]ž`g]bX`Ui`Z`GdYbXYb`i`bX`Y`fYbUa`h]W`Y`<`Y`Z`Yf`
Ub[`]Yk`]YgYbž`i`a`]\`fY`A`]gg]cb`Zc`f`h`ni`gYhnYb`"A`]h`ϕ`h]Uh]j`Yb`k`]Y`
_cg`hYb`cgYb`ϕ`d`ZU`_h]cbYbž`?`UghfUh]cbgdfc[`]fUa`a`Yb`i`bX`
5i`Z`_`Åfi`b[`]g`Ua`dU[`]bYb`j`Yf`gi`W`Yb`X]YgY`C`f[`]Ub]gUh]cbYbž`XUg`
6Yk`i`gghgY]b`ZØf`X]Y`6YXØfZb]ggY`j`cb`H]YfYb`ni`gW`ÅfZYb`i`bX`X]Y`
5bnU`\`XYf`Ui`g[`]YgYhnYb`H]YfY`ni`j`Yff]b[`]Yfb`"8]Y` : ØfXYfi`b[`]XYg`
j`YfUb`hk`c`f`h`i`b[`]gVYk`i`gghYb`l`a`[`]Ub[`]g`a`]h`<`Ui`gh]YfYb`gd]Y`h`XUVY`
Y]bY`nYb`hfU`Y`F`c`Y`"

8`UfØVYf`\]bUi`g`V]YhYb`j`]Y`Y`H]Yf\Y]a`Y`gdYn]Y`Y`Dfc[`]fUa`a`Y`Ubž`
i`a`X]Y`J`Yfa`]h`i`b[`]gW`UbW`b`j`cb`H]YfYb`ni`Yf\Ø`Yb`"8`Uni`
[`Y\ØfYb`Y`hk`U`DZY[`]Yd`_`Å`hnY`ZØf`H]YfYž`X]Y`j`cfØVYf[`]Y`YbX`]b`
Y]bYa`Ni` \Ui`gY`YVYb`_ØbbYbž`cXYf`HU[`]Y`XYf`c`ZYbYb`HØf`ž`i`a`

dchYbn]Y`Yb`5Xcdh]j ZUa]]Yb`X]Y`A Ò[`]W_X]h`ni` [YVYbž`X]Y`H]YfY`
_YbbYbni`YfbYb``8]YgY`Dfc[fUa`a`Y`\Y`ZYb`b]W`h`bi`f`XYb`H]YfYbž`
gcbXYfb`ZØfXYfb`Ui`W`XUg`; Ya`Y]bgW`UZhg[YZØ`\`i`b`X`X]Y`
GYbg]V`]g]Yfi`b[`ZØf`H]YfgW`i`hnUb`]Y[Yb`"

6YXYi hi b[`XYf`5Xcdh]cb`j`cb`H]YfYb`

8]Y`5Xcdh]cb`Y]bYg`H]YfYg`\Uh`k`Y]hfY]W`YbXY`J`cfhY]`Yž`gck`c`\`ZØf`
XUg`H]Yf`gY`Vgh`U`g`Ui`W`ZØf`XYb`bYi`Yb`6Yg]hnyf``H]YfY`Ui`g`
H]Yf\Y]a`Yb`\UVYb`c`Zi`VYgcbXYfY`6YXØfZb]ggY`i`b`X`Y]bY`VYk`Y[hY`
J`Yf[Ub[Yb\Y]hž`_ØbbYb`UVYf`Y]bY`i`b[`Ui`V`]W`Y`E`i`Y`Y`XYf`
: fYi`XY`i`b`X`XYg`6Y[`Y]hYfgW`UZhg`gY]b``8]Y`9b`hgW`Y]Xi`b[ž`Y]b`H]Yf`
Ui`g`Y]bYa`H]Yf\Y]a`ni`UXcdh]YfYbž`i`b`hYfgh`Ø`h`h`b]W`h`bi`f`XYb`
H]YfgW`i`hž`gcbXYfb`hfÀ[h`Ui`W`ni`f`J`Yff]b[Yfi`b[`XYf`
, VYfdcdi`Uh]cb`]b`XYb`<Y]a`Yb`VY]`"

GhUh]gh]_Yb`nY][Ybž`XUgg`UXcdh]YfhYb`H]YfYb`b]W`h`bi`f`Y]b`bYi`Yg`
Ni`\Ui`gY`[YgW`Yb`_hž`gcbXYfb`Ui`W`bY[Uh]j`Y`J`Yf\U`hYb`gk`Y]gYb`
c`Zi`Xi`f`W`X]Y`bYi`Y`I`a`[YVi`b[`i`b`X`]YVYj`c`Y`DZY[Y`ØVYfk`i`b`XYb`
k`YfXYb``9]bY`Ghi`X]Y`XYg`8Yi`hgW`Yb`H]YfgW`i`hnVi`b`XYg`nY][hž`XUgg`
j`]Y`Y`5Xcdh]cbg`_UbX]XUhYb`]a`H]Yf\Y]a`[i`hY`J`cfUfVY]h[Y`Y]ghYh`
Yf\U`hYb``8]Y`H]YfY`k`YfXYb`]b`XYf`F`Y[Y`d`fc`ZYgg]cbY``gc`n]U`]g]Yfh`
i`b`X`j`cf`XYf`J`Yfa`]h`i`b[`[fØb`X`]W`Ui`Z]\fY`9][bi`b[`[YhYghYh`
fk`Y]hYfY`ϕ`Zcfa`Uh]cbYb`Z]bXYb`G]Y`Ui`Z`XYf`K`YVgY]hY`XYg`
8Yi`hgW`Yb`H]YfgW`i`hnVi`b`XYg`"

8]Y`K`UfhYnY]hYb`ZØf`H]YfUXcdh]cbYb`_ØbbYb`j`Uf]]YfYbž`UV\`Ab[][
j`cb`XYf`F`UggY`i`b`X`XYb`gdYn]Y`Yb`6YXØfZb]ggYb`XYf`H]YfY``J]Y`Y`
H]Yf\Y]a`Y`Yfa`i`h][Yb`ϕ`hYfYggYb`hYbž`b]W`h`bi`f`b`UW`VYgh]a`a`hYb`
F`UggYb`ni`gi`W`Ybž`gcbXYfb`Ui`W`c`ZYb`ZØf`À`hYfY`H]YfY`c`XYf`
gc`W`Y`a`]h`gdYn]Y`Yb`6YXØfZb]ggYb`ni`gY]b`"

6Ygi W\Yb`G]Y`i bg`Ui Z.`b!U["XY